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Estimating economic costs of wilderness areas

by

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# INTRODUCTION

In 1964 the Wilderness Act (78 Stat. Sec. 890) was passed, establishing the National Wilderness Preservation System (NWPS). Since, many areas have been designated and added to that System. However, decisions about many areas will be made before the NWPS is complete. Participation in wilderness recreation activities has increased rapidly in the recent past and most projections indicate this trend will continue in the future (Davis and Knetsch, 1965; Frissell and Stankey, 1972; Krutilla, 1967; Krutilla and Fisher, 1975; ORRRC, 1962). In response to public interest in expanding the System, the U.S.D.A. Forest Service has selected 274 "new study areas" totalling 12.3 million acres to be studied for possible addition to the NWPS (U.S.D.A. Forest Service, 1974). In addition, the Forest Service Manual (U.S.D.A. Forest Service, 1974) has provided the mechanism by which even more roadless areas can be added to the 274 selected "new study areas".

Determining how large the NWPS should be and what areas to include is a major resource allocation problem. Some would have us believe the economics should enter this problem only to a very minor extent, while others believe it is completely irrelevant. Ise (1962) believes that wilderness decisions should be based only in very small part on economic analysis. Kelso (1962) goes a step farther. He believes that no economic analysis is appropriate and concluded "better choice concerning wilderness will come from more research into the process of social action than from the determination of economic 'normative maxims'". Brewer (1962) echoes essentially the same sentiment in that he believes that optimization for outdoor recreation activities is mostly irrelevant. Further, Steiner (1959) does not believe it is correct to invest in all public projects (wilderness could be thought to be included) to the point where marginal benefit equals marginal cost, the pure efficiency criterion.

In contrast, others point out the need for making economically sound judgements in the wilderness decision-making process. Wambach (1975) points out that one of the biggest problems in forest management today is the lack of economic and other information upon which to base sound decisions. Robinson (1967) points out that the supply function of outdoor recreation activities is not costless and that these costs should be included in the decision-making process. This same idea could easily be extended to include wilderness. Krutilla and Fisher (1975) point out the importance of including in the decision-making process the opportunity cost of designating specific areas as wilderness. In addition, Hines (1951) points out the importance of valuing the alternative use of primitive land. Forest Service Deputy Chief Nelson stated the point quite clearly in a recent speech (1974):

> Before recommending (a wilderness area) to the Congress we must ascertain that it is available. That is, what values must be foregone if it is designated a Wilderness Area? What are the trade-offs? What are the mineral values that will be tied up? The sustained-yield timber harvest foregone? Or the recreational potential never developed?

The preceding discussion and the vigorous public debate on questions of wilderness designation throughout the United States serve to point out the need for economic information in wilderness decision-making. The question remains, how and to what extent should economics be applied?

Many who have considered this question believe that economics is best used in the supportive role of providing information to the decision-making process. For example, Davis and Bentley (1967) have stated that economic analysis of resource alternatives should seek to ascertain the amount and incidence of costs and benefits involved. Hughes (1965), who has studied wilderness allocation specifically, stated that economics has two roles to play in the wilderness decision process: (1) to ensure all the associated costs and benefits are considered in the decision, and (2) to instill the basic logic of choice of economics in the decision process when warranted. Since, Alston (1972) and Beardsley et al. (1975) came to the same conclusion. This appears to be the most useful approach of economics in wilderness decision-making.

It is important that economic analyses of wilderness allocation fit well in the existing land use planning and wilderness decision-making processes. The Forest Service Manual (U.S.D.A. Forest Service, 1974) outlines this process for both "new study areas" identified in the Roadless Area Review and Evaluation study (U.S.D.A. Forest Service, 1973) and for other areas on national forests which might be desired for wilderness designation in the NWPS.

The desirability of designating "new study areas" as wilderness is first studied at the national forest level as part of the comprehensive land-use planning process. Once a land-use plan is selected by the Forest Supervisor, it is reviewed by the Regional Forester and subsequently by the Chief of the Forest Service in Washington, D.C. Approval must be gained at both levels and unapproved plans resubmitted. The approved plan may have identified the "new study area(s)" for further study, or allocated them to non-wilderness status. For those chosen for further study, public hearings are held and analyses of the suitability of the areas for wilderness are carried out. The study findings again go to the Regional Forester and the Chief for approval. If wilderness status is not recommended, the land-use plan will be modified to allocate the former "new study area(s)" to other uses. If the recommendation is for wilderness, the report goes to the Secretary of Agriculture. He in turn submits his recommendations to Congress, which has authority under the Wilderness Act of 1964 (78 Stat. Sec. 890) to designate areas to the NWPS.

The desirability for wilderness of roadless areas not selected as "new study areas" must also be evaluated in the development of land-use plans or national forests. If, in this planning process, the best use of a roadless area appears to be wilderness, a wilderness proposal is made in the environmental impact statement of the land-use plan for the forest. Approval of the Chief is required prior to filing the statement. If, following the process laid out by the National Environmental Policy Act of 1969 (83 Stat. Sec. 890), the environmental impact statement is approved, the roadless area becomes a "new study area" and a wilderness report is prepared following the procedure outlined above.

As seen, the decision for given areas is not made at any one level, but in fact is a series of decisions made at various levels of management. Cost information generated at the lowest or forest level could be passed up through the decision process. The decision-maker could then consider these costs in deciding which areas to allocate to wilderness in much the same manner as any consumer considers price in a decision on what to purchase.

## OBJECTIVES

The main objective of this study is to develop a technically possible and economically feasible method for estimating the economic cost of designating specific areas as wilderness. This can be broken down into the following subobjectives:

1. To identify what costs are associated with wilderness designation and which should be of concern to the decision-maker.
2. To determine a theoretically appropriate technique for measuring the costs associated with designating land to be part of the NWPS.
3. To develop a method by which cost estimates can be made given the data available for the Northern Rocky Mountain region.
4. To empirically test the merit and feasibility of the method developed in objective 3.

## CONCEPTUAL ASPECTS OF COST ESTIMATION

### What Cost Should be Measured?

Many different costs are potentially associated with designating large areas of public land for a specific use such as wilderness. The most obvious of these is the cost of managing that land. This, however, represents only a small portion of the costs associated with wilderness designation. The major portion is the net annual flow of products that could be obtained from the area if it were not managed as wilderness, but must be given up under the wilderness alternative (Herfindahl and Kneese, 1974, p. 12). This flow is potentially comprised of a large number of values and is likely different in content and amount for every area to be considered for wilderness classification.

Beardsley et al. (1974) catalog major activities and opportunities which generally must be foregone under wilderness classification:

(a) Road-dependent recreation (except, perhaps on the fringes) and capital-intensive recreational developments, such as ski areas.

(b) Capital improvements for grazing or for water control.

(c) Mining, at least as under yet-to-be defined controls.

(d) Opportunities to manipulate the forest to reduce fire hazards or to improve or protect wildlife and fish habitat.

(e) Opportunity to manage and harvest timber.

This list is quite general and no doubt could be expanded and made more specific for any given area.

The question of which of these costs should be of concern to the decision-maker still remains. Since the national forests are managed for the public, the appropriate cost for the decision-maker to consider is social cost or all costs born by those affected by wilderness designation. Knetsch et al. (1969) have come to the same conclusion while analyzing issues in benefit and cost estimation for use in natural resource decisions. Others which have expressed a similar opinion are Davis and Bentley (1967), Chappelle, Mang and Miley (1975), the Division of Forest Economics, Intermountain Forest and Range Experiment Station (U.S.D.A. Forest Service, 1956), and Hines (1951).

## Estimating Value Foregone

Few attempts to estimate costs associated with wilderness designation have been made in the past. These were carried out by the Outdoor Recreation Resource Review Commission (ORRRC, 1962) and by the Forest Service in the

Roadless Area Review and Evaluation Study (U.S.D.A. Forest Service, 1973). The ORRRC study concentrated on the rent the wilderness land would bring if it were in the private sector and on the value of foregone man-days of nonwilderness recreation, while Forest Service opportunity cost estimates were concerned with foregone timber values. Since selling national forest land to individuals in the private sector is not considered a viable alternative, estimating foregone rent does not appear to be a good estimate of the actual value foregone. Both studies can be criticized for not estimating a more complete range of foregone values. As discussed earlier, this is the cost information needed by decision-makers.

It was previously discussed that the cost of wilderness is the value of the goods and services which must be given up in order to have wilderness. This cost is represented by Equation 1:

$$\text{Cost of wilderness} = PNW_A^r - PNW_W^r \quad . \qquad (1)$$

Here, $PNW_A^r$ represents the present value (discounted at rate r) of all future net benefits resulting from the nonwilderness alternative A. $PNW_W^r$ represents the present value (discounted at rate r) of all nonwilderness-specific future net benefits derived from the wilderness alternative W. The nonwilderness-specific values in $PNW_W^r$ include those goods and services which would be obtained from the land, at least to some extent, whether designated as wilderness or not. This includes such things as water yield, wildlife forage, wildlife cover, and recreation not specific to wilderness areas. Things not included are (for example) the value of wilderness for historic preservation, the preservation of gene pools, scientific purposes, existence value, and wilderness-specific recreation--the "immeasurable" values of wilderness, against which its cost must be compared.

Subtracting the nonwilderness-specific benefits from the cost of wilderness is done for the convenience of the decision-maker. Since they must be measured for the nonwilderness alternative, it makes sense to quantify them for the wilderness alternative as well. Secondly, including these nonwilderness-specific values in the cost of wilderness allows the decision-maker to concern himself with only the wilderness-specific benefits in his judgements on the value of certain areas as wilderness. It is important, however, that the decision-maker understand thoroughly what benefits have been included in the cost estimates.

An alternative approach to handling nonwilderness-specific values in the wilderness alternative would be to omit them entirely from the cost estimates and instead allow the decision-maker to include them in his benefit estimations. Either approach is theoretically appropriate. Consider Figure 1 where hypothetical marginal cost and marginal benefit of wilderness are represented on a per acre basis over a large number of acres. As indicated in this figure, $MC_1$ represents the marginal cost of wilderness when no benefits of wilderness are included, and $MB_1$ represents the marginal benefit of wilderness when only wilderness-specific benefits are included. Nonwilderness-specific benefits occurring on the marginal acre have thus far been omitted. If these benefits are included in the benefit of wilderness (added), marginal benefit is shifted vertically to $MB_2$. The optimum level of wilderness, q*, is indicated by point A, where marginal benefit ($MB_2$) equals marginal cost ($MC_1$). Alternatively, these benefits could be subtracted from marginal cost (the Equation 1 approach) shifting this curve down vertically to $MC_2$. Now the point at which marginal benefit ($MB_1$) equals marginal cost ($MC_2$) is point B, but the optimal level of wilderness, q*, remains the same.

Beardsley et al. (1974) point out that special care is required to determine what values will in fact be foregone when areas are designated as wilderness. To be legitimately counted as a value foregone, there must be an absolute scarcity of alternative areas on which part of the

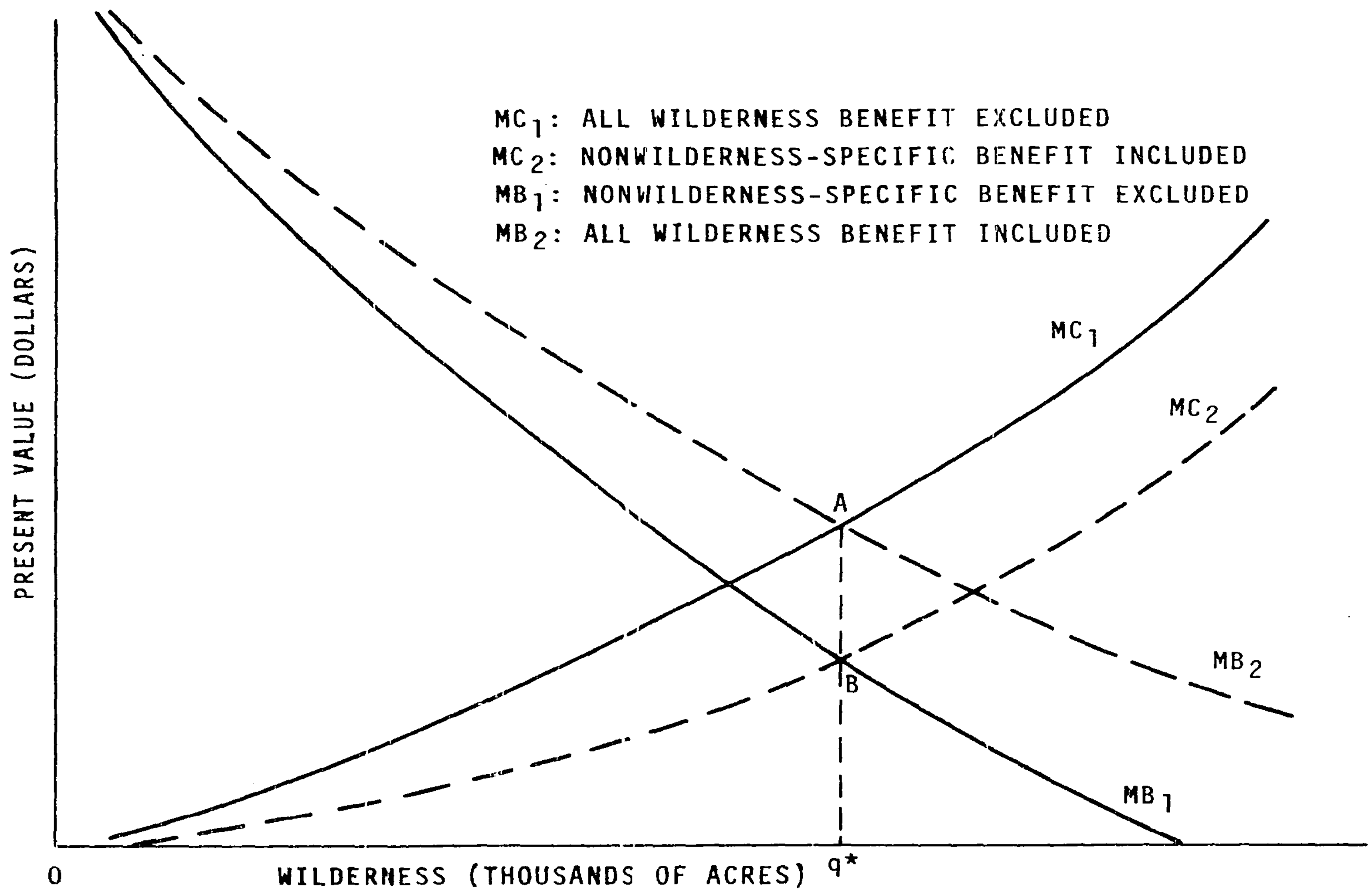


Figure 1. Hypothetical marginal benefit and marginal cost curves demonstrating implied optimal social allocation of wilderness (q*)

value foregone on the wilderness area might be obtained. This includes areas on which management could be intensified to offset values foregone as well as areas on which lower value activities could be displaced by higher value activities foregone on wilderness land. This point may be made more explicit with the help of an example. Assume that a proposed wilderness area contains a site (Z) which would make an excellent developed campground. Assume further that under the alternative to wilderness (A) this campground would be developed. Initially one might be tempted to claim the value of the campground which must be foregone for wilderness is equal to the present value of the future use of that campground ($V_{ZC}$). This would be true if there is an absolute scarcity of equivalent quality campground sites (Y where $V_{YC} = V_{ZC}$) outside the boundary of the proposed wilderness that under A would be used for an activity (O) which has a value $V_{YO} < V_{YC}$. This situation is highly unlikely. More often an alternative site Y will exist such that $V_{YO} < V_{YC}$. If a campground would be developed on Y under the wilderness alternative (which it should be if management is effective), then the actual value foregone for wilderness is $V_{YO}$ and not $V_{ZC}$. In this instance, $V_{ZC}$ overstates the actual value foregone by an amount equal to $V_{ZC} - V_{YO}$.

The campground example shows how the benefit foregone from one activity can be overestimated by not considering availability for that activity on areas surrounding the proposed wilderness. Surely the foregone value of many other activities and commodities could be overestimated in much the same manner. Others (ORRRC, 1962, p. 85; Jolly, 1973, p. 351) have noted that such a small proportion of forest land has been proposed for wilderness that the remaining lands can probably be more intensively managed to make up for lost timber production, forage production, and developed-site recreation.

It appears that the only way to satisfactorily determine the marginal availability of resources for estimating true value foregone is to internalize into the cost estimates effects of wilderness designation on the surrounding area. This requires complete management plans along with expected costs and benefits for the total area affected for both the most likely wilderness and nonwilderness alternatives. These values would then be applied in Equation 1.

The question of how much surrounding area should be included in the cost estimates remains. Ideally, all area on which equivalent activity could take place (within some reasonable distance) should be included. The basic Forest Service planning unit is the national forest. For this reason the national forest unit appears to be the most logical choice, even though some interrelationships in supplying certain commodities may exist with adjacent national forests and other land.

One additional point warrants discussion before leaving this section. Equation 1 implies that estimates for cost of wilderness should be made in dollar terms. While this is the traditional approach, there is no reason why cost of wilderness cannot also be presented in terms of physical amounts of goods and services foregone. The expected changes in output and the time when they are expected to occur are then clearly identified for the decision-maker. This information would be useful for all goods and services foregone, but would be especially useful for those that are difficult to measure in dollar terms. This idea has also been stressed by Knetsch et al. (1969) and by Davis and Bentley (1967).

## Compensation cost

Compensation or replacement cost has been suggested by several (Beardsley et al., 1974; U.S. President, Proclamation, 1973, pp. 39-40; Jepson, 1970) as an alternative method for estimating value foregone. This method is defined as the cost of the most likely alternative means of obtaining that which must be foregone to have specific areas as designated wilderness.

Several points about the use of this method have been brought out by Beardsley et al. (1974). First, problems may exist in defining opportunities that will, in fact, produce equivalent goods. Secondly, an opportunity cost may also be incurred in applying the compensation technique. That is, the presently existing opportunity to produce additional goods (such as timber) for other reasons is foregone. Compensation cost may actually underestimate the true cost if this opportunity cost is not included. In addition, the compensation cost technique may be impractical for a very pragmatic reason. Very little is known about the form of the production functions for most forest-based goods. Even for timber (for which by far the most work has been done) we have only rough ideas about the increases in growth rates that can be expected with increases in the intensity of management. Thus, getting a good estimate of compensation cost may be a quite difficult thing to do.

Moving to a more basic point, consider more closely what the compensation cost method measures. Since it measures the cost of producing in another manner that which must be foregone for wilderness, it is not a true measure of the net benefit which must be foregone unless, of course, this alternative method of production will be carried out. If this alternative method of production will not be carried out, compensation cost does not even provide a consistent estimate of value foregone (i.e., short or long by a constant percentage) because it bears no relationship to what is foregone by the consumer. On the other hand, if the alternative method of production would be undertaken to offset that given up on the wilderness area, then compensation cost is, in fact, the same thing as opportunity cost. That is, what actually is foregone under this alternative is the expenditure required for the additional production. It is concluded that compensation cost, if applied correctly, is nothing more than a special case of opportunity cost.

Community impacts

The withdrawal of small amounts of national forest land probably has little effect on the national supply of forest-based goods and services. However, this action could potentially have a substantial impact when considered on a local scale. This was recognized by the Outdoor Recreation Resources Review Commission while considering potential effects of wilderness designation on timber supplies; they stated:

> While wilderness withdrawals of productive forest lands considered in isolation from other land use changes do not appear to have important impact on timber supplies in national terms, the situation is changed as the area of reference is progressively narrowed from the nation to the region, from the region to the state, and from the state to the local community (ORRRC, 1962, p. 82).

Reduction of timber supply in these successively smaller areas could result in a loss in timber industry-related income and jobs which could in turn effect tax revenues, unemployment compensation payments and generally reduce economic vitality of areas. Changes in the availability of such things as recreation sites and range for forage production could also produce secondary impacts in a similar manner.

Well-known methods, such as economic base and input-output studies, have been developed for measuring local and regional effects such as those described. These methods can be applied in many levels of sophistication and accordingly vary in the data required for application. A comprehensive discussion of these techniques is found in Isard (1960). Examples of the application of these techniques in the Rocky Mountain and Pacific Northwest regions include Johnson (1972), Darr and Fight (1974), Polzin and Schweitzer (1975) and Rafsnider and Kunin (1971).

Before secondary impacts can be measured, the direct changes in output associated with wilderness designation must be determined. As stressed in the introduction, very little is known at present about direct effects. Thus, while secondary impacts are recognized as being of potential importance in wilderness decision-making, the scope of this research is limited to measuring direct effects.

## Information Requirements and Availability

The type of information required for estimating direct cost of wilderness is much the same as that required for predicting potential outcomes for any major land-use decision. To estimate wilderness cost the analyst must:

a. Identify the potentially important goods and services supplied by the wilderness and surrounding area.

b. Determine likely alternatives of management both in the presence and absence of wilderness.

c. Estimate how resources that give rise to important goods and services would be developed for each of the management alternatives.

d. Estimate costs of management for the alternatives.

e. Predict how and to what extent people would use the resources made available under the management alternatives.

f. Estimate in dollar terms the value of the goods and services derived from the resources.

As one can easily see, the information requirements are very demanding. If a technique of cost estimation is to be developed that is feasible in terms of cost and time requirements, secondary data sources must be relied upon. The linear programming matrices in Forest Service Resource Allocation Analysis (RAA) models are a source which appear to have great potential for providing this information. RAA models have been built or are in various stages of construction for several national forests in the Rocky Mountain region. These include the Beaverhead, Custer, Flathead, Idaho Pan Handle, and Willamette National Forests.[1] Specific discussion relating to the form of these models and their use in cost estimation is presented in the following section.

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[1]Private correspondence with C. R. Hartgraves, staff assistant, National Forest System, U.S.D.A. Forest Service, Washington, D.C. (July 7, 1975) and H. T. Nygren, coordination planner, Region 1, U.S.D.A. Forest Service, Missoula, Mont. (September 25, 1975).

# A LINEAR PROGRAMMING APPROACH TO COST ESTIMATION

## Basic Concepts

Linear programming refers to the use of a special class of mathematical models to describe problems of allocating available resources to best satisfy specific management objectives. The general form of these models in matrix notation is:

maximize (minimize) $Z = C'X$ (objective function)

subject to:

$AX \lesseqgtr B$ (constraints)

$X \geq 0$ (nonnegativity restriction)

where:

C: Vector of objective function coefficients (n x 1)

X: Vector of activities (n x 1)

A: Constraint matrix (m x n)

B: Vector of resource constraints (m x 1).

While scientists have been solving problems of this type for many years, the capability of efficiently solving problems of a large enough size to be useful did not exist until Dantzig developed the simplex algorithm in 1947. Since that time, numerous texts have been written on the subject (e.g., Sposito (1975), Hillier and Lieberman (1974), Ackoff and Sasieni (1968), Bierman, Bonini, and Hausman (1969), and Gupta and Cozzolino (1974). Computer programs utilizing various forms of the simplex algorithm have been greatly increasing the capability of the technique. Specific applications are numerous, and span such fields as economics, business, statistics, and engineering.

Several assumptions are implied by the mathematical form of linear programming models. First, it is assumed proportionality exists in the objective function and the constraints. That is, the value of each of these equations is directly proportional to levels of the activity variables. Second, additivity exists in all equations, or in other words, no interaction between the variables exists. Third is the divisibility assumption which means that all activities can be divided into fractional levels. Last is the deterministic assumption which states that all parameters of the model are known constants.

These assumptions are restrictive enough that it is difficult to find applications in the real world where all hold simultaneously. However, certain things can be done to make the assumptions less restrictive and thus enable the technique to be applied to a greater number of situations. For example, the additivity assumption can be made less critical by formulating problems in a manner in which interrelationships between variables are kept to a minimum. Second, situations in which particular variables are not divisible can be handled by an extension of linear programming called integer programming.[1] Third, the deterministic assumption can be made less restrictive by carrying out sensitivity analysis on parameters for which the true value is either not known, or is not constant. In this manner, the sensitivity of optimal solutions to changes in these parameters can be measured, and inferences about the reliability of the solution can be made.[2]

In spite of such improvements, the model still cannot be made a perfect representation of many real problems. For this reason, the optimal solution indicated by the model is generally only an estimate of the optimal solution for the real problem. Thus, models of this type (and most other types for that matter) do not replace the decision maker, but instead only provide information to the decision process.

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[1]For a detailed description of integer programming see Hillier and Lieberman (1974).

[2]Sposito (1975) has a good discussion on the theory involved in sensitivity analyses while Hillier and Lieberman (1974) have good discussion on application.

## An Application of Linear Programming in the Forest Service: Resource Allocation Analysis (RAA)

The Resource Allocation Analysis system was developed by the U.S.D.A. Forest Service Watershed Systems Development Unit, located in Fort Collins, Colorado. The system incorporates a special formulation of the linear programming model and is designed to aid managers in developing and evaluating resource allocation alternatives. In addition to the linear programming model, the system contains a computer program which generates the linear program matrix and several report writers to summarize the information in the solution. The programs which support the linear programming model are not of primary interest here and thus will not be discussed further. The interested reader is referred to Resource Allocation Analysis (U.S.D.A. Forest Service, ca. 1975b) for detailed information concerning these programs.

A description of the general form of linear programming model used in the system is presented in Table 1. As seen here, the columns or variables of the model consist of RAU's in activity and time period of implementation combinations. The RAU's are tracts of land into which the forest (or land area of interest) is delineated. All acres within a given RAU are assumed to be homogeneous in all respects. The activities are management plans which apply from the time

Table 1. The general form of an RAA linear programming matrix[a]

| | RAU$_1$[b] | | | $\ldots$RAU$_m\ldots$RAU$_M\ldots$ | B |
|---|---|---|---|---|---|
| | Activity 1 | Activity n | Activity N | | |
| | $T_1 \ldots T_k \ldots T_K$ ... | $T_1 \ldots T_k \ldots T_K$ ... | $T_1 \ldots T_k \ldots T_K$ | | |
| $C_1T_1$ | | | | | |
| $\vdots$ | | | | | |
| $C_1T_k$ | | | | | |
| $\vdots$ | | | | | |
| $C_1T_K$ | | (commodity rows) | | | |
| $\vdots$ | | | | | |
| $C_jT_k$ | | | | | |
| $\vdots$ | | | | | |
| $C_jT_K$ | | | | | |
| $COST_1$ | | | | | |
| $\vdots$ | | | | | |
| $COST_k$ | | (economic rows) | | | |
| $\vdots$ | | | | | |

[a]Adapted from Figure 1, page 21.08 of Resource Allocation Analysis (U.S.D.A. Forest Service, ca. 1975b).

[b]Resource allocation unit.

Table 1 (continued)

| | $RAU_1$ [b] | | | | | $\ldots RAU_m \ldots RAU_M \ldots$ | B |
|---|---|---|---|---|---|---|---|
| | Activity 1 | ... | Activity n | ... | Activity N | | |
| | $T_1 \ldots T_k \ldots T_K$ | ... | $T_1 \ldots T_k \ldots T_K$ | ... | $T_1 \ldots T_k \ldots T_K$ | | |
| $COST_K$ | | | | | | | |
| ⋮ | | | | | | | |
| TCOST[c] | | | | | | | |
| TBENEFIT[d] | | | | | | | |
| $NPW_1$ [e] | | | | | | | |
| ⋮ | | | | | | | |
| $NPW_r$ | | | | | | | |
| ⋮ | | | | | | | |
| $NPW_R$ | | | | | | | |
| $RAU_1$ | | | | | | | |
| ⋮ | | | | | | | |
| $RAU_m$ | | | (acreage control rows) | | | | |
| ⋮ | | | | | | | |
| $RAU_M$ | | | | | | | |
| | | | (supplemental control rows) | | | | |

[c] Total undiscounted cost.
[d] Total undiscounted benefit.
[e] Present net worth.

of implementation ($T_k$) until the end of the analysis period.

The rows in the model can be divided into four major classes. The commodity rows are first, and specify commodities considered in the model. These commodities are further defined by the period of time in which they are produced. When the model is solved, each commodity row indicates average yearly output for each commodity j, in time period k. The second section illustrated is the economic rows section, which contains both the cost and present net worth rows. The cost rows are in terms of average annual cost per time period. The $NPW_r$ rows indicate expected present net worth at discount rate r. Next are the acreage control rows, which ensure that the correct number of acres are allocated in each RAU. Last, are the supplementary control rows. In this section, the user can specify constraints he may want included in the model.

Any row in the commodity or economic sections could be used as the objective function. However, maximizing one of the present net worth rows is appropriate for most of the possible applications.

## Framework for Cost Estimation

Multiple solutions as the cost estimation process

To illustrate how the cost of wilderness can be estimated using linear programming, let us make the following assumptions. First, that a model of the form shown in Table 1 has been built for a given national forest on which exists a wilderness study area. Two, that a row exists for each of the commodities of importance, including wilderness, and that wilderness columns for the study area are present in the model. Finally, that the $NPW_r$ coefficients for the wilderness include values for nonwilderness-specific commodities produced, but not values for wilderness-specific benefits. Maximizing this model on $NPW_r$, subject to certain management constraints, generates one alternative management mix for the forest. In addition, it estimates the expected commodity outputs and corresponding present net worth. If the model is maximized a second time with the wilderness study area forced into solution as wilderness, the management mix, expected commodity outputs, and corresponding present net worth have been determined for the wilderness alternative. The difference in $NPW_r$ between the two solutions is equivalent to Equation 1, the cost of wilderness in dollar terms. The cost in physical output terms can be determined by finding the difference in the level of the respective commodities produced between the two solutions.

A set of factors affecting the level of cost estimated for given increments of wilderness are the management constraints placed on the model. These constraints reflect the objectives for management of the forest. The manager must have a good idea of what these are before any estimation of wilderness cost can be made, whether linear programming is used or not.

Yet another aspect of linear programming cost estimation needs discussion. Since no model can be a perfect representation of the world, situations may exist in which it would be useful to make additional cost estimates outside the model, given the resource allocation mix suggested by the model. Some may disapprove of this procedure on the grounds that linear programming is an optimization model and all relevant facts should be built in. Alternatively, if one regards the solutions to linear programming models as alternatives that merely approach optimality, cost estimation outside the model is a legitimate process.

## Expected advantages of the linear programming approach

RAA models have been built or are in various stages of construction for several national forests and indications are that more Forest Service planners will utilize this tool in the future. The cost of modifying these models to the form needed for wilderness cost estimation would vary, but in most cases would be modest. More importantly, once the matrix is formulated in the manner needed, wilderness cost estimates can be made at a relatively low cost. Utilizing already-existing models appears to be an efficient approach for estimating these costs.

There are two important features of the optimization capability of the linear programming model. First, it can be used to generate efficient management alternatives (in terms of the model), given the objectives for managing the forest. These alternatives should at least approach points on the production possibility frontier. To the extent that in the future management of our forest resources will approach efficient allocation of resources for the management goals selected, the cost estimates for these alternatives should be a good representation of the cost of wilderness.

Second, it provides a way of determining the marginal availability of resources in the cost estimation process. This has several aspects. First, we would expect the cost of a specific area (x) as wilderness to be affected by the extent to which other nearby areas have been already designated as wilderness. The more total area already designated as wilderness, the greater one would expect the cost of area x to be. Some of this increase in cost would be reflected by a linear programming model if, as area x is forced in as wilderness, reallocation of resources from other areas is required to meet management constraints in the model. If no reallocations are required as the level of wilderness on the forest is increased, then the cost estimated for area x would not increase at higher levels of wilderness. Second, the activity that would have taken place on area x is not necessarily foregone entirely as x is designated wilderness. That is, there very well may be other areas on the forest (y) which are being used for lower value activity that would be replaced by the activity forced off x. In this case, the real opportunity cost of wilderness is this lower value activity which must be foregone, reflected by the net change in value that would take place for the forest as a whole. The linear programming model would reflect this reallocation if constraints were preventing the higher value use from being allocated to y in the nonwilderness solution, but were relaxed (either by the analyst, or as a result of a change in management mix) in the wilderness solution. Situations such as this could be numerous, especially if management cost constraints, or other less than or equal to constraints such as might be formulated to restrict sedimentation, are present.

