VALUING WATERSHED RESTORATION PROJECTS

by

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EXECUTIVE SUMMARY

The goals of this report are to (1) develop, to the extent possible, a 'hydro-bio-economic' approach to the valuation of watershed restoration projects, and (2) to show how that approach might be used for three different kinds of valuation. In order to meet the first of these goals, a project flow chart was first developed (see Appendix A). That chart was initially based on a restoration demonstration project located on Red Clover Creek, near Quincy, California. It was subsequently expanded and generalized so that it would be could be use for a variety of similar projects. Because all physical and biological relationships likely to have an effect on the value of the final project must be clearly quantified, a flow chart or similar device is all but essential in the valuation process.

The three types of valuation that are covered in this report are benefit-cost analysis, regional analysis, and what we refer to as 'financial analysis.' Benefit-cost analysis considers all benefits and costs across the entire economy, regardless of the persons or groups who realize them. Regional analysis considers the benefits and costs that accrue to pre-defined region, such as a county. Input-output analysis, using regional multipliers, is recommended for this type of valuation. Financial analysis considers the costs and benefits realized by a specific economic entity—e.g., a landowner or corporation.

The main conclusion reached in this report is that, for many restoration projects (including the Red Clover Creek Demonstration Project), some of the necessary baseline data and impact modeling capability will not be available when the project begins. Without these data and models, economic predictions become either unreliable, or simply not possible. Among the crucial missing analytical tools in the case of the Red Clover Creek Demonstration Project, for example, was the lack of any method of reliably predicting the response of floodplain vegetation to rising water tables and periodic flooding. Also missing were methods for accurately predicting the response of fish populations.

Based on the finding that predictive methods are sometimes lacking, we conclude with a recommendation that the analysis of watershed restoration projects be conducted by an interdisciplinary team, such that, for every conceivable project outcome, a resident specialist will be able to either locate or generate the needed data and predictive methodology.
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CHAPTER I

Concepts of Social and Economic Value

Purpose and Objectives of This Report

The primary purpose of this report is to provide a conceptual framework for relating the physical and biological effects of small watershed projects to the economic benefits and costs associated with such projects. Within this framework, data requirements are described, some important data sources are identified, and the economic techniques needed to perform a comprehensive benefit cost analysis are presented. Although a multi-disciplinary approach is taken, the authors wish to emphasize that their area of expertise extends only to economic analysis. Technical information from fields other than economics appearing in this report was obtained from secondary sources, and may or may not reflect the 'state of the art' in those fields.

We have provided a framework that an interdisciplinary team could implement to assess benefits and costs; however, development of a detailed "cookbook" complete with data and equations is beyond the authors' capability and perhaps beyond the current technical capabilities of the disciplines of fisheries biology, hydrology, range science, etc.

The application of economic criteria presupposes that the project will achieve its intended physical and biological effects. The economic issue is whether the benefits induced by the project are greater than the costs of bringing those beneficial changes about. Economic methods cannot provide any
information about whether or not the physical effects actually occurred. Rather, economics can only value the physical and biological effects that are predicted by resource specialists in other fields.

Due to the nature of small watershed projects, the physical, biological, and economic techniques presented herein are generally somewhat simple. Because performing an exhaustive study of such projects could easily cost more than the project itself, elaborate, data intensive analyses are generally not justified. Hence the rigor of the analysis must be tailored to the magnitude of the project and its potential effects.

The methods provided are intended to be as general as possible—applicable to forest and agricultural lands as well as to rangeland settings. No effort was made to tailor this framework to projects in one specific region (e.g., the northern Sierra Nevada Mountains). Thus, not every section of this report will be pertinent to every individual project to which it is applied.

While we had originally hoped to apply our framework to the Red Clover demonstration project, it became clear early on that much of the physical and biological data necessary has not been collected. Nor are all of the requisite predictive mechanisms (quantitative models; methods relying on professional judgement) available. Although this is in part due to the fact that not all of the effects of the recently-installed Red Clover project have begun occurring, it is nonetheless clear that the a priori evaluation of such projects will require certain baseline data, as well as appropriate predictive capabilities. It is perhaps this report's main contribution that such prerequisites are clearly identified. As such, the framework presented can best serve as a foundation for future evaluations of small watershed projects.