Another and perhaps less important value of the use of linear programming is that it forces one into using a structured approach in the cost estimation process. This helps ensure that management objectives are identified, and that the various management alternatives and resulting cost estimates are in accordance with these objectives.

## Specific Applications in Cost Estimation

Two basic methods can be identified for utilizing linear programming to calculate opportunity cost of wilderness. These will be referred to as Method 1 and Method 2. They differ in the way that wilderness constraints are formulated, resulting in a different way in which wilderness activity is brought into solution. Each generates slightly different information.

The following sections include a discussion of specific aspects of applying these methods. It is assumed that a linear programming model of the form shown in Table 1 exists and that the previously outlined assumptions concerning formulation of this model hold.

### Method 1

In the Method 1 analysis, only the total number of acres to come into solution as wilderness activity are specified. Thus, any RAU that has wilderness potential specified in the model could be allocated to wilderness. Since the model is maximized on a present net worth row, it brings into solution the wilderness areas which impose the smallest cost (or greatest benefit).

Method 1 could probably be most advantageously used early in the planning process. With this method, the analyst can estimate marginal cost curves for wilderness, determine where the least expensive wilderness areas are, and get an idea of how the boundaries might be drawn for these areas.

Matrix formulation A Method 1 analysis requires that there be a wilderness activity in the matrix for every RAU that the analyst wishes to consider for possible wilderness designation. A wilderness commodity constraint row is required to force in the desired wilderness acreage for each run of the model. This constraint would take the following form:

$$\ldots 1X_{10} + \ldots + 1X_{20} \ldots + 1X_{30} \ldots = B_w \tag{2}$$

where

$X_{10}$, $X_{20}$, $X_{30}$: Wilderness activity columns

$B_w$: Total number of wilderness acres desired for a given solution.

Additional constraints will be required if only portions of some RAU's are considered as potential wilderness. In this case, the relevant wilderness variable must be set less than or equal to the maximum value it can take, as in

Equation 3:

$$1X_{30} \leq 1200 \quad . \tag{3}$$

Here, the maximum allocatable wilderness acreage in activity $X_{30}$ is 1200 acres. Each wilderness variable that has an upper limit that is less than the total acres of that RAU, will require an additional constraint of this type.

Cost estimation procedure The first solution of the model can be found in the normal manner after the matrix is formulated. Let us assume wilderness is set equal to zero for this solution. For the second solution, the right hand side value for Equation 2 is increased by the desired increment of wilderness, say 100 acres and the problem is resolved. The difference between these two solutions provides the marginal cost of 100 acres of wilderness given that existing wilderness is assumed equal to zero. Let us say that the next marginal cost desired is for wilderness at 10,000 acres. The right hand side value for Equation 2 is increased to 10,000 acres and the problem is solved. For the fourth solution, Equation 2 is incremented yet another 100 acres and the model is again resolved. Again the level of marginal cost for this new point is equal to the difference between the two solutions. By repeating this process other points on the wilderness cost curve can be also generated.

There are trade-offs in determining the size of increment to use to estimate marginal cost. The larger the increment, the more acres marginal cost per acre is averaged across. Alternatively, if the increment is too small, differences between solutions may be lost in rounding. Increments of size equal to about 100 acres appear to be a good compromise.

Since this method requires a large number of solutions, the computer techniques used become critical from a cost standpoint. Basically, there exist two ways to solve these problems. One is to solve all problems, starting from the original tableaus. Although straightforward, this method is very inefficient since many arithmetic operations are duplicated. A more efficient alternative exists in which the information generated in the first solution is used to help solve the second problem and so on. This technique is available in most linear programming packages and can be used to save considerable computer cost. These savings become larger, the larger the linear programming model.

The basis of the technique is as follows. There exists a matrix ($B_{opt}^{-1}$) such that this matrix times the original tableau will yield the optimal solution:

$$[B_{opt}^{-1}] \text{ [original tableau] } = \text{ [optimal tableau]}$$

where:

$B_{opt}^{-1}$ = inverse of the matrix containing the original columns of the variables in the final optimal basis.

Unfortunately, this matrix is determined as the linear programming problem is being solved. Thus, knowledge of $B_{opt}^{-1}$ does not exist until the optimal solution has already been found. However, $B_{opt}^{-1}$ for a given problem can be used to help solve a revised (e.g., higher wilderness acreage) problem. Multiplying the revised problem by $(B_{opt}^{-1})$ will give an advanced state of the new problem:

$$[B_{opt}^{-1}]_{old} \quad \begin{bmatrix}\text{revised original} \\ \text{tableau}\end{bmatrix} = \begin{bmatrix}\text{advanced iteration} \\ \text{of new problem}\end{bmatrix}$$

If a feasible region for the new problem exists, the advanced iteration can result in two possible outcomes. Either the point described by the solution is inside the feasible region or it is outside. If the point is inside, the optimal solution can be found by continuing with the normal simplex algorithm. In most cases, only a few iterations will be required to arrive at an optimal solution. If the point described is infeasible, the linear programming algorithm has the capability to get back to the feasible region and an optimal solution.[1] For either case, the less the right

[1]The linear programming package utilizes one of two possible methods to accomplish this. These are the dual simplex algorithm discussed by Sposito (1975, p. 69-70) and by Hillier and Lieberman (1974, p. 662-665), and the pseudo-objective function technique discussed by Sposito (1975, p. 48-49).

hand side has been changed, the faster the new solution is found. When run streams are set up, one should enter the right hand side values in order of increasing size in successive solutions.

The reader interested in a more detailed discussion is referred to Sposito (1975), Hillier and Lieberman (1974) or any other texts dealing with the theory of linear programming applications.

Discussion of cost estimates    As mentioned in an earlier section, a marginal cost curve for wilderness can be estimated by solving the model repeatedly for a series of wilderness levels. It was also mentioned that a different marginal cost curve exists for each possible combination of management constraints that might be placed on the forest. Figure 2 illustrates the form a family of such curves might take. The curve which is most appropriate for wilderness decision-making is the curve which is generated by the set of constraints that most closely describe the management objectives for the area.

For some cases, the goals of management may not be closely defined, making it difficult to determine the appropriate constraints. However, a certain range for these constraints should be identifiable. Estimating curves for the extremes of these constraints will give the analyst information as to how changes in the constraint set affect

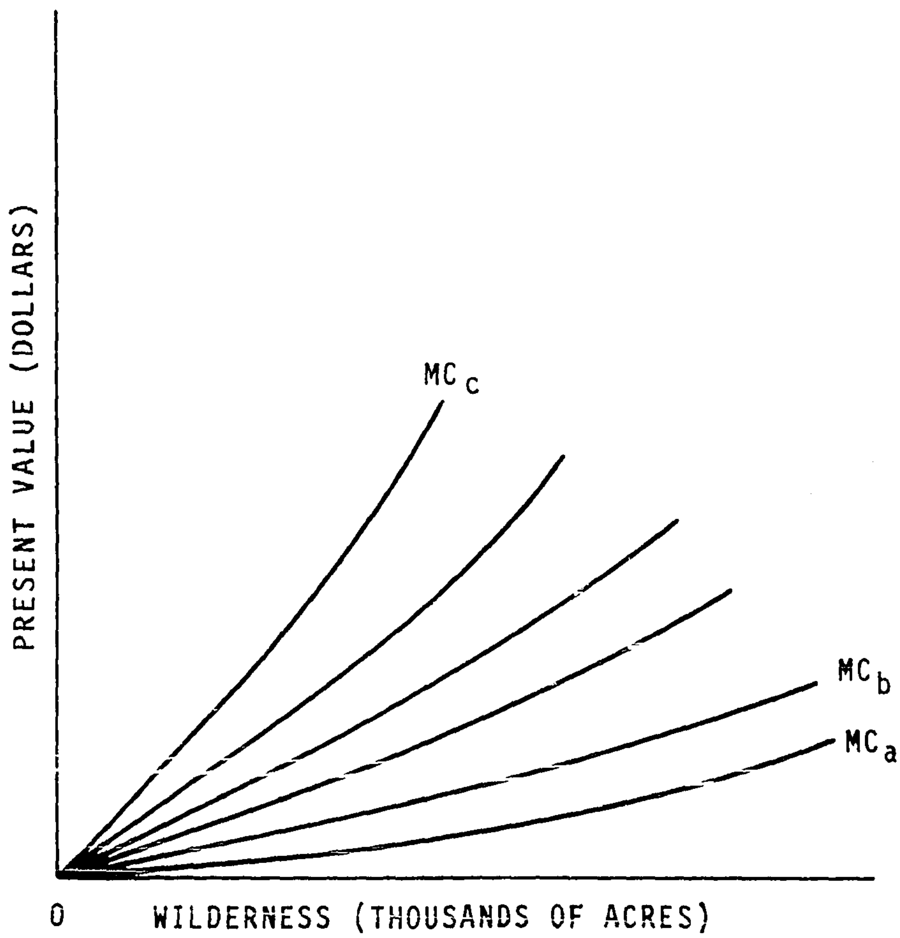


Figure 2. Hypothetical family of marginal cost curves for wilderness

wilderness cost. For example, a range such as the one shown in Figure 2 by $MC_a$ and $MC_b$ indicates that the cost of wilderness is not greatly affected over the maximum potential range of the constraint set. Alternatively, one may be faced with a situation such as that described by $MC_a$ and $MC_c$ in Figure 2. Here, wilderness cost is greatly affected by changes in the constraint matrix. In the first case, therefore, determining the appropriate constraints is much less critical than in the latter case. Unfortunately, it is impossible to generalize what this range might look like since objectives and production capability vary greatly over forests. Thus, their determination must be dealt with on an individual forest basis.

<u>Assumptions of cost curve</u> In addition to the standard linear programming assumptions discussed earlier, the Method 1 technique of wilderness cost estimation implies another assumption. Since only total number of wilderness acres is specified at each solution point, the wilderness increment could come from any RAU which has wilderness defined as a possible activity. This would be appropriate for marginal cost curves constructed for products such as timber or grazing. However, in the specific case of wilderness, it necessitates relaxing the legislative constraint that wilderness areas are to be at least 5000 contiguous acres in size.

The result of this assumption can be predicted. At any point in the process the model chooses the least cost increment of wilderness. If this parcel of land is not contiguous to existing wilderness, the cost for all contiguous parcels of land of equal size must be greater. Thus, the estimated curve, at that point, would underestimate the expected real curve, as shown in Figure 3.

Including the 5000 acre legislative constraint in cost estimation presents some very difficult problems. For a given solution, it is essentially impossible to constrain the incremental wilderness activity to be either contiguous to already existing wilderness or to be an area of 5000 contiguous acres, while still retaining a large number of RAU's that could enter the solution as wilderness. The 5000 acre constraint could be included by forcing in as wilderness many different 5000 acre areas or smaller areas contiguous to existing wilderness (one solution per area) and in each increment choosing the area with the least cost. However, such a procedure would be extremely time consuming and expensive. Considering the lack of accuracy expected in any long range projections, the benefits associated with including the 5000 acre constraint more than likely do not offset the additional cost.

Additional information    Each successive solution contains an increment of wilderness as the model is repeatedly solved. Coding and plotting these increments on

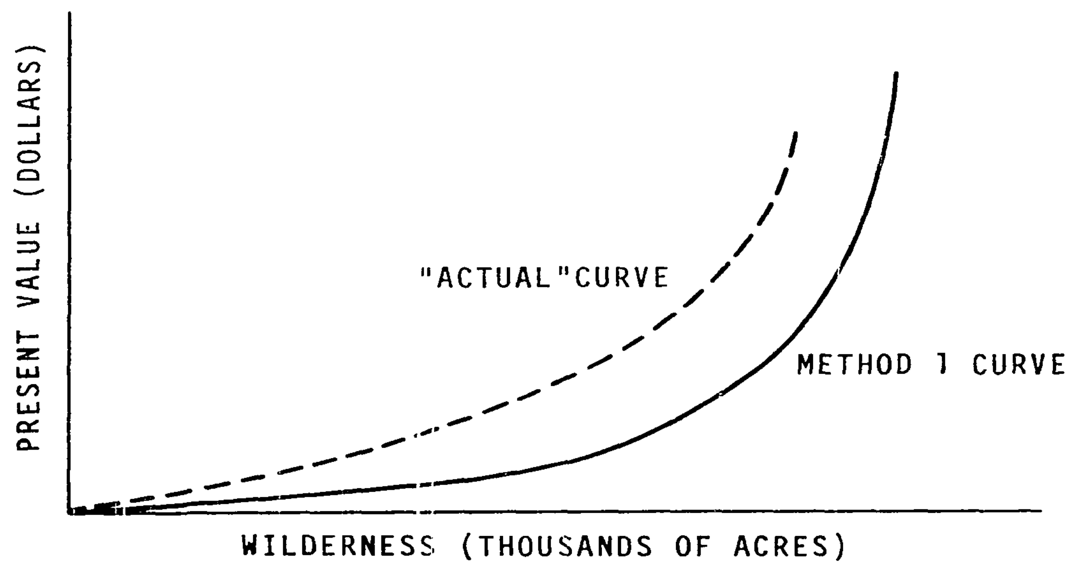


Figure 3. Likely position of "actual" marginal cost curve relative to Method 1 curve

a map yields useful information, although the increments may fall in what appears to be a haphazard manner over the potential wilderness RAU's. Each successive increment consists of higher cost areas, since in each solution the model chooses the least cost areas to be wilderness. The manner in which these increments are allocated implies relative wilderness cost of various areas on the forest. For example, roadless areas for which wilderness is relatively inexpensive would have a large proportion of wilderness allocated in early increments.

Many potential techniques for comparing relative costs exist. The most simple would be making simple mental comparisons among the areas. Alternatively, one may develop an indexing system to note the order in which RAU's enter solution as wilderness. Relative rankings for wilderness areas, either in terms of total marginal cost or average per acre marginal cost, could be made by weighting the index by acres and carrying out the appropriate arithmetic operations.

Method 2

Method 2 can be used to estimate the marginal cost of adding any specific area to the National Wilderness Preservation System under various assumptions as to management constraints and already existing wilderness. Thus, in contrast to Method 1 the analyst designates a priori the area(s) to be investigated for cost. This method is most applicable to the latter stages of the planning process when the wilderness alternatives have become clear, perhaps in part by a Method 1 analysis.

Matrix formulation and the cost estimation process

Several ways to force specific RAU's into solution as wilderness can be identified. The most straightforward and efficient way is to enter an equality constraint for every RAU to be forced in as wilderness in each solution. This can be accomplished as follows:

$$\ldots = 1X_{10} \ldots + 1X_{20} \ldots + 1X_{30} \ldots \vdots \leq B_{wc} \tag{4}$$

$$1X_{20} = B_{20} \tag{5}$$

$$\vdots$$

$$1X_{30} = 0 \tag{6}$$

where:

$X_{10}$: Wilderness activity variable not desired in solution

$X_{20}$: Wilderness activity variable desired in first solution

$X_{30}$: Wilderness activity variable desired in a later solution

$B_{wc}$: Total wilderness acres desired in first solution

$B_{20}$: Total acres of wilderness desired in RAU represented by $X_{20}$.

Each RAU to be forced into the first solution is set equal to its desired number of wilderness acres (Equation 5). The RAU's to be forced in as wilderness in later solutions are set equal to zero or some small number (Equation 6). In this manner, these rows (associated with RAU's to be entered later) have been defined in the model, but are not used in the early solutions. In addition, a wilderness commodity constraint formulated as either less than or equal to, or equal to the total number of wilderness acres desired, may be included (Equation 4). This ensures that an unwanted wilderness activity will not be included in the final basis.

After formulating the initial constraint set, the first problem can be solved. The appropriate changes that must be made before the second problem can be solved include, changing the right hand side for the wilderness commodity constraint to equal the new total wilderness acreage, and changing the right hand sides of the new wilderness RAU's from zero to their respective desired acreages. As before, the difference between the solutions is the estimated marginal cost of the wilderness increment.

For many situations it may be desirable to estimate the marginal costs associated with many alternative areas under different assumptions of existing wilderness. This may require taking certain RAU's out of wilderness designation and putting others in. New areas can be forced into solution in the same manner as described for the second solution above. Areas can be taken out of wilderness designation by changing the associated right hand side values back to zero. Thus, by utilizing advanced basic starts as described earlier, it is possible to generate in one computer runstream the solutions required for estimating the marginal costs of designating many alternative areas as wilderness. For example, assume an estimate is desired of the marginal costs of adding either area A or area B to the existing wilderness system. A reasonable runstream for generating the required information would be as follows:

Problem 1: Solve with only the existing wilderness areas forced into the model as wilderness. The wilderness activities relating to A and B are set equal to zero acres.

Problem 2: Solve with existing wilderness areas and A forced into the model as wilderness. The wilderness activities relating to B remain set equal to zero acres.

Problem 3: Solve with existing wilderness areas and B forced into the model as wilderness. The wilderness activities relating to A are set back to zero acres.

This procedure results in efficient computer use in two ways. First, each wilderness activity that is set in a supplementary equality constraint in the original tableau will have a basic variable in the optimal solution of the first problem and in all problems to follow in the runstream. Thus, the wilderness variables which are to be forced into the latter problems at some prespecified level are actually already in the basic solution of the first problem, only at a value of zero. This means that there is a high probability that the optimal solution of succeeding problems can be found in only a few iterations. Secondly, tableaus for resource problems such as these are normally quite large. Thus, significant computer input cost is saved when problems are solved in the same runstream.

Infeasibility problems

Potential for infeasibility caused by the introduction and use of the wilderness commodity constraint and related supplementary constraints comes from two general sources. One source is the interaction among the wilderness commodity constraints, acreage control constraints, and the supplementary control row constraints. For example, the wilderness commodity constraints may be set equal to more wilderness acres than are available in the model. Infeasibilities that arise in this manner result from model specification errors, and present no real problems to the analysis.

Infeasibilities could also result from interactions of the wilderness commodity constraint and other commodity constraints. Such a situation would exist if a given wilderness allocation resulted in insufficient acreage of nonwilderness land to meet one or more of the other commodity constraints. Given that no errors have been made in model formulation, infeasibilities arising in this manner are not a modeling problem, but do in fact provide useful information to the analysis. This implies it is not possible, given the management activities identified in the model, to satisfy all the constraints specified for managing the forest. At this point, the analyst could either take the information at face value or carry the analysis further by determining what constraints must be relaxed in order to generate a feasible solution. Most linear programming packages print out the status of the point which most nearly satisfies infeasible problems. This report generally includes information as to which constraints are binding and by how much. From this, the changes required to make the problem feasible can easily be determined.

In the past, most national forests have been managed at a level of intensity much below what is technically possible. If fairly intensive management activities are included in the model and if realistic constraints are placed on other commodities, then it is not likely that infeasibilities will appear until relatively high and unrealistic amounts of wilderness are forced into solution.

Sensitivity analysis

The extent to which Method 1 and 2 cost estimates represent actual value foregone depends greatly on the information upon which the model is based. In most cases, the true parameters are unknown and the coefficients in the model are only estimates of these parameters. In fact, most parameters are not constants, but are affected by factors which vary over often unknown distributions of their own, and usually are not controllable by man. An example would be the growth potential of land as it is affected by the amount of yearly moisture. Even more uncertainty is added into models of this type by the extremely long time frames which must be used. Not only is it difficult to estimate physical outputs resulting from specific management practices on specific parcels of land, but it is even more difficult to estimate accurately the value of these outputs in the future.

Obviously, as the information on which RAA models are developed improves in the future, the accuracy of wilderness cost estimates will also improve. However, since all parameters will never be known with certainty, there will always be a need for sensitivity analyses, which can in many cases provide much insight into the reliability of linear programming cost estimates.

<u>Using standard L.P. output</u> Most linear programming computer packages print out in their standard output the $Z_j - C_j$ values[1] (shadow prices) for the optimal solution nonbasic variables. These shadow prices represent the amount that each objective function coefficient would have to increase before the nonbasic variable associated with them would be introduced into the optimal basis.[2] If the model is of the form outlined in Table 1, this change is in terms of total present net worth of all commodities involved in the activity. Although these terms give some information as to the sensitivity of the optimal solution, it would be more meaningful to express this in terms of the changes required in the value or quantity of specific commodities produced.

The contribution of a specific commodity to the total present net worth of a variable can be expressed as follows:

$$PV_{kj} = \sum_{i=1}^{n} \bar{F}_i \, P_{ji} \, G_{kji} \tag{7}$$

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[1]In Resource Allocation Analysis (U.S.D.A. Forest Service, ca. 1975b) these values are referred to as "Reduced Costs" on page 3.35.

[2]More specific discussion concerning sensitivity analysis can be found in Sposito (1975, p. 70-71), Hillier and Lieberman (1974, p. 188-190), and Bierman, Bonini, and Hausman (1970, p. 331-336).

where:

$PV_{kj}$ = Contribution of commodity j to present net worth of activity k over i time periods.

$F_i$ = Discount factor for determining the present value of an equal annual sum in the ith time period at a given rate of interest.

$G_{kji}$ = Average annual output of jth commodity for activity k in the ith time period.

$P_{ji}$ = Average price or value of the jth commodity in the ith time period.

n = Number of time periods.

First, consider the change in average price of commodity j required to make the total present net worth contribution of this commodity equal to its present contribution plus the shadow price. From Equation 7 this could be written as:

$$PV_{kj} + SP_k = \left[\sum_{i=1}^{n} F_i\, P_{ji}\, G_{kji}\right] + \left[\overline{\Delta P}_j \sum_{i=1}^{n} F_i\, G_{kji}\right] \quad (8)$$

where

$SP_k$ = Shadow price of variable k in optimal solution.

$\overline{\Delta P}_j$ = Increase in average price of j required to raise the present net worth of k by an amount equal to $SP_k$.

Subtracting Equation 7 from Equation 8 yields:

$$SP_k = \overline{\Delta P}_j \sum_{i=1}^{n} F_i\, G_{kji}$$

or

$$\Delta P_j = \frac{SP_k}{\sum_{i=1}^{n} F_i \; G_{kji}} \quad . \tag{9}$$

$F_i$ can be either found in or calculated from standard interest tables (depending on the structure of the tables) and $G_{kji}$ values are found in the commodity row section of the linear programming matrix. Thus, the change in the average price of commodity j that would be required to enter any activity k into the optimal basic solution (other things remaining equal) can be calculated by Equation 9.

The sensitivity of the final basis to increases in per acre productivity can be found in a similar manner. We again start with Equation 7 but now ask how much productivity would have to increase to increase the contribution of commodity output by an amount equal to $SP_k$. This could be written as:

$$PV_{kj} + SP_k = [\sum_{i=1}^{n} F_i \; P_{ji} \; G_{kji}] + [\sum_{i=1}^{n} F_i \; P_{ji} \; G'_{kji}] \tag{10}$$

where:

$SP_k$ = Shadow price of variable k in optimal solution.

$G'_{kji}$ = Increase in per acre productivity of j required to raise the present net worth of k by an amount equal to $SP_k$.

Subtracting Equation 7 from Equation 10 yields:

$$SP_k = \sum_{i=1}^{n} F_i \, P_{ji} \, G'_{kji} \quad . \qquad (11)$$

If we let:

$$T_{kj} = \sum_{i=1}^{n} G_{kji}$$

and:

$$X_{kji} = \frac{G_{kji}}{T_{kj}}$$

then:

$$G_{kji} = X_{kji} \, T_{kj} \quad .$$

If we assume the increase in productivity is distributed in the same proportion over the years as is the present productivity:

$$G'_{kji} = X_{kji} \, T'_{kj} \qquad (12)$$

where:

$T'_{kj}$ = Total increase in productivity.

Substituting $X_{kji} \, T'_{kj}$ into Equation 11 for $G'_{kji}$ we get:

$$SP_k = \sum_{i=1}^{n} F_i \, P_{ji} \, X_{kji} \, T'_{kj} = \sum_{i=1}^{n} F_i \, P_{ji} \, X_{kji}$$

or:

$$T'_{kj} = \frac{SP_k}{\sum_{i=1}^{n} F_i \; P_{ji} \; X_{kji}} \quad . \tag{13}$$

The total increase in productivity required for a change in the optimal basic solution can be calculated from Equation 13. This increased productivity is assumed to be uniformly distributed over the years as indicated by Equation 12. Thus, to find the yearly per acre increase, Equation 12 can be solved for each time period, i, using the calculated $T'_{kj}$. Other assumptions about the distribution of the increase in per acre output needed can be made by setting the $X_{kji}$ values as desired in the beginning of the analysis. As is required for all weights, their sum must equal one.

Equations 9 and 13 imply that increases in objective function coefficients required to bring about a different basic solution must come from one source. Actually one could make any number of assumptions about how the shadow price might be split up among commodities in determining what specific increases are required for a different solution. For example, one might be interested in determining the changes in the price of timber and value of a certain outdoor recreation activity that would be required to indicate another solution if the required total increase in present value were split equally between the two.

With the procedure described thus far, one can determine the increase in present value that must take place in any commodity or combination of commodities j, before any variable k would enter into the optimal basic solution. However, we have not answered the question of what minimum increase in price or output for commodity j produced by nonbasic activity is required before any change in the optimal basis is indicated. For example, one might be interested in the minimum amount of the average stumpage price for nonbasic variables would have to increase before there would be any change in the optimal basis. This could be easily done for either price or output, using Equation 9 or 13 respectively, if the nonbasic variable that would come into solution first can be identified. A first guess might be that variable with the smallest shadow price. However, shadow price is not the only determining factor. In the case of price, the level of output per acre per year in each of the time periods ($G_{kji}$) also is important. In the level of output case, the assumption about distribution of output over time is important in addition to shadow price. Thus, for a given commodity it is possible that the first variable to come into solution as price increases would be different than the first variable to come in as output increases.

The only solution to the problem of determining the first entering variable appears to be to calculate the change required for more variables than just the one with minimum shadow price. The number that needs to be calculated before being reasonably sure of having identified the first depends on the model, and only rough guidelines are possible. First, the smaller the variance of the non-shadow price factors, the fewer cases need be calculated. Second, the larger the spread of the lower shadow prices, the fewer need be calculated.

It should be pointed out that this technique is relevant for across-the-board increases in price and output for nonbasic variables only. This is because of the "everything else remaining constant" assumption that is always present in sensitivity analysis of linear programming models. To determine the effects of actual across-the-board or forest-wide increases in price and quantity, one must rerun the model with the new values specified.

Another facet of sensitivity analysis might prove useful to the decision maker. He might be interested in knowing the extent of acreage allocation changes that result from changes in the optimal basis as price and output levels are increased. The model must be rerun using the new coefficients to get a good estimate of this relationship. However, an estimate can be made by considering the range of the shadow prices. If there is a clustering of shadow prices close to the smallest, one might expect a large number of acres to be reallocated, and so forth.

<u>Other possible sensitivity analysis</u>  Sensitivity analysis on other parameters and combinations of parameters can also be done on models of this type. However, to calculate the information needed for these, special features in the computer packages usually need to be used. These, in most cases, involve significantly more computation expense and should be used accordingly.

The first analysis to be discussed is the range that basic variable objective function coefficients can take before a change in the optimal basic solution is indicated.[1] As implied above, most computer packages provide the user access to these ranges. Using them, and the same techniques used in the nonbasic case, one can determine the changes required in terms of commodity price and output. The only difference between the two cases in models of this type is the direction of change. The sensitivity of the solution mix to commodity and variable-specific increases in per acre output or price is found in the nonbasic variables. Obviously, decreases in the objective function value of these variables would have no effect on the solution mix. Alter-

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[1]For detailed discussion on sensitivity analysis on basic variable objective function coefficients see Sposito (1975, p. 71-75), or Hillier and Lieberman (1974, p. 190-192).

natively, the sensitivity to commodity and variable-specific decreases in per acre output or price is found in the basic variables, because an increase in their objective function coefficients would have no effect on the solution mix.

A second generally available analysis which may be of interest to the decision-maker would be to investigate the change that could take place in specific right hand side variables (resource vector) before a change in the optimal basis is required for feasibility.[1] This information gives an indication of how much management constraints on the forest can be relaxed before a different solution mix would be required for optimality.

Another analysis which may be carried out is the effect of constraint matrix coefficient changes on the optimal solution mix. Such an analysis would provide implications about the confidence one should have in the optimal solution. Second, it would give an indication of the importance of estimating coefficients more accurately in the future. Unfortunately, the model must be resolved with the appropriate changes for this analysis.[2] However, significant

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[1]Detailed discussion can be found in Sposito (1975, p. 75-77) and Hillier and Lieberman (1974, p. 186-188 and 195).

[2]For discussion see Sposito (1975, p. 77-78), and Hillier and Lieberman (1974, p. 188-192).

savings in computer cost can be realized by starting from an advanced basis as described earlier.

To this point, only the sensitivity of the solution to changes in parameters of one variable, or special groups of variables, have been considered. It would be helpful in some situations to know the sensitivity of a particular solution to forest-wide changes in certain factors. This is particularly true for price, where changes likely would effect the whole forest, as opposed to only some areas, as is assumed in all previous examples. This can be accomplished on the computer using the parametric programming routine available in most linear programming packages. However, the appropriate change vector must be included in the constraint matrix in order to provide the needed information.

Parametric programming is discussed in depth in linear programming texts.[1] Briefly, it can be used to determine how much elements of the objective function might be changed in specified proportions before the present solution becomes nonoptimal. In matrix notation, the objective function formulation for parametric programming is:

$$Z = [C + \Theta\ (\Delta C)]\ X \quad .$$

[1]For discussion see Sposito (1975, p. 78-84), Hillier and Lieberman (1974, p. 193-195, 665-671), and Bierman, Bonini, and Hausman (1969, p. 336-340).

C represents the original objective function vector and $\Delta C$ represents the specified change in the vector. $\Theta$ is the amount of change that must take place in the objective function before a change is required in the basis to maintain optimality.

To see how this technique fits the problem at hand we must again refer to Equation 7, the contribution to present net worth by commodity j. If P is assumed constant over time, this equation becomes:

$$PV_{kj} = P_j \sum_{i=1}^{n} F_i \, G_{kji} \quad .$$

For each unit increase in $P_j$, $PV_{kj}$ increases by the amount equal to

$$\sum_{i=1}^{n} F_i \, G_{kji} \quad .$$

If we let the vector of these values equal the change vector $\Delta C$:

$$Z = [C + \Theta \, (\sum_{i=1}^{n} F_i \, G_{kji})] \, X \quad \text{(for all k)} \quad .$$

$\Theta$ then equals the change in unit price required for the solution to be nonoptimal, since

$$\Theta \, (\sum_{i=1}^{n} F_i \, G_{kji})$$

represents total change required. Overall decreases in price required to indicate a new optimal solution can be determined in the same manner by entering negative values of

$$\sum_{i=1}^{n} F_i \, G_{kji}$$

for the $\Delta C$ vector ($\Theta$ cannot be negative in parametric programming). In this manner, the objective function is reduced by the change vector for each unit of price and the amount $P_j$ would have to decrease before a new solution is indicated is equal to $\Theta$.

# BEAVERHEAD NATIONAL FOREST LINEAR PROGRAMMING MODEL

## Introduction

A RAA linear programming model of the Beaverhead National Forest was chosen as a vehicle to test the procedures and hypotheses described previously. The model is of the form outlined in Table 1 and includes the important commodities and management options (including wilderness) as seen by the staff of the Beaverhead Forest. Secondly, approximate matrix dimensions are 2600 columns by 1000 rows (depending on the particular formulation), a size adequate for getting good estimates of computer costs involved in the estimation process. Thirdly, the Beaverhead appeared to be at a decision point between further development for more intensive management or extensive management including more area of designated wilderness. All things considered, the Beaverhead National Forest appeared to offer an excellent case for testing the wilderness cost estimating techniques.

## Beaverhead National Forest

The Beaverhead National Forest is located in southwestern Montana and is made up of the eight planning units depicted in Figure 4. Total area is 2,113,396 acres. The soils and geology of the forest are diverse and elevations vary from 5,200 feet to 11,316 feet. At lower elevations,

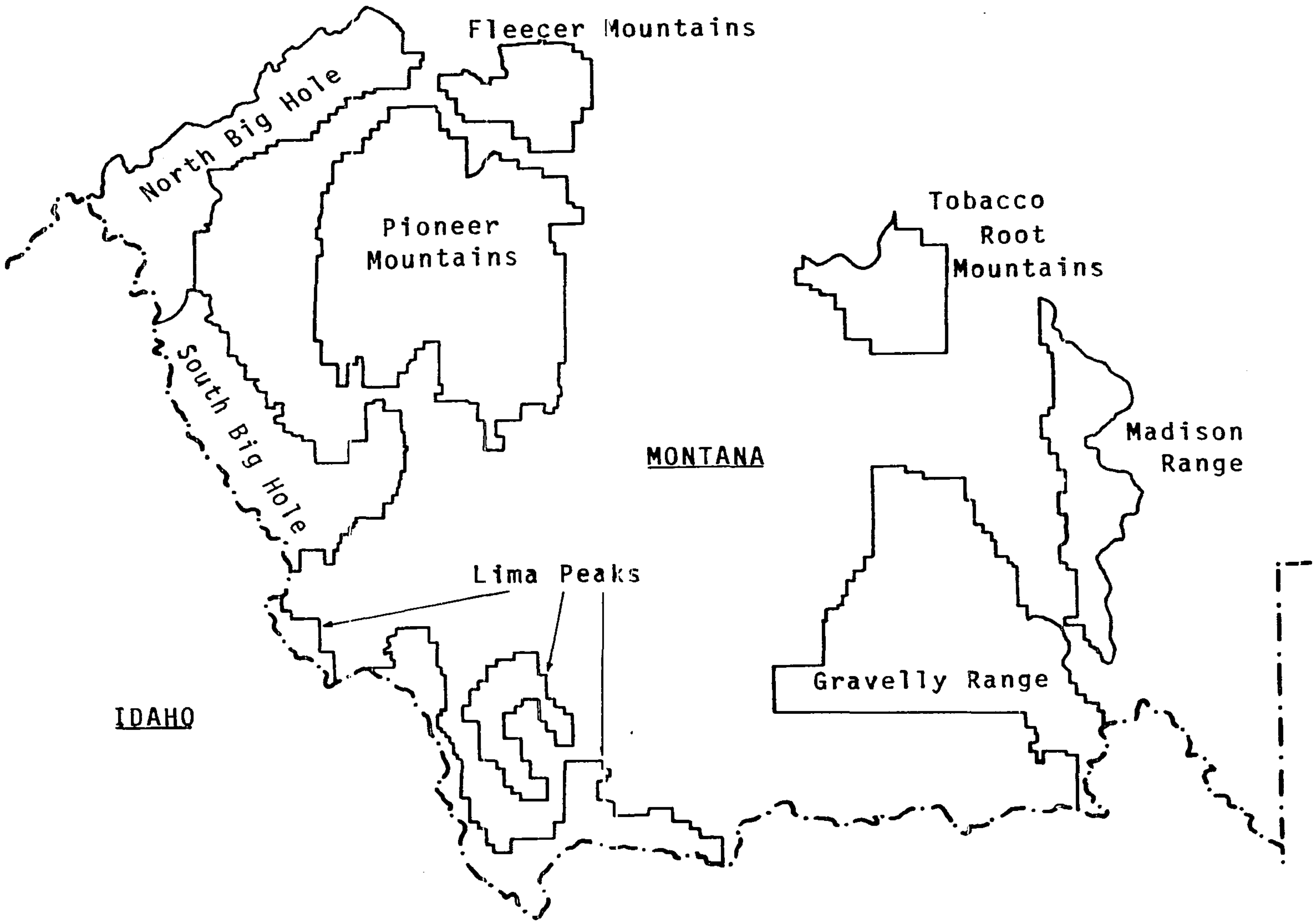


Figure 4. Location of the eight Beaverhead National Forest planning units in southwestern Montana

the forest consists of rolling slopes covered with sagebrush, grass, and patches of timber. Middle elevations are basically timber with subalpine vegetation dominating at the higher levels. Timberline is about 9,200 feet.

Approximately 40 percent of the Beaverhead Forest is classified as commercial timberland and is considered moderately productive for the Rocky Mountain area. The commercial species on almost two-thirds of the timbered area is lodgepole pine with Douglas fir and Engelmann spruce making up the remaining third.

Annual precipitation is also variable, giving from 12 inches in some lower valleys to over 50 inches in the mountains. Water is an important product of the Forest. It provides about .74 inches per acre of high quality water to the Missouri River drainage each year.

Another major use of the Beaverhead National Forest is forage production for grazing animals. In 1974, 763,197 acres were used for livestock grazing. At present there are 197 range allotments to ranchers, about half of which are under some form of intensive management.

Recreation is yet another important use of the Forest, which is nationally known for its hunting and fishing opportunities as well as fine scenery. In recent years there has been an increase in the use of modern recreational vehicles. Also, dispersed recreation oriented to the natural characteristics of the Forest is increasing.

At present about 70 percent of the National Forest is essentially roadless with no major development. On these acres, the Forest Service has identified six areas (totalling 187,559 acres) that will be studied for possible wilderness classification. In addition, other areas appear to have potential for being included in the Wilderness System in the future. To date there is only one official wilderness area on the Forest, the Anaconda Pintlar Wilderness Area. The Beaverhead contains 72,329 acres of the total 157,803 acres of wilderness in that area.[1]

## Model Formulation

The Beaverhead linear programming model was built by the staff of the Beaverhead Forest with assistance from members of the Forest Service Resource Allocation Analysis (RAA) group, presently located in Fort Collins, Colorado. The only changes made in the model for this research are formulation changes that will be discussed in a following section. No changes were made in the commodity, row, cost, or present net worth coefficients of the model.

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[1]All information describing the Beaverhead National Forest was adapted from U.S.D.A. Forest Service (1975c).

<u>Resource analysis unit (RAU) delineation</u>

The eight planning units depicted in Figure 4 were delineated by the Forest Service into management analysis units (MAU's). These are designed to reflect differences in management and roading costs resulting from location differences. The location of these MAU's is presented in Slides 1 through 8. By integrating such factors as soils, slope, aspect, vegetation, and climate, the MAU's were further delineated into ten types on the basis of timber and forage production capability. These ten types, called resource analysis units (RAU's), are listed in Table 2. All the area classified as a particular RAU type within a specific MAU makes up what is called a RAU. This, then, is the basic unit to which the management options are related.

In total there are 359 RAU's delineated on the Forest. Slides 1 through 8 show their location on the eight planning units. A three element code is used to identify RAU's. The first element is a number and refers to the planning unit. The second element is a letter referring to the MAU and the third is a letter referring to the RAU type. Thus, the code 7BH would refer to the RAU that has high forest production potential (RAU type H), and is located in the B$^{th}$ MAU on the Madison Range Planning Unit, the seventh planning unit (Slide 7).

Table 2. RAU types into which the Beaverhead National Forest was delineated[a]

| Code | Description |
|---|---|
| O | Rock (noncommercial forest and nonrange) |
| H | Forest: high production potential |
| M | Forest: moderate production potential |
| L | Forest: low production potential |
| S | Forest: spruce types |
| T | Forest: slopes equal to or greater than 45 percent |
| P | Range: primary |
| I | Range: secondary |
| A | Alpine - subalpine range |
| W | Willow and wet meadow |

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

Management options

Twenty-three management options or plans were identified by the Forest Service for consideration within the model. These are summarized with their codes and descriptions in Table 3. (A more comprehensive description of these options is presented in Table 23 in Appendix A.) Option 00 provides a baseline against which the merits of more intensive management can be compared. If a particular acre on the forest is not allocated to any other options, it remains allocated to Option 00.

Options 01 through 09 are the extensive management alternatives in the model. The main objective in these options is to preserve already existing resource uses and values. These include natural, semiprimitive, and lightly developed recreation settings, key wildlife habitats, and water yield. Management actions are limited to monitoring and preventing excessive use. Option 09 is unique in that it is always applied on the Anaconda Pintlar Wilderness Area.

The range management alternatives are Options 11 through 13. Increasing code size reflects increasing intensity of management. Option 11 limits grazing to areas where water is available, while Option 12 expands useable range by increasing water availability to livestock through the use of simple water developments, such as springs with headboxes

Table 3. Summary of management options defined in the Beaverhead linear programming model[a]

| Management Option Code | Description[b] |
|---|---|
| 00 | Custodial management: provide only fire control and law enforcement (relevant RAU types: all) |
| 01 | Recreation management: retain natural recreation settings (relevant RAU types: all) |
| 02 | Recreation management: retain semiprimitive recreation settings (relevant RAU types: all) |
| 03 | Recreation management: retain lightly developed recreation settings (relevant RAU types: all) |
| 04 | Watershed management: retain present quality and quantity of water (relevant RAU types: A, H, I, L, M, P, T, and W) |
| 05 | Wildlife management: retain key habitats for big game species (relevant RAU types: all) |
| 09 | Wilderness management: retain environmental characteristics of the Anaconda Pintlar Wilderness Area (relevant RAU type: O) |
| 11 | Range management: restrict livestock to available forage near water (relevant RAU types: A, I, P, and W) |
| 12 | Range management: fully utilize available forage production by improving livestock distribution and water availability (relevant RAU types: I, P, and W) |
| 13 | Range management: increase forage production through cultural practices and by improving livestock distribution and water availability (relevant RAU types: P and W) |

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

[b]See Appendix A for more complete description of management options.

Table 3 (continued)

| Management Option Code | Description[b] |
| --- | --- |
| 21 | Recreation management: rehabilitate natural recreation settings where needed (relevant RAU types: all) |
| 22 | Recreation management: rehabilitate semi-primitive recreation settings where needed (relevant RAU types: all) |
| 23 | Recreation management: rehabilitate lightly developed recreation settings where needed (relevant RAU types: A, H, I, L, M, P, S, and W) |
| 31 | Timber management: uneven-aged management at medium intensity of shade tolerant tree species (relevant RAU types: H, L, M, T, and S) |
| 32 | Timber management: even-aged management at medium intensity on high productivity sites (relevant RAU type: H) |
| 33 | Timber management: even-aged management at medium intensity on medium productivity sites (relevant RAU type: M) |
| 34 | Timber management: even-aged management at medium intensity on low productivity sites (relevant RAU type: L) |
| 35 | Timber management: even-aged management at medium intensity on sites with some slopes in excess of 45 percent (relevant RAU type: T) |
| 36 | Timber management: even-aged management at high intensity on high productivity sites (relevant RAU type: H) |
| 37 | Timber management: even-aged management at high intensity on medium productivity sites (relevant RAU type: M) |
| 38 | Timber management: even-aged management at high intensity on low productivity sites (relevant RAU type: L) |

Table 3 (continued)

| Management Option Code | Description[b] |
|---|---|
| 52 | Wildlife management: enhance wildlife habitat where needed (relevant RAU types: all) |
| 92 | New-wilderness-study-area management: retain environment characteristics until final wilderness decision is made (relevant RAU types: all) |

and stock tanks. Option 13 increases forage availability more by improving the productivity of range land through the use of cultural practices such as sagebrush control.

Options 21 through 23 are recreation site rehabilitation and enhancement alternatives for the three types of recreation sites listed previously. For natural sites (Option 21) and semiprimitive sites (Option 22) management actions include removing existing structures, and revegetating abandoned roadbeds. For lightly developed sites, actions include construction of trails, two-wheel drive roads, and campgrounds.

Options 31 through 38 are concerned with managing commercial timber land for the production of wood. These options are designed to reflect the differences in wood production which result from differences in productive capability of the land and differences in intensity of management. Option 31 is the only uneven-aged timber management alternative in the model and includes site preparation, regeneration, thinning, harvesting, and slash disposal. Options 32 through 34 are even-aged management with medium intensity for three different productivity classes of land: high, medium, and low. Management activities include site preparation, one commercial thinning, harvesting, and slash disposal. Option 35 is a special case in that it applies to areas with slopes in excess of 45 percent. The management actions include site preparation, one commercial thinning, etc., but are applied in a manner that will ensure resource protection. Options 36 through 38 are high intensity, even-aged management alternatives for the three productivity classes. Additional actions include planting and a precommercial thinning.

The last two options include enhancement of wildlife habitat (Option 52) and new-wilderness-study-area management (Option 92). Option 52 is obviously designed to improve the wildlife carrying capacity of the land. Management activities include such things as closing roads, developing better water availability, and excluding livestock. Option 92 represents the management which would take place to protect and preserve the wilderness characteristics on those areas set aside for wilderness study. Management actions include monitoring and preventing excessive use.

Columns

The columns or variables are made up of combinations of management options and RAU's. Thus, the units of measure for the variables are acres. Management options were included in the model for only those RAU types and specific RAU's within these types for which the options were considered to be viable alternatives by the Forest Service. For example, one would consider Option 37 (timber management) a realistic alternative for RAU type H (high forest production potential) but not for type O (rock, noncommercial forest, and nonrange). Secondly, one would not consider enhancing wildlife habitat to be desirable on a particular RAU that already provides an excellent wildlife habitat. The RAU types considered viable for each option are presented in Table 3. Unfortunately, due to the large number of variables (over 2600), it is not possible to present in an effective manner the RAU's within these types considered viable for each option.

A five element code is used later in this paper to identify columns (variables). The first three elements refer to the RAU and the last two refer to the management option. Thus, code 7BH31 refers to Option 31 (uneven-aged timber management) on RAU 7BH (highly productive forest land in MAU B on the seventh or Madison Range Planning Unit).

Time periods

The total period of analysis for the model is 130 years. This is divided into three different periods to allow for comparisons among levels of outputs at different times. These are:

Time Period 1: 15 years (1975-1990)

Time Period 2: 40 years (1991-2030)

Time Period 3: 75 years (2031-2105)

Commodity and cost constraints

The first sets of rows in the constraint matrix are the commodity and cost constraint rows. Sixteen different commodities and two types of cost rows have been included in the model. Table 4 lists these rows along with their codes and units of measure. A separate row exists for each time period, commodity, and cost type. Two exceptions to this are NEWHA3, which has only a third time period row, and NEWSTi, which has second and third time period rows. As indicated, each row is in terms of expected average output (or cost) per year for given time periods. The coefficients for these constraint rows represent the expected level of commodity output (or cost) per acre per year and were generated using the techniques described in Resource Allocation

Table 4. Commodity constraint and cost rows included in the Beaverhead linear programming model[a]

| Code[b] | Units of Measure | Description |
|---|---|---|
| COSTi | DOLLARS/YR. | Management cost |
| OLDHAi | MCF[c]/YR. | Volume of old growth timber harvested |
| OLDSTi | MCF/YR. | Volume of old growth standing timber |
| NEWHAi | MCF/YR. | Volume of new growth timber harvested |
| NESTi | MCF/YR. | Volume of new growth standing timber |
| FORRGi | M.LBS.[d]/YR. | Livestock forage utilized |
| FORTIi | M.LBS./YR. | Livestock forage utilized on harvested timberland |
| REC1i | RVD[e]/YR. | Recreation on undeveloped acres[f] |
| REC2i | RVD/YR. | Recreation on semiprimitive acres |
| REC3i | RVD/YR. | Recreation on lightly developed acres[f] |

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

[b]There are three commodity constrained rows for each commodity, one for each of the three time periods. i at the end of each code name represents these time periods. (There are two exceptions: NEWHAi where i =3, and NEWSTi where i =2, 3).

[c]Thousand cubic feet of wood.

[d]Thousand pounds of forage.

[e]Recreation visitor day (visitation of one person for 12 hours, 12 persons for 1 hr., or any combination equaling 12 hours of visitation).

[f]List of activities for each of the three types of recreation appears in Table 5.

Table 4 (continued)

| Code[b] | Units of Measure | Description |
|---|---|---|
| WATRYi | AF[g]/YR. | Water yield |
| SEDRDi | CU.YD.[h]/YR. | Sediment from roads |
| SEDGEi | CU.YD./YR. | Sediment, general |
| BGFOOi | AE[i]/YR. | Big game food |
| BGCOVi | AE[j]/YR. | Big game cover |
| RDCOSi | DOLLARS/YR. | Cost of primary access roads |
| WILDEi | ACRES/YR. | Wilderness acres |
| WSTUDi | ACRES/YR. | Wilderness study acres |

[g]Acre feet (one acre foot equals the amount of water required to cover one acre at a depth of one foot).

[h]Cubic yards.

[i]Acre equivalent (one acre of food available for wildlife consumption).

[j]Acre equivalent (one acre of cover available for wildlife use).

Analysis (U.S.D.A. Forest Service, ca. 1975b). The recreation rows present a unique case in that expected participation in a variety of recreation activities is totalled to make up the recreation visitor days (RVD) for each recreation type. These recreation activities are presented in Table 5.

Table 5. Activities assumed in the three recreation classes[a]

REC1i (recreation on undeveloped acres)

(a) Viewing outstanding scenery
(b) Enjoying unique-unusual environment
(c) Horseback riding
(d) Nature study
(e) Mountain climbing
(f) Backpacking
(g) Tent camping

REC2i (recreation on semiprimitive acres)

(a) Hunting big game
(b) Hunting small game
(c) Fishing
(d) Gathering forest products

REC3i (recreation on lightly developed acres)

(a) Automobile drive
(b) Scooter riding
(c) Canoeing
(d) Other watercraft
(e) General camping
(f) Picnicking
(g) Touring
(h) Snowmobiling
(i) Automobile camping
(j) Hiking

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

Net present worth rows

The matrix includes three NPWi rows, one for each of the three discount rates which have been considered in the model. These are:

NPW1 at 6.87 percent

NPW2 at 10.00 percent

NPW3 at 15.00 percent

In this research, NPW1 has been used as the objective function.

The coefficients in these rows represent the estimated present net worth per acre of future benefits and costs associated with each of the variables. The value of per unit output used by the Forest Service in developing these coefficients, varied over time. However, the average value used is presented for each commodity in Table 6. As seen, no value was entered into the NPWi rows for standing timber (OLDSTi and NEWSTi), sediment from roads (SEDRDi), or for sediment in general (SEDGEi). Also, no value was entered directly for wilderness (WILDEi) or wilderness study (WSTUDi). However, the value of the commodities that would be produced on wilderness and wilderness study areas (e.g., REC1i, and WATRYi) is included in the coefficients for these variables.

The costs used in developing these NPWi coefficients varied among variables as well as over time. Average cost used is listed by option in Table 7. Implementation costs

Table 6. Average value of commodities assumed in the NPWi rows in the Beaverhead linear programming model[a]

| Benefit Index Value | Unit | Commodity |
|---|---|---|
| $466.80 | MCF | OLDHAi |
| --[b] | MCF | OLDSTi |
| $466.80 | MCF | NEWHAi |
| -- | MCF | NEWSTi |
| $ 2.00 | M. LBS. | FORRGi |
| $ 2.00 | M. LBS. | FORTIi |
| $ 9.80 | RVD | REC1i |
| $ 12.15 | RVD | REC2i |
| $ 5.16 | RVD | REC3i |
| $ 5.00 | AF | WATRYi |
| -- | CU. YD. | SEDRDi |
| -- | CU. YD. | SEDGEi |
| $ 4.85 | AE | BGFOOi |
| $ 4.85 | AE | BGCOVi |
| -- | ACRES | WILDEi |
| -- | ACRES | WSTUDi |

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

[b]No dollar value indicated in the NPWi rows.

Table 7. Average costs per option assumed in the NPWi and COSTi rows in the Beaverhead linear programming model[a]

| Management Option Code | Implementation Costs | Operation and Maintenance Costs | Variable Costs |
|---|---|---|---|
| | $/A./Yr. | $/A./Yr. | $/MCF harvested |
| 00 | --[b] | 0.14 | -- |
| 01 | -- | 0.27 | -- |
| 02 | -- | 0.36 | -- |
| 03 | -- | 0.86 | -- |
| 04 | -- | 0.25 | -- |
| 05 | -- | 0.18 | -- |
| 09 | -- | 0.19 | -- |
| 11 | 3.33 | 0.54 | -- |
| 12 | 11.23 | 1.03 | -- |
| 13 | 14.07 | 1.34 | -- |
| 21 | 8.54 | 0.27 | -- |
| 22 | 8.54 | 0.36 | -- |
| 23 | 60.74 | 0.86 | -- |
| 31 | 18.09 | 35.61 | 487.29 |
| 32 | 18.64 | 35.61 | 488.73 |
| 33 | 18.64 | 35.61 | 488.73 |
| 34 | 18.64 | 35.61 | 488.73 |
| 35 | 20.65 | 35.61 | 527.22 |
| 36 | 18.64 | 49.50 | 435.69 |
| 37 | 18.64 | 49.50 | 435.69 |
| 38 | 18.64 | 49.50 | 435.69 |
| 52 | 6.06 | 0.25 | -- |
| 92 | 0.02 | 0.19 | -- |

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

[b]No dollar costs included.

were entered for all options except the preservation options (Options 00 through 09) and operation and maintenance costs were entered for all variables. Variable costs were included only for timber harvested in the timber alternatives (Options 31 through 38).

Acreage control rows

There are 359 of these rows, one for each RAU. They are composed totally of ones and zeros. A particular coefficient is one if the column activity refers to that RAU and zero if it does not. The right hand side (RHS) for these constraints is always the total number of acres in the RAU.

Supplementary control rows

The supplementary control rows make up the last set of constraint rows in the model. In the Beaverhead model these rows fall into three major types. One type restricts the timber cut on designated RAU's to be less than a certain amount, by restricting certain timber management options to be less than desired acre maximums.

A second type is called the roadless constraints and may be used in one of several ways. By making these constraints equalities, specified acres can be forced into solution as wilderness. If they are made less than constraints, by setting the RHS appropriately they can be used as upper bounds on the amount of roadless acres available for wilderness in each RAU.

A third type puts upper limits on the amount of recreation management rehabilitation (see Table 3) that can take place on specified RAU's. This defines the number of acres in these RAU's which are in need of rehabilitation.

## Choosing Examples

### Background information

The Beaverhead National Forest linear programming model has been used to identify five alternative management plans for the Forest. These plans are labelled A through E and each emphasizes a different management mix. A brief description of these plans follows. A complete presentation of these can be found in the publication entitled, Land Use Planning (U.S.D.A. Forest Service, 1975c).

Alternative A      This alternative emphasizes wilderness study and recreation opportunities, places a moderate emphasis on forage production, and a low emphasis on wood fiber production. Twenty-four different areas totalling 776,841 acres are proposed for wilderness study, including the six areas (with 187,559 acres) previously selected for study by the Chief of the Forest Service. About 80 percent of existing recreation opportunities would be retained and the availability of livestock forage would remain about the same as at present. The harvest of wood fiber would be about half of the current average level.

Alternative B This alternative emphasizes wood fiber production, places a moderate emphasis on wilderness study, and a low emphasis on forage production and recreation opportunities. About 60 percent more wood fiber than the current average would be available. Seven areas totalling 448,502 acres are proposed for wilderness study, including the six selected by the Chief of the Forest Service. About ten percent less livestock forage would be available than under current management, and about 65 percent of the existing recreation opportunities would be retained.

Alternative C This alternative emphasizes livestock forage production, and places moderate emphasis on wood fiber production, wilderness study, and recreation opportunities. About ten percent more than current average livestock forage would be available and approximately the same amount of wood fiber would remain available as at present. Seven areas totalling 448,502 acres are proposed for wilderness study, including the six selected by the Chief of the Forest Service. About 70 percent of the existing recreation opportunities would be retained.

Alternative D This alternative emphasizes recreation opportunities, places a moderate emphasis on livestock forage production, and a low emphasis on wood production and wilderness study. The availability of livestock forage would remain about the same as under present management and wood fiber availability would be about half of present level. The six areas selected by the Chief of the Forest Service, plus an addition to one of these areas, are proposed for wilderness study for a total of 189,575 acres. About 85 percent of the existing recreation opportunities would be retained.

Alternative E This alternative emphasizes wood fiber production, places a moderate emphasis on livestock forage production, and a low emphasis on wilderness study and recreation opportunities. Wood fiber availability would be about 60 percent higher than at present and the availability of livestock forage would remain about the same. The six areas selected by the Chief of the Forest Service, plus an addition to one of these areas, are proposed for wilderness study, totalling 189,575 acres. About 60 percent of the existing recreation opportunities would be retained.

Criteria

Several criteria were identified as bases for choosing examples which would provide the most information concerning the cost estimation techniques. First, examples were desired that would be of use to the Beaverhead National Forest. It was thought that the people who would most likely benefit from this research would be better able to identify with a realistic example. Second, we wanted to measure the effect of management constraints in the model on the level of wilderness cost. Third, we wanted to present as many alternative uses of the techniques as possible. Fourth, we wanted to determine the extent to which the linear model would reflect the increasing marginal cost of a specific area of wilderness, as assumptions of total wilderness elsewhere on the forest are increased.

Example 1

The first example chosen was a Method 1 analysis on the Alternative C constraints. Plan C was chosen because it was a reasonably good compromise among the other plans and appeared to be the most likely direction of future management. Thus, the wilderness cost estimates based on Alternative C management constraints appear to most closely reflect actual costs.

It was hypothesized that the wilderness marginal cost curve (associated with Alternative C constraints) would at first decrease and then increase at an increasing rate. In order to determine the levels at which these changes take place, a larger number of solutions were made at lower acreage levels of wilderness. The actual amounts of wilderness forced into successive solutions were: 72,379; 72,479; 76,379; 76,479; 80,379; 80,479; 100,379; 100,479; 200,379; 200,479; 500,379; 500,479; 927,340; and 927,440 acres. The main marginal cost estimates were then made for the 100-acre increments at each of the seven major levels. One hundred acres were chosen for the increment size because it allowed the per acre marginal cost estimates to be averaged over a relatively small number of acres and yet was large enough that the changes between the solutions would not be lost in rounding. The increments between the other points (100 to 4,000 for example) would also provide per acre marginal cost estimates, but would be less accurate since they are averaged over a larger number of acres.

Example 2

The second example also uses the Method 1 approach, but within a context of management constraints different than Example 1. Maximum efficiency in utilizing the resources of the Forest was chosen as the only management criterion, subject to constrained levels of wilderness acreage. Thus, in the solutions there would be no guarantee of minimum amounts of grazing or timber harvest.

The levels at which wilderness was forced into succeeding solutions were identical to Example 1. This gives comparability between the marginal costs of wilderness estimated under rather different sets of management objectives.

Example 3

The third example chosen was a Method 2 analysis. Beaverhead personnel suggested two areas, Elk River and Snow Crest, that in their opinion had potential for wilderness, but were not included as wilderness study areas in Alternative C. The marginal cost of these areas as wilderness was estimated, assuming the management constraints in Alternative C and already existing wilderness to be those areas included in C.

A second part of this example is an estimate of marginal cost of designating the Elk River area as wilderness under the same Alternative C management constraints, but this time assuming existing wilderness to be the Snow Crest area plus the other Alternative C areas. This provides means for meeting the fourth criterion discussed above.

## Setting Up and Running Examples

All the computer work for solving these examples was carried out using the linear programming package ILONA (U.S.D.A. Forest Service, ca. 1975b) at the U.S.D.A. Fort Collins Computation Center in Fort Collins, Colorado.

### Example 1

With the exception of the wilderness study area constraint, WSTUD2, the commodity and cost constraints used in the original tableau were identical to those used in generating Alternative C. New standing timber in period 3 (NEWST3) was constrained to be greater than or equal to 1,114,000 thousand cubic feet (MCF),[1] and forage production was constrained to be greater than or equal to 324,000 thousand pounds (M.Lbs.)[2] per year. All other nonwilderness commodity and cost rows were entered as free rows. WSTUD2 was set equal to zero acres, while WSTUD1 and WSTUD3 were left unconstrained. No changes were made in the acreage constraint rows.

Most changes which needed to be made in the Alternative

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[1]Adjusted to account for private inholdings NEWST3 actually equals 1,084,470.60 MCF.

[2]Adjusted to account for private inholdings FORRG2 actually equals 309,169.25 M.Lbs. per year.

C formulation occurred in the supplementary row section. In the ILONA linear programming package, the analyst has the option in specific runs of omitting (not defining) selected rows in the original matrix. In the original Alternative C formulation, the wilderness study acres were forced into solution by setting the associated roadless area constraints equal to the desired acreages in each RAU. All other roadless constraints remained undefined. In this example, all roadless area constraints were set less than or equal to the value they could take for maximum wilderness. The resulting potential wilderness is presented in Slides 9 through 15. No changes in any of the other supplementary rows were made.

The model was then maximized using NPW1 as the objective function. In successive solutions, WSTUD2 was set equal to the levels of wilderness outlined previously, while all other constraints remained unchanged. The basis of the prior optimal solution was used as the starting point for each of the successive problems.

Example 2

The model formulation for Example 2 was identical to that for Example 1, except that the constraints on timber (NEWST3) and forage (FORRG2) were relaxed to zero. The successive solutions were handled in the same manner as for Example 1.

Example 3

For Example 3, the commodity and cost constraints were set up identically to those used in generating Alternative C. This includes WSTUD2 which was formulated as a free row. The only difference between the formulations was in the supplementary row section. In the first solution, the roadless constraints relating to the RAU's in the Snow Crest and Elk River areas were set equal to a very small number. In this manner these rows which would be needed later were defined, but entered in the first solution at insignificant levels.

For the second solution the RHS values for the Elk River roadless constraints were changed to the correct number of acres for that area. In the third problem, the Elk River roadless constraints were set back to a small number and the Snow Crest roadless constraints were set equal to their correct number of acres. Finally in the fourth solution, the Snow Crest roadless constraints were left unchanged and the Elk River constraints were again set back to their correct number of acres. All problems after the first were started using the inverse of the previous optimal solution as the starting point.

# PRESENTATION AND DISCUSSION OF RESULTS

The results of the computer runs were printed out by the standard solution output of ILONA. Due to the large amount of data involved, totals for the net present worth, cost, and commodity output levels are presented in Appendix B. The marginal costs presented below were calculated from these totals in the manner described by Equation 1 (p. 10). It should be pointed out that the form of the objective function results in dollar cost estimates being expressed in net terms. The wilderness benefits included in the net terms are those that were included in the objective function (see Table 6, p. 81 for the list of these values). All physical quantities, management costs, and modeling costs are presented in terms of net change.

## Example 1 and 2 Cost Estimates

### Dollar terms

The marginal costs of wilderness for Examples 1 and 2 are presented in Figures 5 and 6. Figure 5 shows the full range of marginal costs estimated for both examples, while Figure 6 is a large scale presentation of the first portion of the cost curves. The (net) marginal cost of wilderness in Example 1 starts out negative and decreases even more until about 80,000 acres is reached. At this point it begins

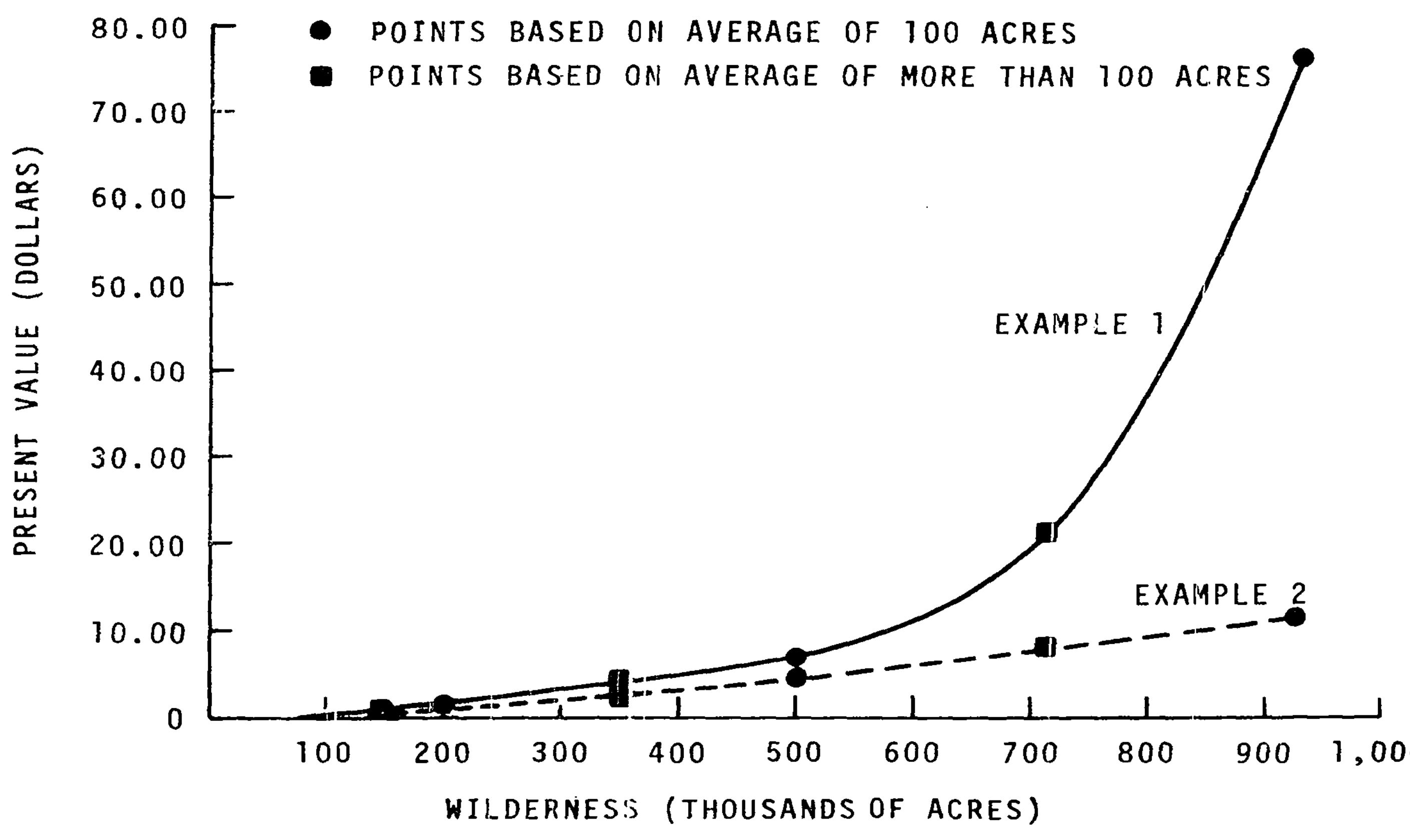


Figure 5. Estimated per acre marginal cost of wilderness for Example 1 and 2 (72,379 to 927,440 acres)

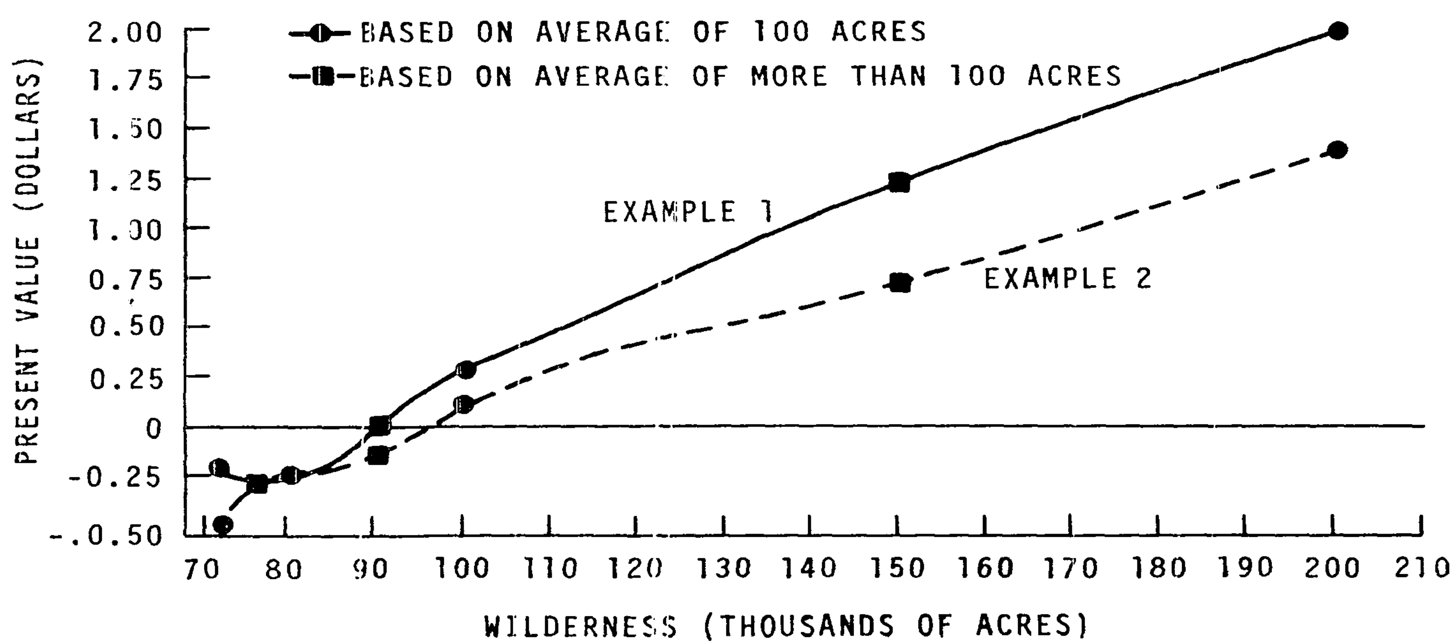


Figure 6. Estimated per acre marginal cost of wilderness for Example 1 and 2 (72,379 to 200,479 acres)

to increase and becomes positive at approximately 90,000 acres. From here it increases at a nearly constant rate to about 500,000 acres, where it begins increasing at an increasing rate. In comparison, the Example 2 (net) marginal cost curve starts out negative and increases through the whole estimated range. The sign of the curve becomes positive at about 97,500 acres and the slope stays relatively constant throughout the remainder of the curve.

As discussed earlier, the purpose of the curves is not to provide the answer to how much wilderness should be set aside. Instead, it is to provide the decision-maker with information about the trade-offs involved as an aid in arriving at a decision. However, certain management implications are apparent. First, consider Example 1. We know that even if the marginal benefits of wilderness are zero, the total amount of wilderness on the Beaverhead should be increased by approximately 20,000 acres to a total of 90,000 acres if the assumptions and unit-values of the model are accepted. This is the point of optimal social allocation where marginal benefit equals marginal cost. Given the philosophy of the present society and the likely direction of more intensive management in the future, it is highly unlikely that the marginal benefit of wilderness would be less than or equal to zero at such a low level. Thus, in all probability, the level of wilderness should be over

90,000 acres.

Certain implications can be drawn from the upper end of the curve also. Consider Figure 7, where the Example 1 cost curve is reproduced and hypothetical demand, or marginal benefit, curves have been added. The vertical difference between hypothetical marginal benefit per acre curve ($MB_1$) and hypothetical $MB_2$ is $30, quite a large range. The optimal allocation implied by these curves differs by approximately 100,000 acres near the high end of the marginal cost curve. This can be contrasted with an equal marginal benefit range in the lower region of the cost curve, represented by $MB_3$ and $MB_4$. Here the range in implied optimal wilderness is about 400,000 acres, or four times larger. In the upper range of the cost curve for this example, the optimal social allocation of wilderness is relatively insensitive to the level of marginal benefit. And, the farther out on the curve, the more insensitive it becomes. On this basis then, one might guess that the upper boundary for the truly optimal wilderness allocation is around 700,000 to 750,000 acres. It cannot be much past this level due to the rapid increase in slope of the curve beyond this point.

For Example 2, it can be concluded, based on the same logic as in Example 1, that optimal wilderness lies somewhere above 97,000 acres (Figure 6). However, since the slope of the Example 2 cost curve remains essentially

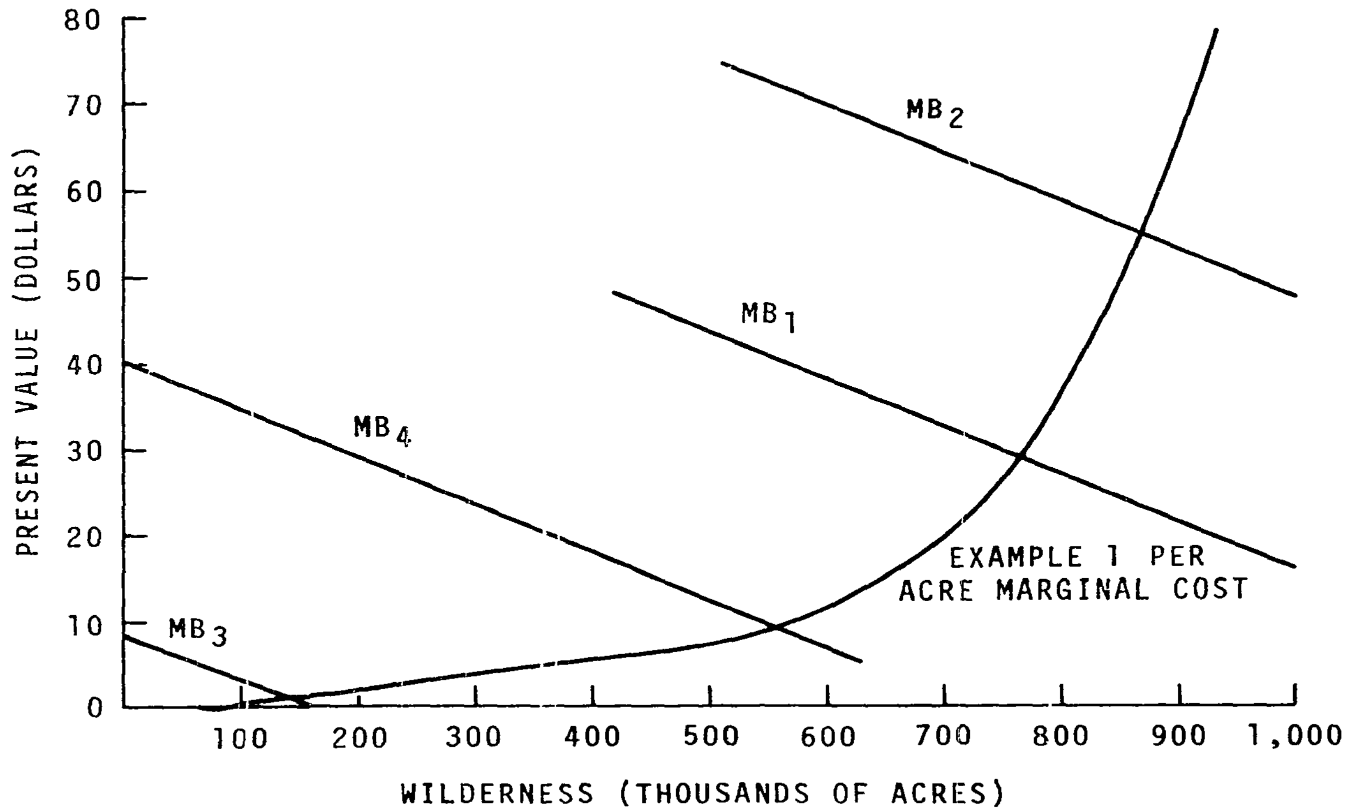


Figure 7. Optimal levels of wilderness implied by hypothetical per acre marginal benefit of wilderness curves and estimated per acre marginal cost of wilderness for Example 1 (72,379 to 927,440 acres)

constant, no criteria for estimating upper boundary levels exist.

Another type of information the two examples provide is the sensitivity of wilderness cost to differences in management goals and objectives. Recall that the management goal leading to the Example 2 formulation is to maximize efficiency. In contrast, the goals implied by Example 1 are maintaining the local economy as well as economic efficiency. Observing Figure 5, one can see that costs for the two examples are gradually getting farther apart as wilderness is increased. However, significant differences do not begin to appear until the upward turn of the Example 1 cost curve occurs. Since the management objectives are significantly different for the two examples, this implies that management objectives are not an extremely important factor in determining the cost of wilderness allocation up to about 500,000 to 600,000 acres. However, after this level the management objectives appear to become very important in determining wilderness cost. It should be pointed out that these results hold only for the Beaverhead National Forest and may be actually quite different for other national forests.

The effect on cost estimates of different discount rates is shown by the NPWi rows. The values of these rows for Examples 1 and 2 are presented in Table 8. For both

Table 8. Example 1 and 2 average per acre wilderness marginal cost estimates for the three discount rates (r) used in the model (present value, in dollars)

| Marginal Increment of Wilderness (acres) | Example 1 NPW1 (r=6.87%) | Example 1 NPW2 (r=10.00%) | Example 1 NPW3 (r=15.00%) | Example 2 NPW1 (r=6.87%) | Example 2 NPW2 (r=10.00%) | Example 2 NPW3 (r=15.00%) |
|---|---|---|---|---|---|---|
| 72,379- 72,479 | -0.21 | -0.04 | 0.04 | -0.50 | -0.18 | -0.07 |
| 72,479- 76,379 | -0.27 | -0.03 | 0.04 | -0.37 | -0.10 | --[a] |
| 76,379- 76,479 | -0.28 | -- | 0.04 | -0.28 | -0.04 | 0.04 |
| 76,479- 80,379 | -0.26 | -0.03 | 0.04 | -0.26 | -0.03 | 0.04 |
| 80,379- 80,479 | -0.28 | -0.04 | 0.05 | -0.25 | -0.04 | 0.05 |
| 80,479-100,379 | 0.01 | 0.27 | 0.26 | -0.16 | 0.05 | 0.09 |
| 100,379-100,479 | 0.28 | 0.42 | 0.37 | 0.11 | 0.39 | 0.34 |
| 100,479-200,379 | 1.24 | 1.21 | 0.87 | 0.72 | 0.72 | 0.51 |
| 200,379-200,479 | 1.98 | 1.63 | 1.04 | 1.38 | 1.42 | 0.99 |
| 200,479-500,379 | 4.24 | 3.17 | 1.99 | 2.72 | 1.71 | 0.94 |
| 500,379-500,429 | 7.02 | 5.10 | 3.14 | 4.18 | 2.94 | 1.81 |
| 500,479-927,340 | 21.22 | 13.33 | 7.52 | 8.52 | 5.95 | 3.59 |
| 927,340-927,440 | 76.44 | 45.36 | 24.45 | 12.01 | 8.58 | 5.24 |

[a]Nonzero but less than 0.006 and greater than -0.006.

examples, as the discount rate is increased, the effect of adding wilderness is decreased. This is reflected at lower levels of wilderness by (net) marginal costs which are less negative and at higher levels of wilderness by smaller (net) marginal costs. This is due to the fact that the benefits foregone (or increased at lower levels of wilderness) are generally in the distant future. The larger the discount rate used, the smaller will be the present value of future benefits.

Physical terms

In addition to looking at dollar costs of wilderness, it is useful to see what changes in physical outputs are associated with these costs. Table 9 presents these marginal physical changes for Example 1.

The largest impacts are observed for recreation on natural areas (REC1i) for the three time periods and for recreation on the semiprimitive areas (REC2i) for the three time periods. Averaged over the three time periods, REC1i tends to decrease at the lower levels of wilderness, increase in the middle wilderness allocation and then decrease again at the highest level. For the three time periods, REC2i tends to have no change or increase slightly at the lower levels of wilderness, and then begin decreasing at an increasing rate as more wilderness is introduced.

Table 9. Example 1 average annual per acre marginal changes in physical commodities for each of the three time periods considered in the model

| Marginal Increment of Wilderness | OLDHA1[a] | OLDHA2 | OLDHA3 | OLDST1 | OLDST2 | OLDST3 |
|---|---|---|---|---|---|---|
| (acres) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | --[b] | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | -- | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | -- | -- | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | -- | -- | 0.00 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | 0.59 | 0.14 | 0.35 | -2.51 | -13.93 | -32.55 |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

[a]See Table 4, p. 77, for description of commodity codes.

[b]Nonzero but less than 0.006 and greater than -0.006.

Table 9 (continued)

| Marginal Increment of Wilderness | NEWHA3 | NEWST2 | NEWST3 | FORRG1 | FORRG2 | FORRG3 |
|---|---|---|---|---|---|---|
| (acres) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (M.LBS.) | (M.LBS.) | (M.LBS.) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | -- | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | -- | 0.00 | -- |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | -- | 0.00 | -- |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500-479-927,340 | -0.07 | 0.00 | 0.00 | -0.01 | 0.00 | -- |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | -0.02 | 0.00 | -- |

Table 9 (continued)

| Marginal Increment of Wilderness | FORTI1 | FORTI2 | FORTI3 | REC11 | REC12 | REC13 |
|---|---|---|---|---|---|---|
| (acres) | (M.LBS.) | (M.LBS.) | (M.LBS.) | (RVD) | (RVD) | (RVD) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | -0.01 | -0.01 | 0.01 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | -0.02 | -- | 0.00 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | -- | -0.03 | 0.04 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | -- | 0.02 | 0.03 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | -- | -- | 0.04 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | -- | 0.05 | 0.06 |
| 500,479-927,340 | -- | -- | -- | -0.01 | 0.02 | 0.02 |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | -0.02 | -0.04 | -0.03 |

Table 9 (continued)

| Marginal Increment of Wilderness | REC21 | REC22 | REC23 | REC31 | REC32 | REC33 |
|---|---|---|---|---|---|---|
| (acres) | (RVD) | (RVD) | (RVD) | (RVD) | (RVD) | (RVD) |
| 72,379- 72,479 | -- | -- | -- | 0.00 | -- | -- |
| 72,479- 76,379 | -- | -- | -- | -- | -- | -- |
| 76,379- 76,479 | -- | -- | -- | -- | -- | -- |
| 76,479- 80,379 | -- | -- | -- | -- | -- | -- |
| 80,379- 80,479 | -- | -- | -- | 0.00 | -- | -- |
| 80,479-100,379 | -0.01 | -- | -- | -- | -- | -- |
| 100,379-100,379 | -- | 0.01 | 0.01 | -- | -- | -- |
| 100,479-200,379 | -0.02 | -0.02 | -0.02 | -- | -- | -- |
| 200,379-200,479 | -0.03 | -0.03 | -0.03 | -- | 0.01 | 0.01 |
| 200,479-500,379 | -0.04 | -0.04 | -0.03 | -- | -- | -- |
| 500,379-500,479 | -0.08 | -0.07 | -0.06 | -- | -- | -- |
| 500,379-927,340 | -0.11 | -0.16 | -0.16 | -- | 0.01 | 0.01 |
| 927,340-927,440 | -0.23 | -0.53 | -0.53 | 0.01 | 0.03 | 0.03 |

Table 9 (continued)

| Marginal Increment of Wilderness | WATRY1 | WATRY2 | WATRY3 | SEDRD1 | SEDRD2 | SEDRD3 |
|---|---|---|---|---|---|---|
| (acres) | (AF) | (AF) | (AF) | (CU.YD.) | (CU.YD.) | (CU.YD.) |
| 72,379- 72,479 | -- | -- | -- | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | -- | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 80,379 | -- | -- | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | -- | -- | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -- | -- | 0.00 | 0.00 | 0.00 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -0.01 | -0.01 | 0.00 | 0.00 | 0.00 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | -- | -0.01 | -0.01 | 0.01 | -- | 0.01 |
| 927,340-927,440 | -- | -0.01 | -0.01 | 0.00 | 0.00 | -- |

Table 9 (continued)

| Marginal Increment of Wilderness | SEDGE1 | SEDGE2 | SEDGE3 | BGF001 | BGF002 | BGF003 |
|---|---|---|---|---|---|---|
| (acres) | (CU.YD.) | (CU.YD.) | (CU.YD.) | (AE) | (AE) | (AE) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -- |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -0.01 | -0.01 | -- | -- | -- |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -- | -- | -- | -- | -- |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | -0.01 | -0.02 | -0.02 | -0.01 | -0.02 | -0.02 |
| 927,340-927,440 | -0.08 | -0.03 | -0.33 | -0.03 | -0.13 | -0.14 |

Table 9 (continued)

| Marginal Increment of Wilderness | BGCOV1 | BGCOV2 | BGCOV3 |
|---|---|---|---|
| (acres) | (AE) | (AE) | (AE) |
| 72,379- 72,479 | -- | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | -- |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -- | -- |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -- | -- |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | -- | -- | -- |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 |

Somewhat smaller changes are observed in sediment in general (SEDGEi) in all time periods and in big game food (BGFOOi) in all time periods, both of which decrease at higher levels of wilderness. In constrast, small increases are indicated at higher levels of wilderness in all time periods for recreation on lightly developed areas (REC3i).

By far the most important commodity making up the opportunity cost of wilderness is REC2i. This alone accounts for about $60 of the per acre average cost in the last increment of wilderness. Other commodities which decrease and thus add to the cost are forage off rangeland (FORRGi), REC1i (at some points), water yield (WATRYi), and BGFOOi. Commodities which tend to offset the cost are REC1i (at some points), and REC3i. Other commodities that have no value included in the objective function but are still important decision variables in this example are old growth standing timber (OLDSTi), sediment from roads (SEDRDi), and SEDGEi.

The Example 2 marginal physical changes are presented in Table 10. Most of the commodities do not significantly change over the range of wilderness considered. Commodities showing slight decrease are SEDGEi and BGFOOi in all three time periods. Commodities which increase as more wilderness is brought into the solution are REC1i and REC3i, both in all time periods. Again REC2i shows the most

Table 10. Example 2 average annual per acre marginal changes in physical commodities for each of the three time periods considered in the model

| Marginal Increment of Wilderness | OLDHA1[a] | OLDHA2 | OLDHA3 | OLDST1 | OLDST2 | OLDST3 |
|---|---|---|---|---|---|---|
| (acres) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT. |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | --[b] |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | -- | -- | 0.00 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

[a]See Table 4, p. 77, for description of commodity codes.

[b]Nonzero but less than 0.006 and greater than -0.006.

Table 10 (continued)

| Marginal Increment of Wilderness | NEWHA3 | NEWST2 | NEWST3 | FORRG1 | FORRG2 | FORRG3 |
|---|---|---|---|---|---|---|
| (acres) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (M.LBS.) | (M.LBS.) | (M.LBS.) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 10 (continued)

| Marginal Increment of Wilderness | FORT11 | FORT12 | FORT13 | REC11 | REC12 | REC13 |
|---|---|---|---|---|---|---|
| (acres) | (M.LBS.) | (M.LBS.) | (M.LBS.) | (RVD) | (RVD) | (RVD) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | -- | 0.01 | 0.01 |
| 72,479- 76,379 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | -0.01 | -- | -- |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | -0.01 | -- | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | -- | 0.01 | 0.01 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | -- | 0.02 | 0.03 |
| 100,479-200,379 | 0.00 | 0.00 | 0.00 | -- | 0.02 | 0.02 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | -- | 0.04 | 0.05 |
| 200,479-500,379 | 0.00 | 0.00 | 0.00 | -- | 0.02 | 0.02 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | -- | 0.02 | 0.03 |
| 500,479-927,370 | 0.00 | 0.00 | 0.00 | -- | 0.04 | 0.05 |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | -- | 0.08 | 0.08 |

Table 10 (continued)

| Marginal Increment of Wilderness | REC21 | REC22 | REC23 | REC31 | REC32 | REC33 |
|---|---|---|---|---|---|---|
| (acres) | (RVD) | (RVD) | (RVD) | (RVD) | (RVD) | (RVD) |
| 72,379- 72,479 | -0.01 | -0.01 | -0.01 | 0.00 | -- | -- |
| 72,479- 76,379 | -- | -- | -- | -- | -- | -- |
| 76,379- 76,479 | -- | -- | -- | -- | -- | -- |
| 76,479- 80,379 | -- | -- | -- | -- | -- | -- |
| 80,379- 80,479 | -- | -- | -- | 0.00 | -- | -- |
| 80,479-100,379 | -0.01 | -- | -- | -- | -- | -- |
| 100,379-100,479 | -0.02 | -0.02 | -0.02 | 0.00 | -- | -- |
| 100,479-200,379 | -0.02 | -0.02 | -0.01 | -- | -- | -- |
| 200,379-200,479 | -0.03 | -0.03 | -0.03 | -- | -- | -- |
| 200,479-500,379 | -0.03 | -0.03 | -0.02 | -- | 0.01 | 0.01 |
| 500,379-500,479 | -0.05 | -0.04 | -0.04 | 0.00 | -- | -- |
| 500,479-927,340 | -0.08 | -0.08 | -0.07 | -- | 0.01 | 0.01 |
| 927,340-927,440 | -0.12 | -0.11 | -0.10 | -- | -- | -- |

Table 10 (continued)

| Marginal Increment of Wilderness | WATRY1 | WATRY2 | WATRY3 | SEDRD1 | SEDRD2 | SEDRD3 |
|---|---|---|---|---|---|---|
| (acres) | (AF) | (AF) | (AF) | (CU.YD.) | (CU.YD.) | (CU.YD.) |
| 72,479- 72,479 | -- | -- | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | -- | -- | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | -- | -- | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -- | -- | 0.00 | 0.00 | 0.00 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -- | -- | 0.00 | 0.00 | 0.00 |
| 500,379-500,479 | -- | 0.00 | -- | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | -- | -- | -- | 0.00 | 0.00 | 0.00 |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 10 (continued)

| Marginal Increment of Wilderness | SEDGE1 | SEDGE2 | SEDGE3 | BGF001 | BFG002 | BGF003 |
|---|---|---|---|---|---|---|
| (acres) | (CU.YD.) | (CU.YD.) | (CU.YD.) | (AE) | (AE) | (AE) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 72,479- 76.379 | 0.00 | 0.00 | 0.00 | -- | 0.00 | 0.00 |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -- | -- | -- | -0.01 | -0.01 |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -- | -0.01 | -0.02 | -0.06 | -0.06 |
| 500,379-500,479 | 0.00 | 0.00 | 0.00 | 0.00 | -- | -- |
| 500,479-927,340 | -- | -- | -- | -- | -- | -- |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 10 (continued)

| Marginal Increment of Wilderness | BGCOV1 | BGCOV2 | BGCOV3 |
|---|---|---|---|
| (acres) | (AE) | (AE) | (AE) |
| 72,379- 72,479 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | 0.00 | -- | -- |
| 76,379- 76,479 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | 0.00 | 0.00 | 0.00 |
| 80,379- 80,479 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | -- | -- | -- |
| 100,379-100,479 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -- | -- | -- |
| 200,379-200,479 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -- | -- | -- |
| 500,379-500,479 | -- | -- | -- |
| 500,479-927,340 | -- | -- | -- |
| 927,340-927,440 | 0.00 | 0.00 | 0.00 |

significant decrease of all commodities considered.

In this example REC2i is again the most important variable contributing to the dollar cost of wilderness while BGFOOi contributes only minimally to cost. The major variables serving to offset wilderness cost are REC1i and REC3i.

Comparing Tables 9 and 10, generally the same commodities change in level of output as wilderness is increased. The main factor accounting for the spread between the two curves at higher wilderness allocations is the significantly greater magnitude of REC2i at the higher wilderness allocations in Example 1. Other smaller, but yet significant differences, are the higher levels of WATRYi and BGFOOi which are given up at higher levels of wilderness in Example 1.

Management costs

The marginal changes of overall management cost (COSTi) and roading cost (RDCOSi) for both examples appear in Table 11. No changes take place in RDCOSi for either example as wilderness is increased.

The situation for COSTi is slightly different. In both examples, COSTi for each time period decreases as total wilderness is increased, up to about 500,000 acres. For Example 2, this trend continues to the maximum amount of

Table 11. Example 1 and 2 average annual per acre marginal changes in management cost (COSTi) and roading cost (RDCOSi) for each of the three time periods considered in the model (undiscounted dollars)

| Marginal Increment of Wilderness | Example 1 | | | | | |
|---|---|---|---|---|---|---|
| | COST1 | COST2 | COST3 | RDCOS1 | RDCOS2 | RDCOS3 |
| (acres) | | | | | | |
| 72,379- 72,479 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 72,479- 76,379 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 76,379- 76,479 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 76,479- 80,379 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 80,379-80,479 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 80,479-100,379 | -0.08 | -0.12 | -0.12 | 0.00 | 0.00 | 0.00 |
| 100,379-100,479 | -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| 100,479-200,379 | -0.07 | -0.13 | -0.03 | 0.00 | 0.00 | 0.00 |
| 200,379-200,479 | -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| 200,479-500,379 | -0.10 | -0.14 | -0.14 | 0.00 | 0.00 | 0.00 |
| 500,379-500,479 | -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| 500,479-927,340 | 0.47 | 0.18 | 0.30 | 0.01 | --[a] | 0.00 |
| 927,340-927,440 | 2.20 | 1.68 | 1.63 | 0.00 | 0.00 | 0.00 |

[a]Nonzero but less than 0.006 and greater than 0.006.

| Example 2 | | | | | |
|---|---|---|---|---|---|
| COST1 | COST2 | COST3 | RDCOS1 | RDCOS2 | RDCOS3 |
| -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| -0.08 | -0.11 | -0.11 | 0.00 | 0.00 | 0.00 |
| -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| -0.06 | -0.08 | -0.08 | 0.00 | 0.00 | 0.00 |
| -0.08 | -0.11 | -0.10 | 0.00 | 0.00 | 0.00 |
| -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| -0.12 | -0.14 | -0.14 | 0.00 | 0.00 | 0.00 |
| -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| -0.21 | -0.14 | -0.13 | 0.00 | 0.00 | 0.00 |
| -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |
| -0.12 | -0.16 | -0.15 | 0.00 | 0.00 | 0.00 |
| -0.11 | -0.16 | -0.16 | 0.00 | 0.00 | 0.00 |

wilderness specified in the model. In constrast, COSTi begins to rise at a rapid rate at this point in Example 1. This then is another important factor in explaining the rapid increase in the Example 1 marginal cost curve at higher levels of wilderness.

The land allocations

Plotting the wilderness allocations on a map gives several types of information. First, one can see the location of wilderness allocations identified by the model. Second, coding the areas in the order in which they come into solution gives an index of relative costs of wilderness for various areas on the Forest. The least expensive areas will come into solution first and so on. Third, this provides information as to where one might draw wilderness boundaries to obtain the maximum amount of wilderness for a given cost, or to minimize the cost of a given amount of wilderness.

The wilderness allocation at various levels of cost are presented for both examples on Slides 16 through 29. To simplify the maps for the slides, the 13 increments actually calculated are aggregated into four major increments. These are (1) 72,379 acres (present amount of wilderness on forest) to 100,379; (2) 100,379 to 200,379; (3) 200,379 to 500,379; and (4) 500,379 to 927,440 acres.

Specific information relating to each slide is presented in Appendix C in Table 26. This includes per increment figures on acres added, percent of total increment, percent of potential wilderness, and major RAU types. A summary of the information depicted on the slides and Appendix C is as follows.

Slide 16 (North Big Hole Planning Unit - Example 1) In the first increment only one area totalling 2,053 acres came into solution as wilderness and another small area was allocated in the third increment. The bulk of wilderness in this Planning Unit came in the fourth increment and represents about 18 percent of the total area added in that increment. The RAU types allocated to wilderness were varied with type L (forest type with low timber production potential) making up the largest portion. This indicates that areas adjacent to the Anaconda Pintlar Wilderness Area, and areas in this Planning Unit in general, are expensive relative to other possible areas on the Forest.

Slide 17 (North Big Hole Planning Unit - Example 2) Several small areas came into solution as wilderness in the second increment and one small area was added in the third. Again, the bulk of wilderness in this Planning Unit came in the fourth increment. The major RAU types involved were O (rock, noncommercial forest, and nonrange) and T (forest type with slopes in excess of 45 percent). Wilderness in the North Big Hole Planning Unit is relatively more expensive for Example 2 than Example 1. However, the area adjacent to the Anaconda Pintlar Area has about the same cost under both sets of constraints.

Slide 18 (South Big Hole Planning Unit - Example 1) No wilderness was allocated in either of the first two increments, but approximately 16 percent of the total number of acres in the third increment was allocated on this Planning Unit. And, a slightly larger total area than the third increment was added in the fourth increment. Major RAU type was O, with large amounts of type T also. The South Big Hole areas appear to be slightly less expensive for wilderness than the North Big Hole areas, but still expensive relative to other areas on the Forest.

Slide 19 (South Big Hole Planning Unit - Example 2) No areas came into solution as wilderness in the first two increments, about 5 percent of the third increment came in, and 24 percent of the acres available in the fourth increment came into solution. The major RAU type was O, but there were also large amounts of L and I (secondary rangeland). Under Example 2 constraints, wilderness is again less expensive in the South Big Hole than in the North Big Hole, but still is expensive compared to other areas on the Forest. More wilderness came into solution in increment three for Example 1 than for Example 2, indicating that wilderness is slightly less expensive in this Planning Unit for Example 1 constraints.

Slide 20 (Pioneer Mountains Planning Unit - Example 1) About 15 percent of increment one and 49 percent of increment two were allocated on this Planning Unit. In addition, sizeable areas were allocated in both increment three (34 percent of increment) and increment four (28 percent of increment). The first two increments were basically RAU type 0, while the last two increments contained large amounts of type P (primary rangeland), and M (forest type with moderate production potential) as well as 0. For Example 1 constraints, this Planning Unit contains large areas that are relatively inexpensive as wilderness, although some areas are comparable in expense with North and South Big Hole areas.

Slide 21 (Pioneer Mountains Planning Unit - Example 2) Several areas came into solution in the first increment totalling 16 percent of that increment. In the second increment 16,562 acres were added making up 17 percent of this increment. The third and fourth increments were 43 percent and 28 percent of their respective totals. In the first two increments, RAU types were mainly 0 with some I. In the last two increments, large amounts of P, I, M and I were present along with the predominating 0 type. A sizeable area in this unit is relatively cheap as wilderness, with other areas being comparable in price with the first two Planning Units considered. Also, it should be noted that large amounts of P, I and T came into solution (third increment) before large amounts of type O (in the last increment). In comparison, both examples had about the same wilderness allocation in increment one. In increment two, in contrast, Example 1 had significantly more area than did Example 2 (49 percent as opposed to 16 percent). Example 2 had a slight edge in increment three and they are about equal in the last increment. These differences suggest slightly lower relative costs for Example 1 constraints. Also, the relative distribution of wilderness on this Unit may be worth noting. In Example 1, the rock RAU type tended to come into solution earlier. In Example 2, types P, I and T tended to come in first.

Slide 22 (Gravelly Range Planning Unit - Example 1) Large proportions of the first increment (59 percent) and of the second (24 percent) were brought into solution from this area. The third increment allocation was small (7 percent) with the fourth being relatively large again (23 percent of the increment total). The only RAU type making up the first two increments was O, the third increment types were I and O, and the last increment was made up of A (alpine to subalpine rangeland), P, I and T with a small amount of O. In summary, this Planning Unit contains a large portion of the cheaper areas, a small amount of the medium-priced, and again a sizeable portion of the more expensive wilderness acres on the Forest.

<u>Slide 23 (Gravelly Range Planning Unit - Example 2)</u> Large proportions of both the first and second increments were in solution (52 percent and 39 percent, respectively). In contrast, relatively small amounts of increment three (16 percent) and increment four (13 percent), were allocated in this Unit. In the first increment, O was the only RAU type. In the succeeding increments, types A, P, I and T were added. For this set of constraints, the Planning Unit contains a large proportion of the inexpensive wilderness and a very small portion of the expensive wilderness. In comparing the two examples, it appears that a large proportion of the Gravelly Range is much cheaper for wilderness given Example 2 constraints in the model.

<u>Slide 24 (Lima Peaks Planning Unit - Example 1)</u> A small portion of the first increment (4 percent) and 20 percent of the second increment entered into solution in this Planning Unit. In the third increment about 12 percent entered, and about 4 percent entered in the last increment. The acres in the first increment were in RAU type A, while type O was dominant in increments two and three. P was the major type in the fourth increment. The areas on this unit appear on the average to be from medium

to low priced relative to the other areas on the Forest.

Slide 25 (Lima Peaks Planning Unit - Example 2) No areas were allocated to wilderness in the first increment, but relatively large portions were allocated in the second and third increments (21 percent and 22 percent respectively). A small portion of increment four was allocated in this Planning Unit (4 percent). Major RAU types in the second and third increments were O and P with types M and T being added in the last increment. The majority of the areas in this Planning Unit are low to medium priced wilderness. Example 1 tended to have slightly more acreage in the first two increments and Example 2 tended to have more in the last two increments. In this Planning Unit, the relative price of wilderness appears to be somewhat less for Example 1 constraints. In Example 1 there did appear to be a higher percentage of type O in solution in the lower increments.

Slide 26 (Tobacco Root Mountains Planning Unit - Example 1) No areas were allocated to wilderness in the first two increments. Four percent of increment three (a large portion of the potential wilderness on this Planning Unit) was allocated. A slightly smaller area (2 percent of increment four) was allocated in the last increment. In the third increment the main RAU type was O, along with a small amount of I. The increment four additions were RAU types M, I, T and S (forest with mainly spruce type). The areas on this Planning Unit could be considered as medium to high priced.

Slide 27 (Tobacco Root Mountains Planning Unit - Example 2 Wilderness was not allocated in either of the first two increments. And only 3 percent of increment three and 2 percent of increment four were allocated here. In the third increment the only RAU type involved was O. In the last increment the RAU types were P, M, I, T, O and S. Relative to the other allocations in Example 2, the areas on this Unit are from medium to high priced. Slightly more acreage came into solution for Example 1, indicating that relative price is slightly lower for Example 1 than Example 2.

Slide 28 (Madison Range Planning Unit - Example 1) Fourteen percent of increment one and 7 percent of increment two were allocated in this Planning Unit. In addition, a relatively large portion of the third increment (27 percent) and a small portion of increment four (8 percent) were allocated. The RAU types in the first two increments were T and I, while the majority of the third increment was type O. Types M, O, L, H (forest type with high production potential) and T made up the last increment. In summary, there appears to be a wide variation in the cost of wilderness in this Planning Unit, with the average being at the medium level.

Slide 29 (Madison Range Planning Unit - Example 2)

Relatively large proportions of both increments one and two were allocated (32 percent and 20 percent, respectively). Ten percent of increment three and 19 percent of the last increment were allocated. RAU types in all increments were mixed with I, T, P and H making up the first; I, T and P making up the second; T, P and O the third; and H and M making up the last. Some of the area is low priced, but substantial areas are also from medium to high priced. Comparing the examples, most areas on the Madison Range are relatively less expensive for Example 1 than for Example 2.

Discussion and summary of the land allocations

In summary, both examples indicated the majority of wilderness is relatively expensive on the North Big Hole, South Big Hole, and Tobacco Root Mountains Planning Units. Large amounts of relatively low, moderate, and high cost wilderness was indicated on the Pioneer Mountains, Gravelly Range, and Madison Range Planning Units for the examples. Last, the wilderness on the Lima Peaks Planning Units was indicated to be of moderate cost for the examples.

Reviewing the allocations of RAU's to wilderness, it can be seen that types I and P generally came into solution earlier and in greater quantities for Example 2 as illustrated by the North Big Hole, Pioneer Mountains, Gravelly Range, and Lima Peaks Range Planning Units. This implies that these RAU types are less expensive than some other types, for example H, M and L. It is clear that the constraint on minimum forage production in Example 1 prevented more range land from being allocated to wilderness. The timber RAU types were also favored for wilderness in Example 2, although to much less of an extent than was the case for range (as in the Tobacco Root Mountains and Madison Range Planning Units). This implies that the minimum timber constraint in Example 1 is less binding than is the range production constraint.

It is interesting to note that for Example 2, on the Pioneer Mountains, Gravelly Range, Lima Peaks, and Madison Range Planning Units there were sizeable amounts of RAU types A, P, I and T allocated to wilderness before large areas of type O. The same happened to a somewhat lesser degree in Example 1. On the Lima Peaks Planning Unit, RAU type A entered in the first increment and a small amount of I entered in the second. On the Madison Range, 14 percent of the first increment was RAU type T, and 7 percent of the second increment was types T and I. All of these entered before large areas of type O. The implications are clear: rock, noncommercial timber, and nonrange areas (type O) are not always the least expensive areas for wilderness. It appears that the amount of area in type 0 is a measure of cost when considering trade-offs between wilderness and timber or forage, but is less indicative of opportunity costs for other forest-based goods and services, especially recreation.

Not only is the number of acres allocated to wilderness in a specific area an important indicator of relative wilderness cost, but the distribution of these acres is also important. The areas originally designated as potential wilderness in the model predetermine this distribution to some extent. However, in most cases inferences about the cost of given areas can still be made. For example, one would expect the Example 1 wilderness area in MAU 5B of Lima Peaks (Slide 24) to be more expensive on a per acre basis than the upper part of the Snow Crest Area in MAU's 4B and 4C in the Gravelly Range (Slide 22), because of the greater density of lower cost increments on the latter. However, this method gives only an indication of the relative costs of areas as wilderness. For more exact estimates, boundaries can be drawn and a Method 2 analysis used.

One point remains concerning the land allocations. If equivalencies exist in the shadow prices for two or more nonbasic wilderness variables at the point where the model is choosing among wilderness variables to enter the basis, and if these variables (with the equivalent shadow prices) have the smallest shadow prices among the nonbasic variables, then either variable can enter the basis. Obviously, the more often this happens, the less useful the wilderness increments are as an index of the relative cost of areas. These equivalencies arise as a result of equivalencies in objective function coefficients, and tend to disappear as the model is repeatedly solved. Thus, if equivalencies exist, one would expect to find them among the nonbasic variables for the optimal solutions early in the runstream. The shadow prices for the first solution (wilderness equal to 72,379 acres) in both examples were compared to see to what extent equivalencies exist in the Beaverhead model. The 75 nonbasic wilderness variables with the smallest shadow prices were considered. In Example 1, only two wilderness variables had identical shadow prices. In Example 2 there were two pairs with identical values although others had shadow prices that were nearly equal. It is concluded that this is not a significant problem in the Beaverhead model.

## Sensitivity analysis

An analysis of the sensitivity of four solutions to increases in both the price and output of timber was carried out on the nonbasic timber variables with the lowest shadow prices. The four solutions chosen were those with the smallest and largest amounts of wilderness for both Examples 1 and 2. It was thought that these solutions would represent the extremes in the amount of change required to produce new optimal solutions. Tables 12 through 15 present the sensitivity of the solutions to increases in timber price for the 20 nonbasic timber variables with the smallest shadow prices. Included in these tables are the average per acre timber outputs for each time period assumed in the model. The average increase in timber price required was calculated using Equation 9 (p. 52). Percent increase required was calculated assuming average timber price to be $466.80 (Table 6, p. 81). Tables 16 through 19 present the sensitivity of these solutions to increases in output for the ten nonbasic timber variables with the smallest shadow prices. T is the sum over time periods of average per acre per year output and T' is the amount T would have to increase before a new optimal solution would be indicated, and is calculated via Equation 13 (p. 54). Increase in timber harvest required (T') is also presented in terms of average increase required for each time period, assuming an equal proportional increase across time periods.

Referring to Table 12, it can be seen that in Example 1 an increase of 0.016 in the objective function coefficient for variable 5AL38 (see page 75 for description of code)

Table 12. The sensitivity of the first optimal solution for Example 1 (wilderness equal to 72,379 acres) to increases in timber price for the 20 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year | | | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | | Time Period 1 | Time Period 2 | Time Period 3 | | |
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 5AL38 | 0.0159 | 20.4 | 12.1 | 17.0 | 0.06 | --[d] |
| 7DL38 | 1.3482 | 28.0 | 16.6 | 23.2 | 3.84 | 0.8 |
| 2BL38 | 2.4538 | 18.9 | 11.2 | 15.7 | 7.49 | 1.6 |
| 5FL38 | 3.3816 | 16.5 | 9.8 | 13.7 | 16.34 | 3.5 |
| 4GL38 | 5.0052 | 28.8 | 17.0 | 23.9 | 13.87 | 3.0 |
| 2EL38 | 5.6634 | 19.8 | 11.7 | 16.4 | 22.83 | 4.9 |
| 4DL38 | 5.7330 | 24.7 | 14.6 | 20.4 | 18.54 | 4.0 |
| 1CL38 | 6.1209 | 21.8 | 12.9 | 18.1 | 22.35 | 4.8 |
| 3HL38 | 6.8273 | 18.8 | 11.1 | 15.6 | 29.04 | 6.2 |

[a] See page 75 for explanation of variable name codes.

[b] In terms of present value.

[c] Dollar increase required calculated using Equation 9, p. 52. Percent change calculated assuming average price to be $466.80 per MCF.

[d] Less than .05 of one percent.

Table 12 (continued)

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Time Period 2 | Time Period 3 | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 8AL38 | 7.3695 | 26.4 | 15.7 | 21.9 | 22.23 | 4.8 |
| 3AL38 | 7.6045 | 19.8 | 11.7 | 16.4 | 30.66 | 6.6 |
| 3DL38 | 7.6731 | 21.9 | 13.0 | 18.2 | 27.89 | 6.0 |
| 4CL38 | 8.9337 | 27.7 | 16.4 | 22.9 | 25.60 | 5.5 |
| 8CT35 | 9.5032 | 14.1 | 10.8 | 13.3 | 50.25 | 10.8 |
| 3IL38 | 11.3123 | 14.3 | 8.5 | 12.0 | 62.92 | 13.5 |
| 3JL38 | 12.1191 | 16.5 | 9.8 | 13.7 | 58.57 | 12.5 |
| 8BL38 | 12.8032 | 27.2 | 16.1 | 22.6 | 37.56 | 8.0 |
| 8CL38 | 12.8214 | 20.5 | 12.2 | 17.0 | 49.81 | 10.7 |
| 3EL38 | 13.4589 | 21.8 | 12.9 | 18.0 | 49.35 | 10.6 |
| 1EL38 | 13.9625 | 18.7 | 11.0 | 15.5 | 59.69 | 12.8 |

Table 13. The sensitivity of the last optimal solution for Example 1 (wilderness equal to 927,400 acres) to increases in timber price for the 20 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Time Period 2 | Time Period 3 | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 7BT35 | 1.3178 | 22.7 | 17.5 | 21.5 | 4.32 | 0.9 |
| 4CM37 | 2.1693 | 27.1 | 20.9 | 25.7 | 5.95 | 1.3 |
| 7EM37 | 2.2679 | 25.3 | 19.5 | 24.0 | 6.66 | 1.4 |
| 3CM37 | 2.4725 | 20.1 | 15.4 | 19.0 | 9.16 | 2.0 |
| 8BT35 | 3.9348 | 23.9 | 18.4 | 22.7 | 12.24 | 2.6 |
| 3HM37 | 3.9618 | 16.8 | 12.9 | 15.9 | 17.55 | 3.8 |
| 7CT35 | 5.2114 | 22.9 | 17.6 | 21.7 | 16.94 | 3.6 |
| 3BT35 | 8.3085 | 19.9 | 15.3 | 18.8 | 31.08 | 6.6 |
| 8CT31 | 10.4110 | 8.6 | 10.2 | 11.3 | 77.35 | 16.6 |

[a]See page 75 for explanation of variable name codes.

[b]In terms of present value.

[c]Dollar increase required calculated using Equation 9, p. 52. Percent change calculated assuming average price to be $466.80 per MCF.

Table 13 (continued)

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Time Period 2 | Time Period 3 | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 3ET35 | 11.7352 | 21.9 | 16.9 | 20.8 | 39.77 | 8.5 |
| 3KT35 | 12.8614 | 17.4 | 13.4 | 16.5 | 54.85 | 11.8 |
| 7BT31 | 12.9472 | 13.9 | 16.4 | 18.3 | 59.64 | 12.8 |
| 3FT35 | 14.1155 | 21.1 | 16.2 | 20.0 | 49.76 | 10.6 |
| 8BT31 | 15.6366 | 14.6 | 17.3 | 19.3 | 68.37 | 14.6 |
| 7CT31 | 16.1381 | 14.0 | 16.6 | 18.4 | 73.72 | 15.8 |
| 3CT35 | 16.6011 | 18.2 | 14.0 | 17.2 | 67.87 | 14.5 |
| 5DT35 | 19.0558 | 12.8 | 9.9 | 12.2 | 110.28 | 23.6 |
| 7AT35 | 19.8559 | 26.9 | 20.7 | 25.5 | 54.86 | 11.8 |
| 8AT35 | 20.4337 | 26.5 | 20.4 | 25.2 | 57.27 | 12.3 |
| 3BT31 | 21.2127 | 12.2 | 14.4 | 16.0 | 11.53 | 23.9 |

Table 14. The sensitivity of the first optimal solution for Example 2 (wilderness equal to 72,379 acres) to increases in timber price for the 20 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year | | |
|---|---|---|---|---|
| | | Time Period 1 | Time Period 2 | Time Period 3 |
| | (dollars) | (CU.FT.) | (CU.FT) | (CU.FT.) |
| 8CT31 | 78.2942 | 8.6 | 10.2 | 11.3 |
| 7BT31 | 80.8304 | 13.9 | 16.4 | 18.3 |
| 8CH36 | 80.9367 | 33.8 | 36.0 | 38.8 |
| 8CT35 | 81.1011 | 14.1 | 10.8 | 13.3 |
| 8BT31 | 83.5198 | 14.6 | 17.3 | 19.3 |
| 7CT31 | 84.0213 | 14.0 | 16.6 | 18.4 |
| 8DH36 | 87.1342 | 16.9 | 18.0 | 19.4 |
| 3BL38 | 87.4312 | 19.7 | 11.7 | 16.3 |
| 7ET31 | 87.5776 | 15.8 | 18.7 | 20.8 |
| 7BT35 | 88.8040 | 22.7 | 17.5 | 21.5 |
| 3BT31 | 89.0959 | 12.2 | 14.4 | 16.0 |
| 8DH31 | 90.1771 | 10.3 | 12.2 | 13.6 |
| 3ET31 | 90.4343 | 13.4 | 15.9 | 17.7 |
| 8CM37 | 91.0731 | 19.7 | 15.2 | 18.7 |
| 8BT35 | 91.4210 | 23.9 | 18.4 | 22.7 |
| 8DH32 | 91.9553 | 16.9 | 17.0 | 19.7 |
| 3BM37 | 92.3056 | 21.1 | 16.2 | 20.0 |
| 7CT35 | 92.6976 | 22.9 | 17.6 | 21.7 |
| 8EL38 | 92.7001 | 6.6 | 3.9 | 5.4 |
| 5ET31 | 92.8364 | 8.5 | 10.1 | 11.2 |

[a]See page 75 for explanation of variable name codes.

[b]In terms of present value.

[c]Dollar increase required calculated using Equation 9, p. 52. Percent change calculated assuming average price to be $466.80 per MCF.

| Average New Growth Timber Harvested Per Acre Per Year Time Period 3 | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|
| (CU.FT.) | (dollars) | (percent) |
| N.A. | 581.68 | 124.6 |
| N.A. | 372.32 | 79.8 |
| 7.7 | 158.42 | 33.9 |
| N.A. | 428.88 | 91.9 |
| N.A. | 365.03 | 78.2 |
| N.A. | 383.83 | 82.2 |
| N.A. | 344.81 | 73.9 |
| N.A. | 354.12 | 75.9 |
| N.A. | 355.00 | 76.0 |
| N.A. | 290.97 | 62.3 |
| N.A. | 468.43 | 100.3 |
| N.A. | 558.37 | 119.6 |
| N.A. | 430.84 | 92.3 |
| N.A. | 343.93 | 73.7 |
| N.A. | 284.36 | 60.9 |
| N.A. | 370.49 | 79.4 |
| N.A. | 325.36 | 69.7 |
| N.A. | 301.26 | 64.5 |
| N.A. | 1126.37 | 241.3 |
| N.A. | 699.07 | 149.8 |

Table 15. The sensitivity of the last optimal solution for Example 2 (wilderness equal to 927,440 acres) to increases in timber price for the 20 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 2 | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 3 | Average New Growth Timber Harvested Per Acre Per Year: Time Period 3 | Average Increase in Timber Price Per MCF Required to Indicate A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| --[d] | -- | -- | -- | -- | -- | -- | -- |
| 3FT31 | 92.8601 | 12.9 | 15.3 | 17.0 | N.A. | 460.16 | 98.6 |

[a]See page 75 for explanation of variable names codes.

[b]In terms of present value.

[c]Dollar increase required calculated using Equation 9, p. 52. Percent change calculated assuming average price to be $466.80 per MCF.

[d]With the exception of 7ET31, the 20 lowest shadow prices and their associated variables in Table 14 remain unchanged in this table. The shadow price for 7ET31 increased to 98.296625 between the two solutions.

Table 16. The sensitivity of the first optimal solution for Example 1 (wilderness equal to 72,379 acres) to increases in the per acre per year output of timber for the 10 nonbasic variables with the lowest shadow price

| Variable Name[a] | T[b] | T'[c] | Average Increase in Timber Output Per Acre Per Year Required to Indicate a New Optimal Solution[d] | | | Percent Increase Required |
|---|---|---|---|---|---|---|
| | | | Time Period 1 | Time Period 2 | Time Period 3 | |
| | | | (CU.FT.) | (CU.FT.) | (CU.FT.) | |
| 5AL38 | 49.511 | 0.133 | --[e] | -- | -- | 0.3 |
| 7DL38 | 67.907 | 8.217 | 3.4 | 2.0 | 2.8 | 12.1 |
| 2BL38 | 45.876 | 5.031 | 2.1 | 1.2 | 1.7 | 11.0 |
| 5FL38 | 39.972 | 35.014 | 14.4 | 8.6 | 12.0 | 87.6 |
| 4GL38 | 69.724 | 29.710 | 11.8 | 7.0 | 9.8 | 42.6 |
| 2EL38 | 47.920 | 48.914 | 20.2 | 12.0 | 16.8 | 102.1 |
| 1CL38 | 52.916 | 47.874 | 19.8 | 11.7 | 16.4 | 90.5 |
| 3HL38 | 45.423 | 62.208 | 25.7 | 25.7 | 21.3 | 137.0 |
| 8AL38 | 64.045 | 47.624 | 19.7 | 11.6 | 16.3 | 74.4 |
| 3AL38 | 47.920 | 65.678 | 27.1 | 16.1 | 22.5 | 137.0 |
| 3DL38 | 53.144 | 59.757 | 24.7 | 14.6 | 20.5 | 112.4 |

[a]See page 75 for explanation of variable name codes.

[b]T is the sum over time periods of average per acre per year output.

[c]T' calculated using Equation 13, p. 54. Average price of timber was assumed to be $466.80 per MCF.

[d]Assumed an equal proportional increase in productivity for each time period.

[e]Nonzero but less than 0.06.

Table 17. The sensitivity of the last optimal solutkon for Example 1 (wilderness equal to 927,440 acres) to increases in the per acre per year output of timber for the 10 nonbasic timber variables with the lowest shadow price

| Variable Name[a] | T[b] | T'[c] | Average Increase in Timber Output Per Acre Per Year Required to Indicate a New Optimal Solution[d] Time Period 1 | Time Period 2 | Time Period 3 | Percent Increase Required |
|---|---|---|---|---|---|---|
| | | | (CU.FT.) | (CU.FT.) | (CU.FT.) | |
| 7BT35 | 61.683 | 9.251 | 2.0 | 2.5 | 2.7 | 15.0 |
| 4CM37 | 73.663 | 12.752 | 4.7 | 3.6 | 4.4 | 17.3 |
| 7FM37 | 68.820 | 14.270 | 5.2 | 4.0 | 5.0 | 20.7 |
| 3CM37 | 54.546 | 19.629 | 7.2 | 5.6 | 6.8 | 36.0 |
| 8BT35 | 64.997 | 26.215 | 9.6 | 7.4 | 9.1 | 40.3 |
| 3HM37 | 45.625 | 37.602 | 13.8 | 10.6 | 13.1 | 82.4 |
| 7CT35 | 62.193 | 157.946 | 58.1 | 44.8 | 55.1 | 254.0 |
| 3BT35 | 54.025 | 66.582 | 24.5 | 18.9 | 23.2 | 123.2 |
| 8CT31 | 30.147 | 165.746 | 47.3 | 56.1 | 62.4 | 549.8 |
| 3ET35 | 59.644 | 85.200 | 31.3 | 24.1 | 29.7 | 142.8 |

[a] See page 75 for explanation of variable name codes.

[b] T is the sum over time periods of average per acre per year output.

[c] T' calculated using Equation 13, p. 54 . Average price of timber was assumed to be \$466.80 per MCF.

[d] Assumed an equal proportional increase in productivity for each time period.

Table 18. The sensitivity of the first optimal solution for Example 2 (wilderness equal to 72,379 acres) to increases in the per acre per year output of timber for the 10 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | T[b] | T'[c] | Average Increase in Timber Output Per Acre Per Year Required to Indicate a New Optimal Solution[d] Time Period 1 | Time Period 2 | Time Period 3 | Percent Increase Required |
|---|---|---|---|---|---|---|
| | | | (CU.FT.) | (CU.FT.) | (CU.FT.) | |
| 8CT31 | 30.147 | 1246.462 | 355.6 | 421.7 | 469.2 | 4,134.6 |
| 7BT31 | 48.637 | 797.616 | 227.5 | 269.9 | 300.2 | 1,640.0 |
| 8CH36 | 108.608 | 339.368 | 105.5 | 112.5 | 121.4 | 312.5 |
| 8CT35 | 38.233 | 918.540 | 338.0 | 260.3 | 320.3 | 2,402.5 |
| 8BT31 | 51.249 | 782.152 | 223.1 | 264.6 | 294.4 | 1,526.2 |
| 7CT31 | 49.038 | 822.332 | 234.6 | 278.2 | 309.5 | 1,676.9 |
| 8DH36 | 54,304 | 738.767 | 229.6 | 244.9 | 264.2 | 1,360.4 |
| 3BL38 | 47.693 | 758.722 | 313.3 | 185.6 | 259.8 | 1,590.8 |
| 7ET31 | 55.269 | 760.495 | 217.0 | 257.3 | 286.2 | 1,376.0 |
| 7BT35 | 61.683 | 623.426 | 229.4 | 176.6 | 217.4 | 1,010.7 |

[a]See page 75 for explanation of variable name codes.

[b]T is the sum over time periods of average per acre per year output.

[c]T' calculated using Equation 13, p. 54. Average price of timber was assumed to be $466.80 per MCF.

[d]Assumed an equal proportional increase in productivity for each time period.

Table 19. The sensitivity of the last optimal solution for Example 2 (wilderness equal to 927,440 acres) to increases in the per acre per year output of timber for the 10 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | $T^b$ | $T'^c$ | Average Increase in Timber Output Per Acre Per Year Required to Indicate a New Optimal Solution[d] | | | Percent Increase Required |
|---|---|---|---|---|---|---|
| | | | Time Period 1 | Time Period 2 | Time Period 3 | |
| | | | (CU.FT.) | (CU.FT.) | (CU.FT.) | |
| --[e] | -- | -- | -- | -- | -- | -- |
| 3BT31 | 42.608 | 1003.587 | 286.3 | 339.6 | 377.7 | 2,355.4 |

[a]See page 75 for explanation of variable name codes.

[b]T is the sum over time periods of average per acre per year output.

[c]T' calculated using Equation 13, p. 54. Average price of timber was assumed to be $466.80 per MCF.

[d]Assumed an equal proportional increase in productivity for each time period.

[e]With the exception of 7ET31, the 10 lowest shadow prices and their associated variables in Table 14 remain unchanged in this table. The shadow price for 7ET31 increased to 98.299625 between the two solutions.

would cause a change in the optimal basic solution. This corresponds to a \$0.06 increase in the average price of timber (a percent change less than 0.06) over the planning period, other things remaining equal. However, it can be seen that the change in price required for each additional variable to be introduced begins increasing fairly rapidly. Expressions of these changes in terms of timber output are shown in Table 16. A very small increase in the average amount of timber harvested per time period (0.3 percent) would also indicate a small change in the optimal basic solution. However, as with price, the change that would be required to bring additional timber variables into solution increases rapidly. The larger percent increases required for timber output suggest the model is more sensitive to changes in timber price than output.

In summary, it appears that the basic solution is sensitive to small changes in the present value of timber, but that large changes in present value would have to take place before significant changes in the basic solution would be realized.

Moving on to Tables 13 and 17 it can be seen that at a higher level of wilderness, the model is less sensitive to both timber price and output. A \$4.32 per MCF increase (0.9 percent) is required in timber price or a 15.0 percent increase in timber output is required before the variable with the smallest shadow price would be introduced into solution. The required changes for the other nonbasic variables listed in these tables have similarly increased over the changes required for the variables in Tables 12 and 16. It appears that with this set of commodity constraints, as the level of wilderness is increased, the sensitivity of the model to increases in value of timber is decreased.

This decrease in sensitivity can be explained by considering the allocation tendencies of the model as wilderness level is increased. At the lower levels of wilderness, most of the timber is produced on RAU types H and M (forest types with respectively high and moderate production potential). The majority of the timber variables relating to RAU type L (forest type with low production potential) remain in the nonbasic solution, as indicated by Table 12 (the third element in the variable name refers to RAU type). As wilderness is increased, some lower quality timber sites within potential wilderness areas are shifted from timber production to wilderness. To meet the timber constraint, some RAU type L (a large proportion of which is nonroadless) is switched to timber management. This includes all those variables in Table 12. Thus, when maximum wilderness is reached (Table 13) the timber variables in the nonbasic solution are (1) variables associated with RAU type T (forest type with slopes in excess of 45 percent) where timber production is expensive and (2) variables associated with RAU type M that have moved out of the basic solution because these RAU's were allocated to wilderness. The result is nonbasic timber variables with larger shadow prices.

The sensitivity of the Example 2 solutions to increases in timber price and output for nonbasic timber variables is presented in Tables 14 and 18 respectively. The results in these tables indicate the model is extremely insensitive to changes in either timber price or output for this set of commodity constraints. A minimum increase in price of 33.9 percent ($158.42 per MCF, Table 14), or a 312.5 percent increase in output (Table 18) is required to bring about any change at all. And, much larger increases must occur before any significant change in the basis will take place.

Tables 15 and 19 show that essentially no changes in the sensitivity of the model to increase in timber price or output occurred as the level of wilderness was increased. Among the variables with the ten lowest shadow prices, the only difference noted was for variable 7ET31, which increased from a shadow price of $87.58 to $98.30.

Thus, a decrease in the sensitivity of the model to timber as wilderness is increased did not take place in Example 2. The reason for this is the minimum constraint on timber production in the Example 1 formulation, which gives rise to the interrelationship between timber production and wilderness allocation discussed above. In Example 2 this interrelationship was not present, since there was no constraint on minimum timber production.

The management implications of the sensitivity analyses are several. First, the decision-maker can be more confident of the results indicated for Example 2 than he can for Example 1 because the prior is much less sensitive to changes in the value and output of timber. But, even for the Example 1 case, he can be fairly confident that he is close to the true optimal solution in terms of the model. Second, the modeler should be relatively concerned about the estimates of timber price and output in future formulations of the Beaverhead model. This would not be critical, however, if economic efficiency is the only criteria of management to which the model is to be applied.

Here, for example purposes, the sensitivity of the model to changes in one parameter was investigated. If a central purpose of this study was to make an intensive analysis of the wilderness cost situation on the Beaverhead, the sensitivity to other parameters should be investigated as well. Sensitivity analyses which appear to be most useful are those concerned with changes (especially decreases) in the various values assumed for recreation, water, wildlife, range and with increases in the price of timber, using a parametric programming technique.

## Example 3 Cost Estimates

### Results and discussion

It should be recalled that Example 3 derived separate wilderness cost estimates for the Elk River and Snow Crest areas, assuming already existing wilderness to be three areas outlined in Alternative C. The location of the Alternative C areas is presented on Slides 30 through 35 and the location of the Elk River and Snow Crest areas is presented on Slide 36. Table 20 gives the values for the net present worth, cost, and commodity production for each of the four solutions in this example. Also included are total and per acre marginal costs for both areas. It should be noted that only the NPWi rows are expressed in terms of value foregone. All other rows are expressed in terms of net change in physical or dollar cost.

First, compare the differences in physical yield given up by designating the two areas as wilderness (columns 3 and 6). OLDHAi (old growth harvest) for the Forest decreases slightly when the Snow Crest area is designated as wilderness and increases slightly when the Elk River area is designated. As one might expect, the reverse is true for old growth standing timber.

Table 20. Example 3 solutions and their related marginal costs[a] on both a total area and per acre basis.[b]

| Row Name[c] | Unit | Alternative C | Alternative C Plus Elk River Area as Wilderness | Marginal Cost of Elk River as Wilderness | |
|---|---|---|---|---|---|
| | | | | Total | Per A. |
| | | (1) | (2) | (3) | (4) |
| NPW1 | DOLLARS | 395,640,394.16 | 395,499,998.19 | 140,395.97 | 4.62 |
| NPW2 | DOLLARS | 251,537,180.70 | 251,437,719.54 | 99,461.16 | 3.27 |
| NPW3 | DOLLARS | 141,687,084.13 | 141,626,757.49 | 60,326.64 | 1.98 |
| COST1 | DOLLARS/YR. | 5,405,773.61 | 5,401,955.25 | -3,818.36 | -0.12 |
| COST2 | DOLLARS/YR. | 4,984,796.43 | 4,979,823.49 | -4,972.94 | -0.16 |
| COST3 | DOLLARS/YR. | 5,824,126.69 | 5,819,237.15 | -4,889.54 | -0.16 |
| OLDHA1 | CU.FT./YR. | 7,083,276.62 | 7,083,313.47 | 36.85 | --[d] |
| OLDHA2 | CU.FT./YR. | 5,624,034.72 | 5,624,032.59 | -2.13 | -- |
| OLDHA3 | CU.FT./YR. | 6,835,145.20 | 6,835,159.87 | 12.53 | -- |
| OLDST1 | MCF/YR. | 1,680,766.41 | 1,680,766.26 | -0.15 | -- |
| OLDST2 | MCF/YR. | 1,519,425.88 | 1,519,425.04 | -0.84 | -- |
| OLDST3 | MCF/YR. | 1,206,436.20 | 1,206,434.44 | -1.76 | -- |
| NEWHA3 | CU.FT./YR. | 576,253.01 | 576,253.01 | 0.00 | 0.00 |
| NEWST2 | MCF/YR. | 0.00 | 0.00 | 0.00 | 0.00 |
| NEWST3 | MCF/YR. | 1,084,470.60 | 1,084,470.60 | 0.00 | 0.00 |
| FORRG1 | M.LBS./YR. | 48,200.04 | 48,200.04 | 0.00 | 0.00 |
| FORRG2 | M.LBS./YR. | 125,000.00 | 125,000.00 | 0.00 | 0.00 |
| FORRG3 | M.LBS./YR. | 119,176.03 | 119,176.03 | 0.00 | 0.00 |

[a]The marginal costs for the NPWi rows are expressed in terms of value foregone. The marginal costs for all other rows are expressed in terms of net changes.

[b]There are 30,415 acres in the Elk River area and 70,258 acres in the Snow Crest Area.

[c]See page 80 for description of NPWi rows and Table 4 (page 77) for descriptions of commodity and cost rows.

[d]Less than 0.006 and greater than -0.006.

| Alternative C Plus Snow Crest Area as Wilderness | Marginal Cost of Snow Crest as Wilderness Total | Marginal Cost of Snow Crest as Wilderness Per A. | Alternative C Plus Snow Crest and Elk River Areas as Wilderness | Marginal Cost of Elk River Area as Wilderness Assuming Alt. C & Snow Crest as Existing Wilderness Total | Marginal Cost of Elk River Area as Wilderness Assuming Alt. C & Snow Crest as Existing Wilderness Per A. |
|---|---|---|---|---|---|
| (5) | (6) | (7) | (8) | (9) | (10) |
| 395,310,672.54 | 329,721.62 | 8.28 | 395,170,259.48 | 140,403.06 | 4.62 |
| 251,311,839.10 | 225,341.60 | 5.66 | 251,212,385.01 | 99,454.09 | 3.27 |
| 141,553,527.76 | 133,556.37 | 3.35 | 141,493,204.66 | 60,323.10 | 1.98 |
| 5,398,024.86 | -7,748.75 | -0.20 | 5,394,206.74 | -3,818.12 | -0.12 |
| 4,975,573.67 | -9,222.76 | -0.23 | 4,970,604.10 | -4,969.57 | -0.16 |
| 5,815,863.94 | -8,262.75 | -0.21 | 5,810,978.84 | -4,885.10 | -0.16 |
| 7,074,433.91 | -8,842.71 | -0.12 | 7,074,480.90 | 46.99 | -- |
| 5,613,917.50 | -10,117.22 | -0.14 | 5,613,921.47 | 3.97 | -- |
| 6,824,557.93 | -10,587.27 | -0.15 | 6,824,581.03 | 23.10 | -- |
| 1,680,804.12 | 37.71 | -- | 1,680,803.93 | -0.19 | -- |
| 1,519,678.16 | 252.28 | 0.01 | 1,519,677.07 | -1.09 | -- |
| 1,207,147.26 | 711.06 | 0.02 | 1,207,144.83 | -2.43 | -- |
| 576,253.01 | 0.00 | 0.00 | 576,253.01 | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1,084,470.60 | 0.00 | 0.00 | 1,084,470.60 | 0.00 | 0.00 |
| 48,200.04 | 0.00 | 0.00 | 48,200.04 | 0.00 | 0.00 |
| 125,000.00 | 0.00 | 0.00 | 125,000.00 | 0.00 | 0.00 |
| 119,176.03 | 0.00 | 0.00 | 119,176.03 | 0.00 | 0.00 |

Table 20 (continued)

| Row Name[c] | Unit | Alternative C | Alternative C Plus Elk River Area as Wilderness | Marginal Cost of Elk River as Wilderness: Total | Marginal Cost of Elk River as Wilderness: Per A. |
|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) |
| FORTI1 | M.LBS./YR. | 69.92 | 69.92 | 0.00 | 0.00 |
| FORTI2 | M.LBS./YR. | 13,362.64 | 13,362.63 | -0.01 | -- |
| FORTI3 | M.LBS./YR. | 12,526.38 | 12,526.36 | -0.02 | -- |
| REC11 | RVD/YR. | 351,273.67 | 351,317.61 | -43.94 | -- |
| REC12 | RVD/YR. | 346,990.15 | 347,918.11 | -927.96 | 0.03 |
| REC13 | RVD/YR. | 322,255.10 | 323,293.26 | -1,038.16 | 0.03 |
| REC21 | RVD/YR. | 1,218,970.12 | 1,217,351.77 | -1,618.35 | -0.05 |
| REC22 | RVD/YR. | 1,257,705.26 | 1,255,950.44 | -1,754.82 | -0.06 |
| REC23 | RVD/YR. | 1,174,477.29 | 1,172,895.73 | -1,581.56 | -0.05 |
| REC31 | RVD/YR. | 315,485.72 | 315,521.97 | -36.25 | -- |
| REC32 | RVD/YR. | 306,311.53 | 306,503.69 | -192.16 | 0.01 |
| REC33 | RVD/YR. | 297,919.49 | 298,127.08 | -207.59 | 0.01 |
| WATRY1 | A.F./YR. | 1,541,844.35 | 1,541,898.62 | -54.27 | -- |
| WATRY2 | A.F./YR. | 1,560,387.33 | 1,560,569.78 | -182.45 | 0.01 |
| WATRY3 | A.F./YR. | 1,569,650.73 | 1,569,835.75 | -185.02 | 0.01 |
| SEDRD1 | CU.YD./YR. | 13,795.14 | 13,795.14 | 0.00 | 0.00 |
| SEDRD2 | CU.YR./YR. | 12,139.20 | 12,139.19 | -0.01 | -- |
| SEDRD3 | CU.YD./YR. | 15,220.34 | 15,220.34 | 0.00 | 0.00 |
| SEDGE1 | CU.YD./YR. | 167,975.99 | 167,969.99 | -6.00 | -- |
| SEDGE2 | CU.YD./YR. | 173,907.73 | 173,883.99 | -23.74 | -- |
| SEDGE3 | CU.YD./YR. | 175,335.81 | 175,310.20 | -25.61 | -- |
| BGFOO1 | A.E./YR. | 724,475.16 | 724,520.05 | -44.89 | -- |
| BGFOO2 | A.E./YR. | 725,329.79 | 725,440.55 | -110.76 | -- |
| BGFOO3 | A.E./YR. | 726,700.35 | 726,811.35 | -111.00 | -- |
| BGCOV1 | A.E./YR. | 822,605.34 | 822,605.15 | -0.19 | -- |
| BGCOV2 | A.E./YR. | 787,684.34 | 787,683.42 | -0.92 | -- |
| BGCOV3 | A.E./YR. | 758,519.25 | 758,517.72 | -1.53 | -- |
| RDCOS1 | DOLLARS/YR. | 455,057.41 | 454,976.11 | -272.99 | -0.01 |
| RDCOS2 | DOLLARS/YR. | 25,267.69 | 25,263.16 | -4.53 | -- |
| RDCOS3 | DOLLARS/YR. | 0.00 | 0.00 | 0.00 | 0.00 |

| Alternative C Plus Snow Crest Area as Wilderness | Marginal Cost of Snow Crest as Wilderness Total | Per A. | Alternative C Plus Snow Crest and Elk River Areas as Wilderness | Marginal Cost of Elk River Area as Wilderness Assuming Alt. C & Snow Crest as Existing Wilderness Total | Per A. |
|---|---|---|---|---|---|
| (5) | (6) | (7) | (8) | (9) | (10) |
| 69.75 | 0.17 | -- | 69.75 | 0.00 | 0.00 |
| 13,328.63 | -34.04 | -- | 13,328.62 | -0.01 | -- |
| 12,495.04 | -31.34 | -- | 12,495.02 | -0.02 | -- |
| 351,241.02 | -32.65 | -- | 351,284.58 | 43.56 | -- |
| 348,221.53 | 1,231.38 | 0.03 | 349,148.88 | 927.35 | 0.03 |
| 323,644.50 | 1,400.40 | 0.04 | 324,682.36 | 1,037.86 | 0.03 |
| 1,216,033.39 | -2,936.73 | -0.07 | 1,214,414.98 | -1,618.41 | -0.05 |
| 1,254,818.98 | -2,886.28 | -0.07 | 1,253,063.66 | -1,755.32 | -0.06 |
| 1,171,900.09 | -2,577.20 | -0.06 | 1,170,318.59 | -1,581.50 | -0.05 |
| 315,629.66 | 143.94 | -- | 315,660.07 | 36.41 | -- |
| 306,973.33 | 661.80 | 0.02 | 307,165,83 | 192.50 | 0.01 |
| 298,620.20 | 700.71 | 0.02 | 298,828.11 | 207.91 | 0.01 |
| 1,541,849.83 | 5.48 | -- | 1,541,804.08 | 54.25 | -- |
| 1,560,420.52 | 33.19 | -- | 1,560,602.94 | 182.47 | 0.01 |
| 1,569,710.76 | 60.03 | -- | 1,569,895.70 | 184.94 | 0.01 |
| 13,834.47 | 39.33 | -- | 13,835.31 | 0.84 | -- |
| 12,170.47 | 31.27 | -- | 12,171.18 | 0.71 | -- |
| 15,262.93 | 42.59 | -- | 15,263.87 | 0.94 | -- |
| 167,920.68 | -55.31 | -- | 167,914.24 | -6.44 | -- |
| 173,725.39 | -182.34 | -- | 173,701.22 | -24.17 | -- |
| 175,085.30 | -250.51 | -0.01 | 175,059.27 | -26.03 | -- |
| 724,373.40 | -101.76 | -- | 724,418.28 | 44.88 | -- |
| 725,032.94 | -296.85 | -0.01 | 725,143.63 | 110.69 | -- |
| 725,401.12 | -299.23 | -0.01 | 726,512.04 | 110.92 | -- |
| 822,586.28 | -19.06 | -- | 822,586.30 | 0.02 | -- |
| 787,594.65 | -89.69 | -- | 787,594.82 | 0.17 | -- |
| 758,379.59 | -139.66 | -- | 758,379.95 | 0.36 | -- |
| 433,256.67 | -21,800.74 | -0.31 | 433,172.36 | -84.31 | -0.01 |
| 24,054.81 | -1,212.88 | -0.02 | 24,050.12 | -4.69 | -- |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Second, the model shows no forest-wide change in the amount of NEWHA3 (new growth timber harvested in the third time period), NEWSTi (new growth standing timber), and FORRGi (livestock forage) as the areas are allocated to wilderness. A slight decrease in the amount of FORTi (forage produced on timbered areas) is noted for the Snow Crest area.

The major changes which occur are in the levels of recreation. REC1i (recreation on natural areas) increased for both areas and although a larger total increase was noted for Snow Crest, per acre changes were approximately equal. Decreases in REC2i (recreation on semiprimitive areas) occurred on both areas, and on a per acre basis was larger for the Snow Crest area. In comparison, small increases were noted for REC3i (recreation on lightly developed areas) and again were larger on a per acre basis for Snow Crest. WATRYi (water yield) increased for both alternatives, but is slightly greater for Elk River. SEDRDi (sediment from roads) increased as a result of wilderness designation of the Snow Crest Area, but SEDGEi (sediment in general) decreased for both wilderness additions.

BGFOOi (big game food) and BGCOVi (big game cover) are the last two commodities considered. The model indicated an increase in the availability of food if the Elk River area is designated and a decrease in food if the

Snow Crest area is designated. A decrease in cover is indicated for both areas, although the decrease is larger for the Snow Crest area.

The difference in COSTi (management cost) indicated by the model is also interesting. For both areas there is a decrease, but the decrease is much larger when the Snow Crest area is designated. This is also true on per acre basis. Also, RDCOSi (cost of primary access roads) decreased slightly for both alternatives.

The above changes can be expressed in dollar terms by considering the NPWi rows. The model indicates the opportunity cost for wilderness on the Snow Crest area is much larger than on the Elk River area (NPW1). On an average per acre basis the cost of the Snow Crest area is approximately twice that of Elk River area. At higher discount rates (NPW2 and NPW3) the marginal costs of both areas decreased. The reason for this is that the benefits foregone are generally in the distant future. Thus, the larger the discount rate used, the smaller the present value of those benefits. Note further that the opportunity costs maintain their relative positions as the discount rate is increased. This indicates that flow over time of net benefits foregone is nearly the same for both alternatives.

The extent to which increasing marginal cost of wilderness on a specific area is reflected by the model at this level of total wilderness was tested by forcing the Elk River area into solution as wilderness, given that the Snow Crest area and Alternative C areas were already allocated to wilderness. The difference between this solution and the solution in which only Snow Crest was added gives the estimate of the Elk River area wilderness cost under the new assumption of total existing wilderness. These estimates, along with the value of the commodities in the solution, are found in the last three columns (8 through 10) of Table 20. On a per acre basis, the cost estimates are the same as before for all rows in the model (columns 4 and 10). However, a slight increase in the marginal cost for the whole area is indicated by the increase in the level of NPW1 foregone (columns 3 and 9). The most important changes in the commodity outputs which make up this increase in cost are reductions in the amount of increase of OLDHAi, REC1i, and WATRYi in all time periods and greater decreases in REC2i in time periods one and two.

Sensitivity analysis

An analysis of the sensitivity of the Alternative C solution (base solution for Example 3) to increases in timber price was carried out on the 20 nonbasic timber management variables with the smallest shadow prices. The results of this analysis are presented in Table 21 and indicate that it takes an increase of only a few dollars in the average price of timber for the nonbasic variables to produce a change in the optimal basis. However, after the first four variables, the average increase in price required for a change jumps to $27.21 (for 7BT35) and increases relatively rapidly after that for the remaining nonbasic variables. This indicates the present optimal basis is sensitive to increases in the price of timber, but that relatively large increases in price would be required before significant changes would take place in the optimal basis.

In addition, the sensitivity of the same solution to increases in timber output was investigated for the first ten variables listed in Table 21. The results of this analysis are presented in Table 22. The smallest increases required for a change in the basis are 9.5 percent for variable 3EL38 and 13.5 percent for 4EL38. The amount of change required increases quite rapidly after these two variables. This indicates that for these assumptions the model is significantly less sensitive to timber output than it is to timber price.

The sensitivity analyses carried out for Examples 1 and 2 are presented here to provide examples of the types of analyses possible. The sensitivity to other parameters

Table 21. The sensitivity of the alternative C solution to increases in timber price for the 20 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Time Period 2 | Time Period 3 | Average Increase in Timber Price Per MCF Required to Increase A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 8CT35 | 0.6004 | 14.1 | 10.8 | 13.3 | 3.17 | 0.7 |
| 3EL38 | 0.6374 | 21.8 | 12.9 | 18.0 | 2.34 | 0.5 |
| 4EL38 | 0.6809 | 18.8 | 11.2 | 15.6 | 2.88 | 0.6 |
| 1EL38 | 1.1411 | 18.7 | 11.0 | 15.5 | 4.88 | 1.0 |
| 8CL38 | 5.1462 | 9.4 | 5.6 | 7.8 | 43.76 | 9.4 |
| 2AL38 | 7.2120 | 19.2 | 11.4 | 15.9 | 29.92 | 6.4 |
| 7BT35 | 8.3033 | 22.7 | 17.5 | 21.5 | 27.21 | 5.8 |
| 8BT35 | 10.9203 | 23.9 | 18.4 | 22.7 | 33.97 | 7.3 |
| 7CT35 | 12.1969 | 22.9 | 17.6 | 21.7 | 39.64 | 8.5 |

[a]See page 52 for explanation of variable name codes.

[b]In terms of present value.

[c]Dollar increase required calculated using Equation 9, p. 52. Percent change calculated assuming average price to be $466.80 per MCF.

Table 21 (continued)

| Variable Name[a] | Shadow Price[b] | Average Old Growth Timber Harvested Per Acre Per Year: Time Period 1 | Time Period 2 | Time Period 3 | Average Increase in Timber Price Per MCF Required to Increase A New Optimal Solution[c] | |
|---|---|---|---|---|---|---|
| | (dollars) | (CU.FT.) | (CU.FT.) | (CU.FT.) | (dollars) | (percent) |
| 3BT35 | 15.2940 | 19.9 | 15.3 | 18.8 | 57.22 | 12.3 |
| 8CT31 | 15.8313 | 8.6 | 10.2 | 11.3 | 117.62 | 25.2 |
| 7ET35 | 17.5603 | 25.8 | 19.9 | 24.4 | 50.66 | 10.8 |
| 7BT31 | 18.3674 | 13.9 | 16.4 | 18.3 | 84.60 | 18.1 |
| 3ET35 | 18.7207 | 21.9 | 16.9 | 20.8 | 63.44 | 13.6 |
| 5ET35 | 18.7820 | 13.9 | 10.7 | 13.1 | 100.65 | 21.6 |
| 3KT35 | 19.8470 | 17.4 | 13.4 | 16.5 | 84.64 | 18.1 |
| 3FT35 | 21.1010 | 21.1 | 16.2 | 20.0 | 74.38 | 15.9 |
| 7CT31 | 21.5583 | 14.0 | 16.6 | 18.4 | 98.48 | 21.1 |
| 3CT35 | 23.5866 | 18.2 | 14.0 | 17.2 | 96.43 | 20.7 |
| 7ET31 | 25.1146 | 15.8 | 18.7 | 20.8 | 101.80 | 21.8 |

Table 22. The sensitivity of the alternative C solution to increases in the per acre per year output of timber for the 10 nonbasic timber variables with the lowest shadow prices

| Variable Name[a] | T[b] | T'[c] | Average Increase in Timber Output Per Acre Per Year Required to Indicate a New Optimal Solution[d] | | | Percent Increase Required |
|---|---|---|---|---|---|---|
| | | | Time Period 1 | Time Period 2 | Time Period 3 | |
| | | | (CU.FT.) | (CU.FT.) | (CU.FT.) | |
| 8CT35 | 38.233 | 6.800 | 2.5 | 1.9 | 2.4 | 17.8 |
| 3EL38 | 52.689 | 5.007 | 2.1 | 1.2 | 1.7 | 9.5 |
| 4EL38 | 45.649 | 6.174 | 2.5 | 1.5 | 2.1 | 13.5 |
| 1EL38 | 45.196 | 10.449 | 4.3 | 2.6 | 3.6 | 23.1 |
| 8CL38 | 22.712 | 93.778 | 38.7 | 22.9 | 32.1 | 412.9 |
| 2AL38 | 46.557 | 64.112 | 26.5 | 15.7 | 22.0 | 137.7 |
| 7BT35 | 61.683 | 58.291 | 21.6 | 16.6 | 20.5 | 95.3 |
| 8BT35 | 64.997 | 72.755 | 26.8 | 20.6 | 25.4 | 111.9 |
| 7CT35 | 62.193 | 84.922 | 31.2 | 24.1 | 29.6 | 136.5 |
| 3BT35 | 54.036 | 122.561 | 35.8 | 42.4 | 47.2 | 226.8 |

[a]See page 52 for explanation of variable name codes.

[b]T is the sum over time periods of average per acre per year output.

[c]T' calculated using Equation 13, p. 54. Average price of timber was assumed to be $466.80 per MCF.

[d]Assumed an equal proportional increase in productivity for each time period.

ought to be analyzed if the estimates were to be used for decision making. Those that appear to be most useful are analysis of the sensitivity of the solution to decreases in the values of water, wildlife, and the various types of recreation. Also, since grazing and timber are important to the local economy, analysis of the sensitivity of the solution to forest-wide changes in the values of these commodities might be important.

Management implications

The relative size of the cost estimates for the two areas does allow certain conclusions to be drawn. If the expected benefit of the Elk River area is larger than for the Snow Crest area (as the boundaries are drawn), or if there is equality of benefits between the two areas, the Elk River area should be preferred on the basis of its lower cost. In fact, given the differential in cost, the expected benefit of the Snow Crest area would have to be much larger before it should be preferred over the Elk River area.

While the relative level of costs can in some instances imply which areas should be preferred over others, it does not answer the question of whether either area should be designated as wilderness. This decision would, in part, require knowledge of the absolute level of marginal cost. The decision-maker would have to weigh this cost information along with subjective estimates of benefits in arriving at a final decision.

## Computer Costs

Total computation cost for this study was $534.09. Of this amount, $100.84 was spent retrieving and editing computer files and experimenting with the ILONA linear programming package. The remaining $433.25 represents the cost of generating the solutions used in the wilderness cost estimations. The model was solved 32 times, resulting in an average solution cost of about $13.50.

The value of using advanced basis starts (as discussed earlier) is best shown by comparing run times required for solving the model. Five optimal solutions were calculated starting with the original tableau. Average run time for these was about 62.6 seconds. In comparison the average run time for the 27 optimal solutions using advanced basis starts was 5.1 seconds.

Computer costs required for solving linear programming models vary among models and to a lesser extent among formulations within a certain model. Important factors in determining cost among models are the size of the linear programming elements in the matrix and the percentage of nonzero elements in the matrix (density), both of which are correlated positively with cost. Of these two factors, size is most important for this case, since for the RAA formulation density remains relatively constant. Because the Beaverhead model is a large RAA model, one would not expect the expense of estimating wilderness cost on other forests via the techniques described to greatly exceed that experienced in this study. This cost appears to be very reasonable, especially when compared to the cost involved in building the model and to the cost of multiple use planning in general.

# SUMMARY AND CONCLUSIONS

## Generalized Techniques

Many decisions remain before the National Wilderness Preservation System (NWPS) is complete. Wilderness designation involves allocating large areas of national forest land to be managed in a very specific manner. This results in changing to some extent the flow of forest resource values that would be realized if wilderness designation does not take place. The extent to which this flow is decreased is the cost of wilderness. Estimates of this cost for areas under study for wilderness designation would be valuable information to decision-makers. They could consider this information in much the same manner as any consumer considers price, and, along with qualitative estimates of wilderness benefit, logically decide which areas would be most desirable to include in the NWPS. The main objective of this research is to develop a method by which these costs can be estimated.

Conceptual issues and potential problems were analyzed in the first steps of developing a wilderness cost estimation technique. Major observations and conclusions were:

1. Many different costs in terms of goods and services foregone are potentially associated with designating areas as wilderness. Since national forests are

managed for the public, it was concluded that the appropriate cost to consider is social cost (all cost born by all those affected by wilderness designation).

2. Many nonwilderness-specific values would be produced to some extent on forest areas whether designated as wilderness or not. Theoretically these values could either be subtracted from the cost of wilderness or added to the benefit of wilderness. It was concluded that subtracting these values from cost provides the most useful information in that it allows the decision-maker to concern himself with only the wilderness-specific benefits in his judgements on the value of certain areas as wilderness.

3. The manner in which national forest land surrounding proposed wilderness areas would be managed both in the presence and absence of wilderness could greatly affect the scarcity of forest goods and services produced in a region. This in turn can greatly affect the cost of designating specific areas as wilderness. The only way to consider marginal availability of goods and services is to internalize into the cost estimates the effects of wilderness designation on the manage-

ment of the surrounding national forest area. For practical reasons, such as data availability, the national forest unit appears to be the most logical choice for size of area to consider.

The information required to make wilderness cost estimates is both varied and demanding, bringing about the necessity of relying upon secondary data sources. The linear programming matrices in Forest Service Resource Allocation Analysis (RAA) models have great potential for providing this information.

The basis for using RAA linear programming models for estimating wilderness cost is straightforward. The model is optimized twice for each cost estimate, once without wilderness included and once with the desired wilderness forced into solution. The difference in value between the two solutions is the cost of wilderness.

Two ways by which wilderness can be forced into solution are identified and are referred to as Method 1 and Method 2. Each generated slightly different information and when used together provide a process by which (1) least cost wilderness areas can be identified, and (2) the cost of specific areas measured.

Method 1 could be most advantageously used early in the planning process. In this method, only the total number of wilderness acres to go into solution are specified. By repeating the multiple solution process for increasingly larger amounts of wilderness, complete wilderness cost curves for a national forest can be estimated. Since linear programming is an optimizing model, these areas will come into solution in order of increasing cost. The increments of wilderness which go into the basis in the successive solutions can be coded and plotted on a map. The resulting pattern gives a measure of the relative cost of wilderness across the forest (least expensive areas will be allocated first and so on) and information as to how boundaries might be drawn for least cost wilderness.

The Method 2 approach is used to estimate the cost of specific areas as wilderness. Each cost estimate requires two solutions of the model, one with the potential wilderness area forced into the basis as wilderness, and one where it is not. The potential wilderness areas may be identified through the use of a Method 1 approach or by other means.

Analyzing the sensitivity of the linear programming model to changes in the various parameters is recognized as an important aspect of cost estimation. Change in present net worth objective function coefficients required to bring about a different optimal solution can be expressed in terms of change in either level of expected output or value per unit output.

The linear programming approach to wilderness cost estimation provides several advantages.

1. Wilderness cost estimates can be made efficiently on national forests for which RAA models have been constructed.
2. Given the management objectives for the forest, the linear programming model generates efficient management alternatives (in model terms). To the extent that future management of our forest resources approaches efficient allocation of resources for the management goals selected, the cost estimates should be a good representation of the cost of wilderness.
3. Since the linear programming model has the capability of reallocating resources as wilderness is forced into the basis, it provides a manner in which to handle the problem of determining marginal availability of resources in the cost estimation process.
4. It provides a structured approach which helps ensure that management objectives are identified and that cost estimates are made in accordance with these objectives. This is particularly important since the level of cost for a given area could vary greatly depending upon the management

objectives identified for the forest.

Several disadvantages of the linear programming approach to cost estimation can also be identified.

1. The mathematical form of linear programming models limits the type of relationships which can be built into the model. This can affect cost estimates to some extent (e.g., interrelationships between management activities on adjacent RAU's that affect expected output cannot be handled).
2. These cost estimation procedures would be very expensive to implement on those national forests for which RAA models have not been built.

## The Beaverhead Case Study

Three examples utilizing the RAA model of the Beaverhead National Forest were chosen to test the cost estimation procedures. The first example was a Method 1 analysis within the management constraints for Alternative C as identified by the Forest Service. Timber production was constrained to be greater than or equal to present availability, and livestock forage production was constrained to increase a minimum of ten percent over present availability. Wilderness acreage was forced into 14 successive optimal solutions in increasing amounts.

The second example was a Method 1 approach in which no constraints were placed on the commodities to be produced on the forest. Thus, economic efficiency is the only objective of management. Wilderness was forced into solution at the same levels as for the first example.

The third example was a Method 2 analysis of two specific potential wilderness areas, the Elk River and Snow Crest areas. Management constraints and already-existing wilderness were assumed to be those used in generating Alternative C.

The (net) marginal cost of wilderness estimated for Example 1 becomes positive at about 90,000 acres, increases at a relatively constant rate to about 500,000 acres, and then begins increasing much more rapidly. The marginal cost estimates for Example 2 becomes positive at about 97,500 acres and continues to increase at an approximately constant rate throughout the range estimated. The curves lie close to each other at low levels of wilderness and diverge as wilderness is increased. The rate of divergence is approximately constant up to about 500,000 acres, after which it increases rapidly.

Also estimated were the changes which took place in each of the commodities included in the model as wilderness acreage was increased. For Example 1, significant decreases were indicated for recreation on natural areas (REC1i) and for recreation on semiprimitive areas (REC2i). Small decreases were noted for water yield (WATRYi), general sedimentation (SEDGEi), and big game food (BGFOOi). For Example 2, (REC2i) also decreased, although to a smaller extent, while (REC1i) generally increased. Small decreases were also noted in Example 2 for (BGFOOi). All other commodities essentially indicated no change.

The rapid increase in per acre marginal cost at high levels of wilderness for Example 1 is a result of the lower bounds placed on the production of livestock forage and wood fiber production. At lower levels of wilderness, these constraints are easily met on the nonwilderness portions of the forest. At higher levels of wilderness, these commodities must be increasingly produced on less productive land as some of the higher quality land is allocated to wilderness. Thus, increasingly more area under range and timber management is required to meet the production quotas, resulting in both larger management costs (COSTi) and in larger amounts of other commodities foregone.

Several management implications are suggested by the Example 1 and 2 cost estimates.

1. If the Example 1 constraints represent the objectives of management for the Beaverhead National

Forest, total additional amount of wilderness should be something greater than 90,000 acres (presently there are 72,379 acres of wilderness on the forest). The upper bound for desirable amount of wilderness is probably about 700,000 acres.

2. If the Example 2 constraints represent the objectives of management, total amount of wilderness should be something above 97,000 acres. The cost estimates provide no criteria for determining the upper bound of desired wilderness for this example.
3. Management objectives which might be placed on the Beaverhead National Forest do not appear to have a large effect on wilderness cost up to about 500,000 acres. However, after this point, the data indicates that management objectives chosen for the forest can have a large effect on wilderness cost.

The wilderness land allocations occurring for Examples 1 and 2 were mapped in the order in which they came into solution in the model. For both examples, large amounts of both low and high cost wilderness were indicated on the Pioneer Mountains, Gravelly Range, and Madison Range Planning Units. The majority of wilderness on the North Big Hole, South Big Hole, and Tobacco Root Mountains Planning Units was found to be relatively expensive for both examples. For Example 2 especially, sizeable amounts of RAU types P and I (primary and secondary range respectively), and RAU type T (forest type with slopes in excess of 45 percent) were allocated to wilderness before larger areas of type 0 (rock, noncommercial forest, and nonrange). This indicates that type 0 is not always the least expensive type for wilderness.

Finally, an analysis of the sensitivity of the model to increases in timber price and per acre output was carried out. For Example 1, it was found that small changes in either price or output for several timber options would change the basic solution. However, the large shadow prices for most nonbasic timber options indicate that quite large changes would be required to bring about significant changes in the solution. The model was found to be very insensitive to increases in timber price of per acre output for Example 2.

In Example 3 the cost of designating the Snow Crest and Elk River areas as wilderness was estimated given already existing wilderness and management constraints to be those as identified in Alternative C. On an average per acre basis, the Snow Crest area was found to be about twice as expensive as the Elk River area. Greater decreases in recreation on semiprimitive areas (REC2i) and in big game food (BGFOOi) for the Snow Crest area account for the major difference in cost.

The extent to which increasing marginal cost of wilderness on a specific area is reflected by the model was tested by bringing the Elk River area into solution as wilderness, assuming the Snow Crest area and Alternative C areas were already designated as wilderness. A small increase in the total cost of the Elk River area was indicated. This increase in cost appears to be realistic since adding the Snow Crest area to the assumed already existing wilderness represents a relatively small change in total wilderness acreage.

An analysis of the sensitivity of the Alternative C solution (base solution for Example 3) to increases in timber price and per acre output was carried out on nonbasic timber management variables. It was found that small changes in timber price for several timber variables would change the optimal basic solution, but that relatively large increases in price would be required before significant changes would take place. The model was found to be significantly less sensitive to increases in average per acre timber output.

The Example 3 cost estimates imply that the Elk River area should be preferred over the Snow Crest area (as the boundaries are drawn in this study) if the expected benefits of the Elk River area are greater than or equal to those of the Snow Crest area. In fact, given the differential in cost, the expected benefits would probably have to be much larger for the Snow Crest area before it should be preferred.

In conclusion, estimates of wilderness cost for the Beaverhead National Forest have demonstrated that the procedures developed in this study can be used to estimate the cost of wilderness under prespecified management goals. Specifically, it has been shown that the model is capable of reflecting increasing marginal cost at higher levels of wilderness indicating it provides a mechanism for including effects of wilderness designation on management of surrounding national forest land. As mentioned earlier, this is an important aspect that has been ignored in previous attempts to estimate wilderness cost. Second, it has been shown that these procedures of cost estimation are able to reflect the differences in wilderness cost which result when different management objectives are placed on the forest. Last, it has been demonstrated that the cost of applying these procedures is relatively small. The results indicate the procedures would be useful for estimating wilderness cost on other forests for which RAA models of the appropriate form (i.e., with relevant commodity rows, management activities, etc., included) have been developed.

## Suggestions for Future Work

During the course of this study, several areas in which future studies could improve wilderness cost estimates and estimating procedures have been identified. The first involves refinement of data upon which the RAA models are based. There is a great need for relationships between forest resources (inputs) and forest goods and services (outputs) to be quantified in much more detail. By far the best information exists for timber production, yet even here very little information is available concerning expected yields from applying specific management practices (e.g., thinning) on stands of various ages. Considerably less is known about such things as the response of wildlife populations to specific management practices on various forest types and about the amounts of recreation participation that will take place under given circumstances. Obviously, these examples provide only a partial list of the work needed in this area.

Yet another aspect of model information needs is the quantification of management costs and values of various forest goods and services. More work in this area would be useful.

A third area in which cost estimates may be improved involves formulating models to be more representative of actual management situations and problems on the forest being modeled. This is an area of improvement not specific to RAA models, but applies to any model no matter how sophisticated. A specific example for the Beaverhead model involves the sediment "commodity" rows, which are formulated such that sedimentation is predicted on a forest-wide basis. It appears that formulating commodity rows to predict sedimentation by major watersheds would provide much more useful information to decision-makers. This could be done within the structure of the linear programming model, but would require additional constraint rows.

This study was concerned specifically with estimating direct wilderness cost. As discussed in the section entitled community impacts, wilderness withdrawals can have potentially significant economic impacts in small regions and local communities. Since maintaining the economic welfare of such areas is generally thought to be one objective in managing national forests, these impacts represent an important part of overall wilderness cost. Models in the Rocky Mountain region have been developed to estimate these impacts on a state-wide basis (Johnson, 1972; Polzin and Schweitzer, 1975; Rafsnider and Kunin, 1971), but only one attempt (Darr and Fight, 1974) was found that focused on a small economic area. Models that could make economic impact predictions for other local areas would be useful in adding another dimension--the incidence of costs and benefits--to wilderness cost estimates.

For practical reasons discussed early in this paper, this study has used the national forest as the land area upon which cost estimates are based. However, it was recognized that interactions with other national forests and with forest land in other ownerships within a geographic area can effect cost estimates. Developing a method by which these effects might be quantified is yet another possible future study which could improve cost estimates.

It was mentioned earlier in this section that a significant problem in developing RAA models lies in quantifying future values of forest goods and services. A special formulation of linear programming called goal programming[1] is a mathematical optimization approach for which these values need not be estimated. Schuler (1975) has found goal programming to provide a useful approach for analyzing multiple use decisions when relatively small models are utilized. However, the practicality of applying this technique to large RAA models (i.e., the Beaverhead model) remains to be demonstrated. Existing goal programming algorithms (Bottoms, 1976; Field, 1973; Lee, 1972) do not

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[1]The interested reader is referred to Lee (1972) or Schuler (1975) for a complete discussion of the goal programming formulation.

appear to be able to handle models of this large size in a computationally effective manner. More study in this area may provide models by which better cost estimates can be made.

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# APPENDIX A

Table 23. Management options defined in the Beaverhead linear programming model[a]

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Option: 00 (custodial management)

Purpose:
To act as a conceptual management baseline against which the merits of applying more intensive management options can be compared.

Intensity: Low

Actions:
a. Law Enforcement
b. Fire Management

Cost Factors:
a. Implementation Costs: None
b. Operational and Maintenance Costs:
(1) Staff
(2) Equipment and supplies

Option: 01 (recreation management - retention)

Purpose:
To provide recreation opportunities for forest visitors with orientations toward using natural unmodified recreation settings for pursuits such as backpacking, mountain climbing, nature study, etc., by providing existing settings that are conducive to such pursuits.

Intensity: Low

Actions:
a. Monitor recreation use of undeveloped areas
b. Control excessive use
c. Maintain quality of existing recreation settings
d. Prevent degradation of settings by incompatible uses

---

[a]Information taken from U.S.D.A. Forest Service (ca. 1975a).

Table 23 (continued)

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Cost Factors:
- a. Implementation Costs: None
- b. Operation and Maintenance Costs:
  - (1) Monitoring and control activities
  - (2) Maintenance activities
  - (3) Staff salaries

<u>Option</u>: 02 (recreation management - retention)

Purpose:
To provide recreation opportunities for forest visitors with orientations toward using semi-primitive recreation settings for pursuits such as hunting, fishing, gathering forest products, etc., by providing existing settings that are conducive to such pursuits.

Intensity: Low

Actions:
- a. Monitor recreation use of semiprimitive areas
- b. Control excessive use
- c. Maintain quality of existing recreation settings
- d. Prevent degradation of settings by incompatible uses

Cost Factors:
(Identical to those in Option 01)

<u>Option</u>: 03 (recreation management - retention)

Purpose:
To provide recreation opportunities for forest visitors with orientations toward using lightly developed recreation settings for pursuits such as vehicle-oriented camping or picnicking, pleasure driving, day hiking, etc., by providing existing settings that are conducive to such pursuits.

Intensity: Low

Table 23 (continued)

---

Actions:
- a. Monitor recreation use of lightly developed areas
- b. Control excessive use
- c. Maintain quality of existing recreation settings
- d. Prevent degradation of settings by incompatible uses

Cost Factors:
(Identical of those in Option 01)

<u>Option</u>: 04 (watershed management - retention)

Purpose:
To provide water in the quantity and quality that is being produced by watersheds as they presently exist.

Intensity: Low

Actions:
- a. Monitoring water quality and quantity
- b. Prevent degradation of watersheds by incompatible uses

Cost Factors:
- a. Implementation Costs: None
- b. Operation and Maintenance Costs
  - (1) Monitoring activities
  - (2) Staff salaries
- c. Variable Costs: None

<u>Option</u>: 05 (wildlife management - retention)

Purpose:
To provide key habitats as they presently exist for the production of big game species.

Intensity: Low

Table 23 (continued)

Actions:
a. Monitor habitat use
b. Control excessive use
c. Prevent degradation of wildlife habitat by incompatible uses

Cost Factors:
a. Implementation Costs: None
b. Operation and Maintenance Costs:
(1) Monitoring and control activities
(2) Staff salaries
c. Variable Costs: None

Option: 09 (wilderness management)

Purpose:
To maintain the environmental and solitude characteristics of existing classified wilderness areas.

Intensity: Low

Actions:
a. Monitor and maintain the physical environment of classified wilderness areas
b. Control excessive wilderness use to maintain solitude potential

Cost Factors:
a. Implementation Costs: None
b. Operation and Maintenance Costs:
(1) Monitoring and control activities
(2) Maintenance activities
(3) Staff salaries
c. Variable Costs: None

Option: 11 (range management - low intensity)

Purpose:
To restrict livestock grazing to discrete areas and to utilize the available forage production near available water. Only limited attempts are made to achieve livestock distribution within the areas.

Table 23 (continued)

Intensity: Low

Actions:
a. Boundary and drift fencing to restrict grazing
b. Range inspections and administration

Cost Factors:
a. Implementation Costs:
(1) Fence construction
b. Operation and Maintenance Costs:
(1) Fence maintenance
(2) Inspection and administration activities
(3) Staff salaries

Option: 12 (range management - medium intensity)

Purpose:
To fully utilize the available forage production through the application of management systems that seek to obtain relatively uniform livestock distribution and maintain or improve plant vigor. No attempts are made to improve forage production through cultural practices.

Intensity: Medium

Actions:
a. Pasture system fencing
b. Simple water developments (e.g., springs with headboxes and stock tanks)
c. Herding to effect desired management system distribution
d. Cattleguard installations
e. Range inspections and administration

Cost Factors:
a. Implementation Costs:
(1) Fencing
(2) Water developments
(3) Cattleguard installations
b. Operation and Maintenance Costs:
(1) Fence and water development maintenance
(2) Inspection and administration activities
(3) Staff salaries
c. Variable Costs: None

Table 23 (continued)

---

Option: 13 (range management - high intensity)

Purpose:
To improve existing forage productivity through cultural practices and then to fully utilize the increased grazing capacity in accord with applicable management systems.

Intensity: High

Actions:
a. Pasture fencing
b. Water developments (i.e., springs, reservoirs, piping systems)
c. Herding to effect desired management system distribution
d. Cattleguard installations
e. Range inspections and administration
f. Periodic cultural practices (i.e., sagebrush control)

Cost Factors:
a. Implementation Costs:
(1) Fencing
(2) Water developments
(3) Cultural practices
(4) Cattleguard installations
b. Operation and Maintenance Costs:
(1) Fence and water development maintenance
(2) Inspection and administration activities
(3) Staff salaries
c. Variable Costs: None

Option: 21 (recreation management - rehabilitation)

Purpose:
To provide recreation opportunities for forest visitors with orientations toward using natural, unmodified recreation settings for pursuits such as backpacking, mountain climbing, nature study, etc., by rehabilitating deteriorated settings to a quality that makes them conducive to such pursuits.

Intensity: Medium

Table 23 (continued)

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Actions:

a. Close secondary roads and revegetate roadbeds
b. Remove existing structures
c. Monitor recreation use of undeveloped areas
d. Control excessive use
e. Maintain quality of rehabilitated recreation settings
f. Prevent degradation of settings by incompatible use

Cost Factors:

a. Implementation Costs:
   (1) Road closure work (i.e., ripping, contouring, seeding)
   (2) Structure removal work
b. Operation and Maintenance Costs:
   (1) Monitoring and control activities
   (2) Maintenance activities
   (3) Staff salaries
c. Variable Costs: None

<u>Option</u>: 22 (recreation management - rehabilitation)

Purpose:

To provide recreation opportunities for forest visitors with orientations toward using semiprimitive recreation settings for pursuits such as hunting, fishing, gathering forest products, etc., by rehabilitating deteriorated settings to a quality level that makes them conducive to such pursuits.

Intensity: Medium

Actions:

a. Reduce roading density by closures and revegetation
b. Reduce road standards to four-wheel drive type and/or trails
c. Remove modern structures
d. Monitor recreation use of semiprimitive areas
e. Control excessive use
f. Maintain quality of rehabilitated recreating settings
g. Prevent degradation of settings by incompatible uses

Table 23 (continued)

---

Cost Factors:
- a. Implementation Costs:
  - (1) Road closure and standard reduction work
  - (2) Structure removal work
- b. Operation and Maintenance Costs:
  - (1) Monitoring and control activities
  - (2) Maintenance activities
  - (3) Staff salaries
- c. Variable Cost: None

Option: 23 (recreation management - enhancement)

Purpose:
To provide recreation opportunities for forest visitors with orientations toward using lightly developed recreation settings for pursuits such as vehicle-oriented camping or picnicking, pleasure driving, day hiking, etc., by enhancing existing settings to a quality level that makes them conducive to such pursuits.

Intensity: Medium

Actions:
- a. Two-wheel drive road construction (single lane gravel)
- b. Small to medium sized campground or picnic ground construction
- c. Trail construction
- d. Monitor recreation use of lightly developed areas
- e. Control excessive use
- f. Maintain quality of enhanced recreation settings
- g. Prevent degradation of settings by incompatible uses

Cost Factors:
- a. Implementation Costs:
  - (1) Road and trail construction
  - (2) Campground or picnic ground construction
  - (3) Survey and design work
- b. Operation and Maintenance Costs:
  - (1) Monitoring and control activities
  - (2) Facility, road, and trail maintenance
  - (3) Staff salaries

Table 23 (continued)

---

c. Variable Cost: None

Option: 31 (timber management - uneven-aged management - shade tolerant species)

Purpose:
To obtain a sustained yield of wood fiber while maintaining a continuous forest canopy in shade tolerant tree species stands such as Douglas fir and Englemann Spruce.

Intensity: Medium

Actions:
- a. Sale preparation
- b. Construction of logging roads (main haul and spur)
- c. Harvest timber periodically (by uneven-aged silvicultural practices such as individual tree selection or group selection)
- d. Salvage dead or dying trees
- e. Slash disposal
- f. Site preparation and regeneration
- g. Sale administration
- h. Thinning of stands

Cost Factors:
- a. Implementation Costs:
  - (1) Sale preparation
  - (2) Road construction
  - (3) Harvest timber
  - (4) Salvage activities
  - (5) Slash disposal
  - (6) Sale administration
- b. Operation and Maintenance Costs:
  - (1) Site preparation and regeneration
  - (2) Thinnings
  - (3) Staff salaries
- c. Variable Costs:
  - (1) Sale preparation
  - (2) Sale administration
  - (3) Scaling/MBF

Table 23 (continued)

Option: 32 (timber management - even-aged management - high productivity site)

Purpose:
To obtain a sustained yield of wood fiber from commercial timber stands with only the minimum investment of capital necessary to insure regeneration and resource protection. (Applicable on areas with slopes averaging less than 45%.)

Intensity: Medium

Actions:
a. Sale preparation
b. Construction of logging roads (main haul and spur)
c. Harvest timber periodically (by even-aged silvicultural practices such as clearcutting, shelterwood or seed tree)
d. Thinning of stands (one commercial thinning at 50 or 70 years)
e. Salvage dead or dying trees
f. Slash disposal
g. Site preparation and regeneration
h. Sale administration

Cost Factors:
a. Implementation Costs:
   (1) Sale preparation
   (2) Road construction
   (3) Harvest timber
   (4) Salvage activities
   (5) Slash disposal
   (6) Sale administration

b. Operation and Maintenance Costs:
   (1) Site preparation and regeneration
   (2) Thinnings
   (3) Staff salaries

c. Variable Costs:
   (1) Sale preparation
   (2) Sale administration
   (3) Scaling/MBF

Table 23 (continued)

---

<u>Option</u>: 33 (timber management - even-aged management - medium productivity sites)

(This option is identical to option 32 with the exception that it applies to medium productivity sites.)

<u>Option</u>: 34 (timber management - even-aged management - low productivity sites)

(This option is identical to option 32 with the exception that it applies to low productivity sites.)

<u>Option</u>: 35 (timber management - even-aged management - sites with some slopes in excess of 45 percent)

Purpose:
To obtain a sustained yield of wood fiber from commercial timber stands with only the minimum investment of capital necessary to insure regeneration and resource protection, except that this option will reflect the higher application costs for areas with slopes in excess of 45%.

Intensity: Medium

Actions:
a. Sale preparation
b. Construction of logging roads (main haul and spur)
c. Harvest timber periodically (by even-aged silvicultural practices such as clearcutting, shelterwood, or seed tree)
d. Thinning of stands (one commercial thinning at 50 years)
e. Salvage dead or dying trees
f. Slash disposal
g. Site preparation and regeneration
h. Sale administration

Cost Factors:
a. Implementation Costs:
(1) Sale preparation
(2) Road construction

Table 23 (continued)

---

(3) Harvest timber
(4) Salvage activities
(5) Slash disposal
(6) Sale administration

b. Operation and Maintenance Cost:
(1) Site preparation and regeneration
(2) Thinnings
(3) Staff salaries

c. Variable Costs:
(1) Sale preparation
(2) Sale administration
(3) Scaling/MBF

<u>Option</u>: 36 (timber management - even-aged management - high productivity site)

Purpose:
To obtain a sustained yield of wood fiber from commercial timber stands with a moderate investment of capital in cultural practices.

Intensity: High

Actions:
a. Sale preparation
b. Construction of logging roads
c. Harvest timber periodically (by even-aged silvicultural practices such as clearcutting, shelterwood, or seed tree)
d. Planting
e. Thinning of stands (one precommercial thinning at age 20)
f. Salvage dead or dying trees
g. Slash disposal
h. Site preparation and regeneration
i. Sale administration

Cost Factors:
a. Implementation Costs:
(1) Sale preparation
(2) Road construction
(3) Harvest timber
(4) Planting
(5) Salvage activities
(6) Slash disposal
(7) Sale administration

Table 23 (continued)

---

b. Operation and Maintenance Costs:
   (1) Site preparation and regeneration
   (2) Thinnings
   (3) Staff salaries
c. Variable Costs:
   (1) Sale preparation
   (2) Sale administration
   (3) Scaling/MBF

<u>Option</u>: 37 (timber management - even-aged management - medium productivity site)

(This option is identical to option 36 with the exception that it applies to medium productivity sites.)

<u>Option</u>: 38 (timber management - even-aged management - low productivity site)

(This option is identical to option 36 with the exception that it applies to low productivity sites.)

<u>Option</u>: 52 (wildlife management - enhancement)

Purpose:
To rehabilitate or improve wildlife habitat; either to its former productivity level or to improve a habitat's natural capacity to provide wildlife values.

Intensity: Medium

Actions:
a. Introduce food and/or cover
b. Close roads
c. Develop water availability
d. Habitat type conversions
e. Plantings
f. Monitor and manage habitat use
g. Fence for exclusive wildlife use

Table 23 (continued)

---

Cost Factors:
- a. Implementation Costs:
  - (1) Road closures
  - (2) Vegetative type conversions
  - (3) Water developments
  - (4) Many different direct project costs possible
- b. Operation and Maintenance Costs:
  - (1) Monitoring and control activities
  - (2) Staff salaries
- c. Variable Costs: None

<u>Option</u>: 92 (new wilderness study area management)

Purpose:

To designate study areas for potential wilderness classification and to protect these areas to preserve their wilderness potential during the study period and until a final determination is made. (Applicable to all areas already selected by the Chief and to new areas which meet the basic wilderness criteria.)

Intensity: Low

Actions:
- a. Monitor and maintain physical environment of designated study areas
- b. Prevent degradation by incompatible uses
- c. Study designated areas for possible wilderness classification

Cost Factors:
- a. Implementation Costs:
  - (1) Wilderness classification study
  - (2) Staff salaries
- b. Operation and Maintenance Costs:
  - (1) Monitoring and maintenance activities
  - (2) Staff salaries
- c. Variable Costs: None

---

# APPENDIX B

Table 24. Example 1 values for the net present worth, commodity, and cost rows for each level of wilderness allocation considered

| Wilderness Total in Each Solution | NPW1[a] | NPW2 | NPW3 |
|---|---|---|---|
| (acres) | (dollars)[b] | (dollars)[b] | (dollars)[b] |
| 72,379 | 387,290,709.18 | 246,964,482.90 | 139,412,592.88 |
| 72,479 | 387,290,730.46 | 246,964,486.44 | 139,412,589.35 |
| 76,379 | 387,291,768.80 | 246,964,596.30 | 138,412,431.64 |
| 76,479 | 387,291,797.15 | 246,964,596.30 | 139,412,428.09 |
| 80,379 | 387,292,831.94 | 246,964,702.62 | 139,412,270.40 |
| 80,479 | 387,292,860.30 | 246,964,706.16 | 139,412,265.08 |
| 100,379 | 387,292,668.93 | 246,969,269.92 | 139,407,011.35 |
| 100,479 | 387,292,640.58 | 246,959,227,40 | 139,406,974.14 |
| 200,379 | 387,169,208.93 | 246,837,872.44 | 139.320,137.86 |
| 200,479 | 387,169,010.47 | 246,837,709.42 | 138,320,033.33 |
| 500,379 | 385,896,137.11 | 245,887,427.49 | 138,723,836.84 |
| 500,479 | 385,895,435.43 | 245,886,917.17 | 138,723,523.22 |
| 927,340 | 376,836,449.06 | 240,198,273.94 | 135,513,740.45 |
| 927,440 | 376,828,805.02 | 240,193,737.84 | 135,511,295.20 |
| | COST1 | COST2 | COST3 |
| | (dollars/YR.) | (dollars/YR.) | (dollars/YR.) |
| 72,379 | 5,583,879.44 | 5,298,755.21 | 6,049,416.46 |
| 72,479 | 5,583,873.44 | 5,298,747.35 | 6,049,408.86 |
| 76,379 | 5,583,636.43 | 5,298,441.40 | 6,049,112.02 |
| 76,479 | 5,583,630.34 | 5,298,433.55 | 6,049,104.42 |
| 80,379 | 5,583,393.32 | 5,298,127.60 | 6,048,807.63 |
| 80,479 | 5,583,387.23 | 5,298,153.07 | 6,048,800.03 |
| 100,379 | 5,581,760.66 | 5,295,776.14 | 6,046,503.20 |
| 100,479 | 5,581,754.66 | 5,295,768.35 | 6,046,495.59 |
| 200,379 | 5,574,728.47 | 5,282,871.28 | 6,033,752.30 |
| 200,479 | 5,574,717.88 | 5,282,854.86 | 6,033,736.10 |

[a]See page 80 for description of NPWi rows and Table 4, p. 77 for descriptions of commodity and cost rows.

[b]Present value.

Table 24 (continued)

| Wilderness Total in Each Solution | COST1 | COST2 | COST3 |
|---|---|---|---|
| (acres) | (dollars/YR.) | (dollars/YR.) | (dollars/YR.) |
| 500,379 | 5,544,332.98 | 5,240,844.22 | 5,992,430.99 |
| 500,479 | 5,544,322.35 | 5,240,827.80 | 5,992,414.79 |
| 927,340 | 5,744,842.68 | 5,316,733.01 | 6,120,818.43 |
| 927,440 | 5,745,062.92 | 5,316,900.57 | 6,120,981.21 |
| | OLDHA1 | OLDHA2 | OLDHA3 |
| | (MCF/YR.) | (MCF/YR.) | (MCF/YR.) |
| 72,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 72,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 76,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 76,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 80,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 80,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 100,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 100,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 200,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 200,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 500,379 | 6,713.31 | 5,606.14 | 6,663.83 |
| 500,479 | 6,713.31 | 5,606.14 | 6,663.83 |
| 927,340 | 6,964.18 | 5,666.01 | 6,812.40 |
| 927,440 | 6,964.18 | 5,666.01 | 6,812.40 |
| | OLDST1 | OLDST2 | OLDST3 |
| | (MCF/YR.) | (MCF/YR.) | (MCF/YR.) |
| 72,379 | 1,682,344.59 | 1,527,654.16 | 1,224,768.83 |
| 72,479 | 1,682,344.59 | 1,527,654.16 | 1,224,768.83 |
| 76,379 | 1,682,344.59 | 1,527,654.16 | 1,224,768.83 |
| 76,479 | 1,682,344.59 | 1,527,654.16 | 1,224,768.83 |
| 80,379 | 1,682,344.58 | 1,527,654.16 | 1,224,768.83 |
| 80,479 | 1,682,344.59 | 1,527,654.16 | 1,224,768.83 |
| 100,379 | 1,682,344.57 | 1,527,654.15 | 1,224,768.83 |
| 100,479 | 1,682,344.57 | 1,527,654.15 | 1,224,768.83 |
| 200,379 | 1,682,344.57 | 1,527,654.15 | 1,224,768.83 |
| 200,479 | 1,682,344.57 | 1,527,654.15 | 1,224,768.83 |
| 500,379 | 1,682,344.55 | 1,527,654.13 | 1,224,768.83 |
| 500,479 | 1,682,344.55 | 1,527,654.13 | 1,224,768.83 |

Table 24 (continued)

| Wilderness Total in Each Solution | OLDST1 | OLDST2 | OLDST3 |
|---|---|---|---|
| (acres) | (MCF/YR.) | (MCF/YR.) | (MCF/YR.) |
| 927,340 | 1,681,274.24 | 1,521,707.95 | 1,210,872.88 |
| 927,440 | 1,681,274.24 | 1,521,707.95 | 1,210,872.88 |

| | NEWHA3 | NEWST2 | NEWST3 |
|---|---|---|---|
| | (MCF/YR.) | (MCF/YR.) | (MCF/YR.) |
| 72,379 | 664.91 | 0.00 | 1,084,470.60 |
| 72,479 | 664.91 | 0.00 | 1,084,470.60 |
| 76,379 | 664.91 | 0.00 | 1,084,470.60 |
| 76,479 | 664.91 | 0.00 | 1,084,470.60 |
| 80,379 | 664.91 | 0.00 | 1,084,470.60 |
| 80,479 | 664.91 | 0.00 | 1,084,470.60 |
| 100,379 | 664.91 | 0.00 | 1,084,470.60 |
| 100,479 | 664.91 | 0.00 | 1,084,470.60 |
| 200,379 | 664.91 | 0.00 | 1,084,470.60 |
| 200,479 | 664.91 | 0.00 | 1,084,470.60 |
| 500,379 | 664.91 | 0.00 | 1,084,470.60 |
| 500,479 | 664.91 | 0.00 | 1,084,470.60 |
| 927,340 | 633.82 | 0.00 | 1,084,470.60 |
| 927,440 | 633.82 | 0.00 | 1,084,470.60 |

| | FORRG1 | FORRG2 | FORRG3 |
|---|---|---|---|
| | (M.LBS./YR.) | (M.LBS./YR.) | (M.LBS./YR.) |
| 72,379 | 105,682.11 | 309,169.26 | 311,862.88 |
| 72,479 | 105,682.12 | 309,169.25 | 311,862.88 |
| 76,379 | 105,682.12 | 309,169.25 | 311,862.88 |
| 76,479 | 105,682.12 | 309,169.25 | 311,862.88 |
| 80,379 | 105,682.12 | 309,169.25 | 311,862.88 |
| 80,479 | 105,682.12 | 309,169.25 | 311,862.88 |
| 100,379 | 105,682.12 | 309,169.25 | 311,862.88 |
| 100,479 | 105,682.12 | 309,169.25 | 311,862.88 |
| 200,379 | 105,510.10 | 309,169.25 | 311,876.57 |
| 200,479 | 105,510.10 | 309,169.25 | 311,876.57 |
| 500,379 | 105,043.56 | 309,169.25 | 311,923.25 |
| 500,479 | 105,043.56 | 309,169.25 | 311,923.25 |
| 927,340 | 99,079.55 | 309,169.25 | 312,515.96 |
| 927,440 | 99,077.07 | 309,169.25 | 312,516.01 |

Table 24 (continued)

| Wilderness Total in Each Solution | FORTI1 | FORTI2 | FORTI3 |
|---|---|---|---|
| (acres) | (M.LBS./YR.) | (M.LBS./YR.) | (M.LBS./YR.) |
| 72,379 | 64.54 | 12,346.20 | 11,821.98 |
| 72,479 | 64.54 | 12,346.20 | 11,821.98 |
| 76,379 | 64.54 | 12,346.20 | 11,821.98 |
| 76,479 | 64.54 | 12,346.20 | 11,821.98 |
| 80,379 | 64.54 | 12,346.20 | 11,821.98 |
| 80,479 | 64.54 | 12,346.20 | 11,821.98 |
| 100,379 | 64.54 | 12,346.20 | 11,821.98 |
| 100,479 | 64.54 | 12,346.20 | 11,821.98 |
| 200,379 | 64.54 | 12,346.20 | 11,821.98 |
| 200,479 | 64.54 | 12,346.20 | 11,821.98 |
| 500,379 | 64.54 | 12,346.20 | 11,821.98 |
| 500,479 | 64.54 | 12,346.20 | 11,821.98 |
| 927,340 | 64.67 | 12,554.68 | 11,890.77 |
| 927,440 | 65.67 | 12,554.68 | 11,890.77 |
| | REC11 | REC12 | REC13 |
| | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 350,820.74 | 324,289.18 | 297,860.29 |
| 72,479 | 350,819.84 | 324,288.99 | 297,860.29 |
| 76,379 | 350,785.22 | 324,281.58 | 297,860.29 |
| 76,479 | 350,784.32 | 324,281.39 | 297,860.29 |
| 80,379 | 350,749.71 | 324,273.97 | 297,860.29 |
| 80,479 | 350,748.81 | 324,273,78 | 297,860.29 |
| 100,379 | 350,620.92 | 324,477.35 | 298,121.06 |
| 100,479 | 350,619.14 | 324,476.97 | 298,121.06 |
| 200,379 | 350,679.34 | 327,668.87 | 301,708.69 |
| 200,479 | 350,679.52 | 327,671.44 | 301,711.54 |
| 500,379 | 349,530.32 | 337,076.09 | 312,608.60 |
| 500,479 | 349,530.71 | 337,081.23 | 312,614.31 |
| 927,340 | 346,765.26 | 345,806.76 | 322,869.29 |
| 927,440 | 346,763.55 | 345,803.24 | 322,865.86 |

Table 24 (continued)

| Wilderness Total in Each Solution | REC21 | REC22 | REC23 |
|---|---|---|---|
| (acres) | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 1,212,684.56 | 1,204,350.12 | 1,122,341.30 |
| 72,479 | 1,212,684.58 | 1,204,350.63 | 1,122,341.87 |
| 76,379 | 1,212,686.07 | 1,204,370.68 | 1,122,364.13 |
| 76,479 | 1,212,686.10 | 1,204,371.19 | 1,122,364.70 |
| 80,379 | 1,212,687.59 | 1,204,391.22 | 1,122,386.95 |
| 80,479 | 1,212,687.61 | 1,204,391.73 | 1,122,387.54 |
| 100,379 | 1,212,523.67 | 1,204,334.34 | 1,122,362.41 |
| 100,479 | 1,212,523.74 | 1,204,355.38 | 1,122,363.56 |
| 200,379 | 1,210,083.50 | 1,202,394.46 | 1,120,759.07 |
| 200,479 | 1,210,080.20 | 1,202,391.40 | 1,120,756.42 |
| 500,379 | 1,196,894.37 | 1,191,475.48 | 1,111,664.77 |
| 500,479 | 1,196,886.85 | 1,191,468.47 | 1,111,658.67 |
| 927,340 | 1,149,239.73 | 1,123,590.75 | 1,045,133.30 |
| 927,440 | 1,149,217.06 | 1,123,537.77 | 1,045,080.60 |
| | REC31 | REC32 | REC33 |
| | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 314,067.80 | 300,555.67 | 291,971.39 |
| 72,479 | 314,067.80 | 300,555.72 | 291,971.44 |
| 76,379 | 314,067.93 | 300,557.38 | 291,973.28 |
| 76,479 | 314,067.94 | 300,557.43 | 291,973.34 |
| 80,379 | 314,068.06 | 300,559.10 | 291,975.20 |
| 80,479 | 314,068.06 | 300,559.14 | 291,975.24 |
| 100,379 | 314,069.35 | 300,576.75 | 291,994.81 |
| 100,479 | 314,069.36 | 300,576.96 | 291,995.05 |
| 200,379 | 314,051.76 | 300,638.00 | 292,070.31 |
| 200,479 | 314,051.81 | 300,638.65 | 292,071.02 |
| 500,379 | 314,236.63 | 302,093.60 | 293,662.41 |
| 500,479 | 314,236.66 | 302,094.03 | 293,662.89 |
| 927,340 | 314,428.76 | 305,197.22 | 297,491.87 |
| 927,440 | 314,429.83 | 305,200.19 | 297,494.89 |

Table 24 (continued)

| Wilderness Total in Each Solution | WATRY1 | WATRY2 | WATRY3 |
|---|---|---|---|
| (acres) | (A F/YR.) | (A F/YR.) | (A F/YR.) |
| 72,379 | 1,553,499.01 | 1,599,170.74 | 1,608,349.91 |
| 72,479 | 1,553,498.99 | 1,599,170.72 | 1,608,349.90 |
| 76,379 | 1,553,498.99 | 1,599,170.72 | 1,608,349.91 |
| 76,479 | 1,553,498.99 | 1,599,170.72 | 1,608,349.91 |
| 80,379 | 1,553,499.01 | 1,599,170.74 | 1,608,349.91 |
| 80,479 | 1,553,499.01 | 1,599,170.74 | 1,608,349.91 |
| 100,379 | 1,553,498.99 | 1,599,170.72 | 1,608,349.91 |
| 100,479 | 1,553,498.99 | 1,599,170.72 | 1,608,349.91 |
| 200,379 | 1,553,374.71 | 1,598,752.67 | 1,607,926.24 |
| 200,479 | 1,553,374.71 | 1,598,752.67 | 1,607,926.24 |
| 500,379 | 1,552,578.69 | 1,596,075.50 | 1,605,212.86 |
| 500,479 | 1,552,578.69 | 1,596,075.50 | 1,605,212.86 |
| 927,340 | 1,551,015.97 | 1,591,011.67 | 1,600,279.12 |
| 927,440 | 1,551,015.62 | 1,591,010.50 | 1,600,277.94 |
| | SEDRD1 | SEDRD2 | SECRD3 |
| | (CU.YD./YR.) | (CU.YD./YR.) | (CU.YD./YR.) |
| 72,379 | 10,258.16 | 9,223.38 | 11,381.47 |
| 72,479 | 10,258.16 | 9,223.38 | 11,381.47 |
| 76,379 | 10,258.16 | 9,223.38 | 11,381.47 |
| 76,479 | 10,258.16 | 9,223.38 | 11,381.47 |
| 80,379 | 10,258.16 | 9,223.38 | 11,381.47 |
| 80,479 | 10,258.16 | 9,233.38 | 11,381.47 |
| 100,379 | 10,258.16 | 9,233.38 | 11,381.47 |
| 100,479 | 10,258.16 | 9,233.38 | 11,381.47 |
| 200,379 | 10,258.16 | 9,233.38 | 11,381.47 |
| 200,479 | 10,258.16 | 9,233.38 | 11,381.47 |
| 500,379 | 10,258.16 | 9,233.38 | 11,381.47 |
| 500,479 | 10,258.16 | 9,233.38 | 11,381.47 |
| 927,340 | 12,642.85 | 11,188.16 | 13,976.61 |
| 927,440 | 12,642.85 | 11,188.16 | 13,976.61 |

Table 24 (continued)

| Wilderness Total in Each Solution | SEDGE1 | SEDGE2 | SEDGE3 |
|---|---|---|---|
| (acres) | (CU.YD./YR.) | (CU.YD./YR.) | (CU.YD./YR.) |
| 72,379 | 166,163.08 | 166,573.98 | 167,340.11 |
| 72,479 | 166,163.08 | 166,573.98 | 167,340.11 |
| 76,379 | 166,163.08 | 166,573.98 | 167,340.11 |
| 76,479 | 166,163.08 | 166,573.98 | 167,340.11 |
| 80,379 | 166,163.08 | 166,573.98 | 167,340.11 |
| 80,479 | 166,163.08 | 166,573.98 | 167,340.11 |
| 100,379 | 166,163.08 | 166,573.98 | 167,340.11 |
| 100,479 | 166,163.08 | 166,573.98 | 167,340.11 |
| 200,379 | 165,858.50 | 165,474.32 | 166,164.94 |
| 200,479 | 165,858.50 | 165,474.32 | 166,164.94 |
| 500,379 | 165,520.23 | 164,186.10 | 164,681.31 |
| 500,479 | 165,520.23 | 164,186.10 | 164,681.31 |
| 927,340 | 161,960.13 | 155,272.69 | 155,347.35 |
| 927,440 | 161,952.18 | 155,242.91 | 155,314.21 |
| | BGF001 | BGF002 | BGF003 |
| | (AE/YR.) | (AE/YR.) | (AE/YR.) |
| 72,379 | 681,944.66 | 604,061.10 | 604,650.27 |
| 72,479 | 681,944.66 | 604,061.10 | 604,650.27 |
| 76,379 | 681,944.66 | 604,061.10 | 604,650.27 |
| 76,479 | 681,944.66 | 604,061.10 | 604,650.27 |
| 80,379 | 681,944.65 | 604,061.09 | 604,650.26 |
| 80,479 | 681,944.65 | 604,061.09 | 604,650.26 |
| 100,379 | 681,944.65 | 604,061.09 | 604,650.25 |
| 100,479 | 681,944.65 | 604,061.09 | 604,650.25 |
| 200,379 | 682,018.58 | 604,092.37 | 604,676.72 |
| 200,479 | 682,018.58 | 604,092.37 | 604,676.72 |
| 500,379 | 681,645.38 | 602,625.05 | 603,187.79 |
| 500,479 | 681,645.38 | 602,625.05 | 603,187.79 |
| 927,340 | 679,222.77 | 591,973.96 | 592,341.72 |
| 927,440 | 679,219.57 | 591,960.47 | 592,328.00 |

Table 24 (continued)

| Wilderness Total in Each Solution | BGCOV1 | BGCOV2 | BGCOV3 |
|---|---|---|---|
| (acres) | (AE/YR.) | (AE/YR.) | (AE/YR.) |
| 72,379 | 822,703.97 | 787,738.48 | 758,835.46 |
| 72,479 | 822,703.96 | 787,738.48 | 758,835.46 |
| 76,379 | 822,703.96 | 787,738.48 | 758,835.46 |
| 76,479 | 822,703.96 | 787,738.48 | 758,835.46 |
| 80,379 | 822,703.96 | 787,738.48 | 758,835.45 |
| 80,479 | 822,703.96 | 787,738.48 | 758,835.45 |
| 100,379 | 822,703.96 | 787,738.48 | 758,835.45 |
| 100,479 | 822,703.96 | 787,738.48 | 758,835.45 |
| 200,379 | 822,703.93 | 787,738.45 | 758,816.41 |
| 200,479 | 822,703.93 | 787,738.45 | 758,816.41 |
| 500,379 | 822,703.86 | 787,738.38 | 758,835.36 |
| 500,479 | 822,703.86 | 787,738.38 | 758,835.36 |
| 927,340 | 822,732.42 | 787,731.60 | 758,661.61 |
| 927,330 | 822,732.42 | 787,731.60 | 758,661.61 |
| | RDCOS1 | RDCOS2 | RDCOS3 |
| | (dollars/YR.) | (dollars/YR.) | (dollars/YR.) |
| 72,379 | 463,822.59 | 25,751.32 | 0.00 |
| 72,479 | 463,822.59 | 25,751.32 | 0.00 |
| 76,379 | 463,822.59 | 25,751.32 | 0.00 |
| 76,479 | 463,822.59 | 25,751.32 | 0.00 |
| 80,379 | 463,822.59 | 25,751.32 | 0.00 |
| 80,479 | 463,822.59 | 25,751.32 | 0.00 |
| 100,379 | 463,822.59 | 25,751.32 | 0.00 |
| 100,479 | 463,822.59 | 25,751.32 | 0.00 |
| 200,379 | 463,822.59 | 25,751.32 | 0.00 |
| 200,479 | 463,822.59 | 25,751.32 | 0.00 |
| 500,379 | 463,822.59 | 25,751.32 | 0.00 |
| 500,479 | 463,822.59 | 25,751.32 | 0.00 |
| 927,340 | 467,291.82 | 25,943.01 | 0.00 |
| 927,440 | 467,291.82 | 25,943.01 | 0.00 |

Table 25. Example 2 values for the net present worth, commodity, and cost rows for each level of wilderness allocation considered

| Wilderness Total in Each Solution | NPW1[a] | NPW2 | NPW3 |
|---|---|---|---|
| (acres) | (dollars)[b] | (dollars)[b] | (dollars)[b] |
| 72,379 | 441,326,809.52 | 279,301,646.81 | 157,376,699.58 |
| 72,479 | 441,326,859.13 | 279,301,664.54 | 157,376,706.64 |
| 76,379 | 441,328,294.38 | 279,302,036.64 | 157,376,713.73 |
| 76,479 | 441,328,322.74 | 279,302,040.18 | 157,376,710.18 |
| 80,379 | 441,329,357.53 | 279,302,146.50 | 157,376,552.48 |
| 80,479 | 441,329,382.34 | 279,302,150.04 | 157,376,547.17 |
| 100,379 | 441,332,469.01 | 279,301,079.81 | 157,374,757.53 |
| 100,479 | 441,332,458.39 | 279,301,040.82 | 157,374,723.87 |
| 200,379 | 441,260,199.66 | 279,229,310.13 | 157,324,061.25 |
| 200,479 | 441,260,061.45 | 279,229,168.38 | 157,323,962.02 |
| 500,379 | 440,444,016.31 | 278,715,025.77 | 157,042,881.27 |
| 500,479 | 440,443,598.14 | 278,714,731.64 | 157,042,700.53 |
| 927,340 | 436,806,712.80 | 276,174,467.21 | 155,511,807.88 |
| 927,440 | 436,805,511.45 | 276,173,609.60 | 155,511,283.40 |
| | COST1 | COST2 | COST3 |
| | (dollars/YR.) | (dollars/YR.) | (dollars/YR.) |
| 72,379 | 637,448.92 | 716,248.42 | 713,110.66 |
| 72,479 | 637,438.29 | 716,232.03 | 713,094.50 |
| 76,379 | 637,128.33 | 715,789.25 | 712,660.88 |
| 76,479 | 637,122.26 | 715,781.40 | 712,653.26 |
| 80,379 | 636,855.26 | 715,475.43 | 712,356.47 |
| 80,479 | 636,879.18 | 715,467.60 | 712,348.85 |
| 100,379 | 635,365.37 | 713,335.41 | 710,263.41 |
| 100,479 | 635,354.72 | 713,318.99 | 710,247.24 |
| 200,379 | 623,472.46 | 698,955.72 | 696,188.51 |
| 200,479 | 623,461.81 | 698,939.31 | 696,172.33 |
| 500,379 | 559,551.13 | 657,828.53 | 656,811.68 |
| 500,479 | 559,540.48 | 657,812.13 | 656,795.50 |

[a]See page 80 for description of NPWi rows and Table 4, page 77 for descriptions of commodity and cost rows.

[b]Present value.

Table 25 (continued)

| Wilderness Total in Each Solution (acres) | COST1 (dollars/YR.) | COST2 (dollars/YR.) | COST3 (dollars/YR.) |
|---|---|---|---|
| 927,340 | 506,288.47 | 590,940.96 | 590,995.65 |
| 927,440 | 506,277.83 | 590,924.55 | 590,979.48 |
| | OLDHA1 (MCF/YR.) | OLDHA2 (MCF/YR.) | OLDHA3 (MCF/YR.) |
| 72,379 | 0.00 | 0.00 | 0.00 |
| 72,479 | 0.00 | 0.00 | 0.00 |
| 76,379 | 0.00 | 0.00 | 0.00 |
| 76,479 | 0.00 | 0.00 | 0.00 |
| 80,379 | 0.00 | 0.00 | 0.00 |
| 80,479 | 0.00 | 0.00 | 0.00 |
| 100,379 | 0.00 | 0.00 | 0.00 |
| 100,479 | 0.00 | 0.00 | 0.00 |
| 200,379 | 0.00 | 0.00 | 0.00 |
| 200,479 | 0.00 | 0.00 | 0.00 |
| 500,379 | 0.00 | 0.00 | 0.00 |
| 500,479 | 0.00 | 0.00 | 0.00 |
| 927,340 | 0.00 | 0.00 | 0.00 |
| 927,440 | 0.00 | 0.00 | 0.00 |
| | OLDST1 (MCF/YR.) | OLDST2 (MCF/YR.) | OLDST3 (MCF/YR.) |
| 72,379 | 1,710,325.90 | 1,710,325.90 | 1,710,325.28 |
| 72,479 | 1,710,325.90 | 1,710,325.90 | 1,710,325.28 |
| 76,379 | 1,710,325.90 | 1,710,325.90 | 1,710,325.28 |
| 76,479 | 1,710,325.90 | 1,710,325.90 | 1,710,325.28 |
| 80,379 | 1,710,325.90 | 1,710,325.90 | 1,710,325.67 |
| 80,479 | 1,710,325.90 | 1,710,325.90 | 1,710,325.67 |
| 100,379 | 1,710,325.88 | 1,710,325.88 | 1,710,325.65 |
| 100,479 | 1,710,325.88 | 1,710,325.88 | 1,710,325.65 |
| 200,379 | 1,710,325.86 | 1,710,325.86 | 1,710,325.63 |
| 200,479 | 1,710,325.86 | 1,710,325.86 | 1,710,325.63 |
| 500,379 | 1,710,325.84 | 1,710,325.84 | 1,710,325.63 |
| 500,479 | 1,710,325.84 | 1,710,325.84 | 1,710,325.63 |
| 927,340 | 1,710,325.67 | 1,710,325.67 | 1,710,325.43 |
| 927,440 | 1,710,325.67 | 1,710,325.67 | 1,710,325.43 |

Table 25 (continued)

| Wilderness Total in Each Solution | NEWHA3 | NEWST2 | NEWST3 |
|---|---|---|---|
| (acres) | (MCF/YR.) | (MCF/YR.) | (MCF/YR.) |
| 72,379 | 0.00 | 0.00 | 0.00 |
| 72,479 | 0.00 | 0.00 | 0.00 |
| 76,379 | 0.00 | 0.00 | 0.00 |
| 76,479 | 0.00 | 0.00 | 0.00 |
| 80,379 | 0.00 | 0.00 | 0.00 |
| 80,479 | 0.00 | 0.00 | 0.00 |
| 100,379 | 0.00 | 0.00 | 0.00 |
| 100,479 | 0.00 | 0.00 | 0.00 |
| 200,379 | 0.00 | 0.00 | 0.00 |
| 200,479 | 0.00 | 0.00 | 0.00 |
| 500,379 | 0.00 | 0.00 | 0.00 |
| 500,479 | 0.00 | 0.00 | 0.00 |
| 927,340 | 0.00 | 0.00 | 0.00 |
| 927,440 | 0.00 | 0.00 | 0.00 |
| | FORRG1 (M.LBS./YR.) | FORRG2 (M.LBS./YR.) | FORRG3 (M.LBS./YR.) |
| 72,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 72,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 76,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 76,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 80,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 80,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 100,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 100,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 200,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 200,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 500,379 | 5,678.82 | 14,009.84 | 14,041.04 |
| 500,479 | 5,678.82 | 14,009.84 | 14,041.04 |
| 927,340 | 5,678.82 | 14,009.84 | 14,041.04 |
| 927,440 | 5,678.82 | 14,009.84 | 14,041.04 |

Table 25 (continued)

| Wilderness Total in Each Solution | FORTI1 | FORTI2 | FORTI3 |
|---|---|---|---|
| (acres) | (M.LBS./YR.) | (M.LBS./YR.) | (M.LBS./YR.) |
| 72,379 | 0.00 | 0.00 | 0.00 |
| 72,479 | 0.00 | 0.00 | 0.00 |
| 76,379 | 0.00 | 0.00 | 0.00 |
| 76,479 | 0.00 | 0.00 | 0.00 |
| 80,379 | 0.00 | 0.00 | 0.00 |
| 80,479 | 0.00 | 0.00 | 0.00 |
| 100,379 | 0.00 | 0.00 | 0.00 |
| 100,479 | 0.00 | 0.00 | 0.00 |
| 200,379 | 0.00 | 0.00 | 0.00 |
| 200,479 | 0.00 | 0.00 | 0.00 |
| 500,379 | 0.00 | 0.00 | 0.00 |
| 500,479 | 0.00 | 0.00 | 0.00 |
| 927,340 | 0.00 | 0.00 | 0.00 |
| 927,440 | 0.00 | 0.00 | 0.00 |
| | REC11 | REC12 | REC13 |
| | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 374,998.33 | 398,747.62 | 398,751.29 |
| 72,479 | 374,998.39 | 398,748.47 | 398,752.24 |
| 76,379 | 374,978.96 | 398,757.77 | 398,767.44 |
| 76,479 | 374,978.08 | 398,757.58 | 398,767.44 |
| 80,379 | 374,943.45 | 398,750.16 | 398,767.43 |
| 80,479 | 374,942.55 | 398,749.96 | 398,767.43 |
| 100,379 | 374,881.24 | 398,873.53 | 398,921.78 |
| 100,479 | 374,881.43 | 398,876.11 | 398,924.63 |
| 200,379 | 374,674.13 | 400,798.08 | 401,146.07 |
| 200,479 | 374,674.44 | 400,802.36 | 401,150.83 |
| 500,379 | 375,004.48 | 407,573.54 | 408,729.57 |
| 500,479 | 375,004.66 | 407,576.11 | 408,732.41 |
| 927,340 | 374,134.64 | 425,638.37 | 429,356.61 |
| 927,440 | 374,135.20 | 425,646.07 | 429,365.17 |

Table 25 (continued)

| Wilderness Total in Each Solution | REC21 | REC22 | REC23 |
|---|---|---|---|
| (acres) | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 1,338,325.11 | 1,503,562.56 | 1,503,589.57 |
| 72,479 | 1,338,324.17 | 1,503,561.69 | 1,503,588.81 |
| 76,379 | 1,338,310.06 | 1,503,559.51 | 1,503,589.78 |
| 76,479 | 1,338,310.08 | 1,503,560.04 | 1,503,590.35 |
| 80,379 | 1,338,311.58 | 1,503,580.06 | 1,503,612.62 |
| 80,479 | 1,338,311.60 | 1,503,580.58 | 1,503,613.17 |
| 100,379 | 1,338,189.26 | 1,503,517.45 | 1,503,571.49 |
| 100,479 | 1,338,187.40 | 1,503,515.69 | 1,503,569.98 |
| 200,379 | 1,336,311.67 | 1,501,956.00 | 1,502,267.48 |
| 200,479 | 1,336,308.37 | 1,501,952.93 | 1,502,264.83 |
| 500,379 | 1,327,171.38 | 1,493,713.56 | 1,495,268.78 |
| 500,479 | 1,327,166.69 | 1,493,709.18 | 1,495,264.94 |
| 927,340 | 1,292,987.67 | 1,459,324.52 | 1,464,813.33 |
| 927,440 | 1,292,975.94 | 1,459,313.59 | 1,464,803.84 |
| | REC31 | REC32 | REC33 |
| | (RVD/YR.) | (RVD/YR.) | (RVD/YR.) |
| 72,379 | 315,188.23 | 306,003.32 | 305,995.78 |
| 72,479 | 315,188.23 | 306,003.36 | 305,995.83 |
| 76,379 | 315,188.36 | 306,005.03 | 305,997.69 |
| 76,479 | 315,188.37 | 306,005.08 | 305,997.74 |
| 80,379 | 315,188.48 | 306,006.74 | 305,999.59 |
| 80,479 | 315,188.48 | 306,006.78 | 305,999.64 |
| 100,379 | 315,190.26 | 306,030.94 | 306,026.48 |
| 100,479 | 315,190.26 | 306,030.98 | 306,026.53 |
| 200,379 | 315,214.76 | 306,313.98 | 306,339.79 |
| 200,479 | 315,214.77 | 306,314.20 | 306,340.03 |
| 500,379 | 315,786.40 | 308,365.42 | 308,483.02 |
| 500,479 | 315,786.40 | 308,365.46 | 308,483.06 |
| 927,340 | 316,523.56 | 313,331.90 | 313,894.97 |
| 927,440 | 316,523.60 | 313,332.33 | 313,895.45 |

Table 25 (continued)

| Wilderness Total in Each Solution | WATRY1 | WATRY2 | WATRY3 |
|---|---|---|---|
| (acres) | (AF/YR.) | (AF/YR.) | (AF/YR.) |
| 72,379 | 1,535,066.49 | 1,535,066.83 | 1,535,066.81 |
| 72,479 | 1,535,066.46 | 1,535,066.81 | 1,535,066.81 |
| 76,379 | 1,535,066.48 | 1,535,066.83 | 1,535,066.81 |
| 76,479 | 1,535,066.48 | 1,535,066.83 | 1,535,066.81 |
| 80,379 | 1,535,066.46 | 1,535,066.81 | 1,535,066.81 |
| 80,479 | 1,535,066.46 | 1,535,066.81 | 1,535,066.81 |
| 100,379 | 1,535,066.46 | 1,535,066.81 | 1,535,066.81 |
| 100,479 | 1,535,066.46 | 1,535,066.81 | 1,535,066.81 |
| 200,379 | 1,535,066.37 | 1,535,066.73 | 1,535,066.73 |
| 200,479 | 1,535,066.37 | 1,535,066.73 | 1,535,066.73 |
| 500,379 | 1,535,066.18 | 1,535,066.54 | 1,535,066.52 |
| 500,479 | 1,535,066.16 | 1,535,066.54 | 1,535,066.50 |
| 927,340 | 1,535,065.82 | 1,535,066.18 | 1,535,066.16 |
| 927,440 | 1,535,065.82 | 1,535,066.18 | 1,535,066.16 |
| | SEDRD1 | SEDRD2 | SEDRD3 |
| | (CU.YD./YR.) | (CU.YD./YR.) | (CU.YD./YR.) |
| 72,379 | 0.00 | 0.00 | 0.00 |
| 72,479 | 0.00 | 0.00 | 0.00 |
| 76,379 | 0.00 | 0.00 | 0.00 |
| 76,479 | 0.00 | 0.00 | 0.00 |
| 80,379 | 0.00 | 0.00 | 0.00 |
| 80,479 | 0.00 | 0.00 | 0.00 |
| 100,379 | 0.00 | 0.00 | 0.00 |
| 100,479 | 0.00 | 0.00 | 0.00 |
| 200,379 | 0.00 | 0.00 | 0.00 |
| 200,479 | 0.00 | 0.00 | 0.00 |
| 500,379 | 0.00 | 0.00 | 0.00 |
| 500,479 | 0.00 | 0.00 | 0.00 |
| 927,340 | 0.00 | 0.00 | 0.00 |
| 927,440 | 0.00 | 0.00 | 0.00 |

Table 25 (continued)

| Wilderness Total in Each Solution | SEDGE1 | SEDGE2 | SEDGE3 |
|---|---|---|---|
| (acres) | (CU.YD./YR.) | (CU.YD./YR.) | (CU.YD./YR.) |
| 72,379 | 174,463.89 | 179,130.57 | 181,634.30 |
| 72,479 | 174,463.89 | 179,130.57 | 181,634.30 |
| 76,379 | 174,463.89 | 179,130.57 | 181,634.30 |
| 76,479 | 174,463.89 | 179,130.57 | 181,634.30 |
| 80,379 | 174,463.89 | 179,130.57 | 181,634.30 |
| 80,479 | 174,463.89 | 179,130.57 | 181,634.30 |
| 100,379 | 174,463.89 | 179,130.57 | 181,634.30 |
| 100,479 | 174,463.89 | 179,130.57 | 181,634.30 |
| 200,379 | 174,417.88 | 178,918.55 | 181,333.20 |
| 200,479 | 174,417.88 | 178,918.55 | 181,333.20 |
| 500,379 | 174,062.42 | 177,280.17 | 179,006.52 |
| 500,479 | 174,062.42 | 177,280.17 | 179,006.52 |
| 927,340 | 174,011.07 | 177,043.58 | 178,670.56 |
| 927,440 | 174,011.07 | 177,043.58 | 178,670.56 |
| | BGF001 | BGF002 | BGF003 |
| | (AE/YR.) | (AE/YR.) | (AE/YR.) |
| 72,379 | 744,621.70 | 777,132.82 | 777,551.66 |
| 72,479 | 744,621.70 | 777,132.82 | 777,551.66 |
| 76,379 | 744,621.69 | 777,132.82 | 777,551.66 |
| 76,479 | 744,621.69 | 777,132.82 | 777,551.66 |
| 80,379 | 744,621.69 | 777,132.82 | 777,551.66 |
| 80,479 | 744,621.69 | 777,132.82 | 777,551.66 |
| 100,379 | 744,598.08 | 777,088.57 | 777,507.39 |
| 100,479 | 744,598.08 | 777,088.57 | 777,507.39 |
| 200,379 | 744,364.71 | 776,401.74 | 776,814.73 |
| 200,479 | 744,364.71 | 776,401.74 | 776,814.73 |
| 500,379 | 738,430.85 | 758,937.24 | 759,201.51 |
| 500,479 | 738,430.85 | 758,937.23 | 759,201.49 |
| 927,340 | 737,978.87 | 757,551.00 | 757,802.65 |
| 927,440 | 737,978.87 | 757,551.00 | 757,802.65 |

Table 25 (continued)

| Wilderness Total in Each Solution | BGCOV1 | BGCOV2 | BGCOV3 |
|---|---|---|---|
| (acres) | (AE/YR.) | (AE/YR.) | (AE/YR.) |
| 72,379 | 830,159.92 | 830,167.48 | 830,167.48 |
| 72,479 | 830,159.92 | 830,167.48 | 830,167.48 |
| 76,379 | 830,159.92 | 830,167.47 | 830,167.47 |
| 76,479 | 830,159.92 | 830,167.47 | 830,167.47 |
| 80,379 | 830,159.92 | 830,167.47 | 830,167.47 |
| 80,479 | 830,159.92 | 830,167.47 | 830,167.47 |
| 100,379 | 830,157.30 | 830,162.56 | 830,162.56 |
| 100,479 | 830,157.30 | 830,162.56 | 830,162.56 |
| 200,379 | 830,157.23 | 830,162.49 | 830,162.49 |
| 200,479 | 830,157.23 | 830,162.49 | 830,162.49 |
| 500,379 | 830,157.14 | 830,162.40 | 830,162.40 |
| 500,479 | 830,157.13 | 830,162.38 | 830,162.38 |
| 927,340 | 830,282.77 | 830,398.12 | 830,398.12 |
| 927,440 | 830,282.77 | 830,398.12 | 830,398.12 |
| | RDCOS1 | RDCOS2 | RDCOS3 |
| | (dollars/YR.) | (dollars/YR.) | (dollars/YR.) |
| 72,379 | 0.00 | 0.00 | 0.00 |
| 72,479 | 0.00 | 0.00 | 0.00 |
| 76,379 | 0.00 | 0.00 | 0.00 |
| 76,479 | 0.00 | 0.00 | 0.00 |
| 80,379 | 0.00 | 0.00 | 0.00 |
| 80,479 | 0.00 | 0.00 | 0.00 |
| 100,379 | 0.00 | 0.00 | 0.00 |
| 100,479 | 0.00 | 0.00 | 0.00 |
| 200,379 | 0.00 | 0.00 | 0.00 |
| 200,479 | 0.00 | 0.00 | 0.00 |
| 500,379 | 0.00 | 0.00 | 0.00 |
| 500,479 | 0.00 | 0.00 | 0.00 |
| 927,340 | 0.00 | 0.00 | 0.00 |
| 927,440 | 0.00 | 0.00 | 0.00 |

# APPENDIX C

Table 26. Example 1 and 2 acres added, percent of total increment percent of potential planning unit wilderness, and major RAU types for each increment by planning units

| Slide Identification | Increment Number | Acres Added | Percent of Total Increment | Percent of Potential Planning Unit Wilderness | Major RAU Types |
|---|---|---|---|---|---|
| Slide 16 (North Big Hole Planning Unit--Example 1) | 1 | 2,053 | 7 | 1 | O |
| | 2 | --[a] | -- | -- | -- |
| | 3 | 1,487 | **[b] | 1 | O |
| | 4 | 77,151 | 18 | 45 | L,M,T |
| Slide 17 (North Big Hole Planning Unit--Example 2) | 1 | -- | -- | -- | -- |
| | 2 | 3,095 | 3 | 2 | O,I |
| | 3 | 707 | ** | ** | I |
| | 4 | 41,561 | 10 | 24 | O,T |
| Slide 18 (South Big Hole Planning Unit--Example 1) | 1 | -- | -- | -- | -- |
| | 2 | -- | -- | -- | -- |
| | 3 | 47,281 | 16 | 37 | O |
| | 4 | 68,306 | 16 | 54 | O,L,T |
| Slide 19 (South Big Hole Planning Unit--Example 2) | 1 | -- | -- | -- | -- |
| | 2 | -- | -- | -- | -- |
| | 3 | 14,212 | 5 | 11 | O |
| | 4 | 103,050 | 24 | 81 | O,L,I |
| Slide 20 (Pioneer Mountains Planning Unit--Example 1) | 1 | 4,326 | 15 | 1 | O |
| | 2 | 48,669 | 49 | 16 | O |
| | 3 | 100,534 | 34 | 33 | O,I |
| | 4 | 121,641 | 28 | 40 | P,M |

[a]No areas added in this increment.
[b]Less than 0.6 percent.

Table 26 (continued)

| Slide Identification | Increment Number | Acres Added | Percent of Total Increment | Percent of Potential Planning Unit Wilderness | Major RAU Types |
|---|---|---|---|---|---|
| Slide 21 (Pioneer Mountains Planning Unit--Example 2) | 1 | 4,432 | 16 | 1 | O,I |
| | 2 | 16,662 | 17 | 5 | O |
| | 3 | 129,177 | 43 | 43 | O,P,I |
| | 4 | 119,363 | 28 | 39 | O,M,T |
| Slide 22 (Gravelly Range Planning Unit--Example 1) | 1 | 16,457 | 59 | 9 | O |
| | 2 | 24,323 | 24 | 14 | O |
| | 3 | 20,268 | 7 | 12 | I |
| | 4 | 98,718 | 23 | 56 | A,T,I,P |
| Slide 23 (Gravelly Range Planning Unit--Example 2) | 1 | 14,465 | 52 | 8 | O |
| | 2 | 38,822 | 39 | 22 | O,A,P |
| | 3 | 46,658 | 16 | 27 | A,I |
| | 4 | 55,682 | 13 | 32 | T,P,I |
| Slide 24 (Lima Peaks Planning Unit--Example 1) | 1 | 1,282 | 4 | 1 | A |
| | 2 | 19,897 | 20 | 19 | O |
| | 3 | 35,023 | 12 | 33 | O |
| | 4 | 18,917 | 4 | 18 | P |
| Slide 25 (Lima Peaks Planning Unit--Example 2) | 1 | --- | -- | -- | -- |
| | 2 | 21,286 | 21 | 20 | O |
| | 3 | 64,586 | 22 | 61 | P |
| | 4 | 17,423 | 4 | 16 | O,P,M,T |

Table 26 (continued)

| Slide Identification | Increment Number | Acres Added | Percent of Total Increment | Percent of Potential Planning Unit Wilderness | Major RAU Types |
|---|---|---|---|---|---|
| Slide 26 (Tobacco Root | 1 | -- | -- | -- | -- |
| Mountains Planning | 2 | -- | -- | -- | -- |
| Unit--Example 1) | 3 | 13,113 | 4 | 59 | O |
| | 4 | 9,120 | 2 | 41 | M |
| Slide 27 (Tobacco Root | 1 | -- | -- | -- | -- |
| Mountains Planning | 2 | -- | -- | -- | -- |
| Unit--Example 2) | 3 | 10,025 | 3 | 45 | O |
| | 4 | 8,265 | 2 | 37 | O,I |
| Slide 28 (Madison | 1 | 3,882 | 14 | 3 | T |
| Range Planning | 2 | 7,111 | 7 | 5 | I,T |
| Unit--Example 1) | 3 | 82,293 | 27 | 58 | O |
| | 4 | 33,106 | 8 | 23 | M,H |
| Slide 29 (Madison | 1 | 9,103 | 32 | 6 | I,P,T |
| Range Planning | 2 | 20,134 | 20 | 14 | I |
| Unit--Example 2) | 3 | 30,628 | 10 | 22 | O |
| | 4 | 81,708 | 19 | 58 | O,M,H |