**Accounting Stances and Benefit-Cost Analysis**

The value of a good can be determined from a variety of perspectives. A new manufacturing plant, for example, can be valued in terms of the net benefits (benefits minus costs) it will yield to (a) the
company that builds the plant, (b) the industry as a whole, (c) the county in which the plant is built, (d) the state in which the plant is built, and so on. Clearly, the net benefits to these parties can vary widely—so much so that some parties might experience a net benefit while others might bear a net cost. The company that built the plant, for example, might improve its financial position. The industry as a whole, however, might experience a net decline in profits due to higher quantities produced, and lower prices. On a national scale, a mere transfer of resources may occur: The benefits realized by the owners of the new plant might be offset by the losses sustained by owners of existing plants elsewhere.

The practice of evaluating the net benefits of a project on the broadest possible scale (national, or, in some cases, international) is known as benefit-cost analysis. The goal of such analysis is to foster 'economic efficiency'—optimal utilization of resources (whether marketed or non-marketed) across the whole economy. Economists recommend that all significant resource decisions be evaluated in this way. In fact, the term "economic analysis" is generally reserved for benefit-cost studies in which all benefits and costs—even those that do not happen to result in actual cash gains or losses—are evaluated. Studies which consider only the cash costs and cash revenues accruing to entities within the larger economy are often referred to as "financial analyses."

In any resource management action there will be many affected parties. Each economic entity will calculate its own individual benefits and costs. However, since some of the benefits to one group may be offset by losses to others, it is important to provide a holistic accounting that focuses on the net gains to society as whole. This necessarily aggregates gains and losses to specific individuals and companies. These individual gains and losses can, however, be identified in the analysis. Thus, a holistic accounting will include all the information that might be needed for smaller-scale, individual accounting efforts. The political and financial acceptability of a particular action may hinge on not only the net benefits to society but also how those benefits are distributed.

Economists recognize, therefore, that economic studies often need to be supplemented with evaluations of more localized impacts to individual landowners and companies. These 'regional studies'
attempt to identify exactly which groups (e.g., industries, counties, etc.) within a region of interest are expected to gain and which to lose if a given resource decision is implemented. Economic activity multipliers presenting changes in local income and employment (see p. 12, below) are used to estimate the expected magnitudes of these gains and losses. Regional studies, it should be remembered, are to be done in addition to—not in place of—economic studies.

It may also be important to perform financial feasibility analyses to determine the likelihood of private landowners and companies participating in the proposed resource management action. Often, each individual entity—whether private or public—participating in a watershed project will only need to know if the benefits it receives outweigh its share of the costs.

This report will cover economic efficiency analysis, regional analysis, and financial analysis. As shown in Figure 1, Federal agencies such as the U.S. Soil Conservation Service and the U. S. Forest Service will probably be most interested in an economy-wide, national-level analysis. Pacific Gas and Electric Company (PG&E) will be most interested in the financial impacts on its operations in California. County governments and local development corporations (e.g. the Plumas Corporation) will be most concerned with regional effects. Private landowners and similar entities can, like PG&E, calculate the financial impacts they will realize via a financial analysis. The data needed for such an analysis will be available in the economy-wide benefit-cost study, if one has been completed.

Before describing the methods used to perform these types of analyses, we will first summarize the principles which underlie economic efficiency and regional analysis.
FIGURE 1:

BENEFIT COST ANALYSIS, REGIONAL ANALYSIS AND FINANCIAL ANALYSIS

National level

State level  County level
Definition of Economic Benefits: The economic value of any good or service, whether marketed or supplied by the environment, is defined as the user's willingness to pay (WTP) to have that good or service. The price a person pays for a particular product in a market is a measure of that person's WTP at the margin for another unit of the good. For goods traded in national or international markets, the individual buyer's or seller's decision as to whether or not to buy or sell one more unit has no effect on price. The price, therefore, measures the marginal WTP: traders will continue to buy and sell at the going price until their net WTP (WTP minus price) is exhausted.

The price a consumer must pay to obtain an additional unit of a good may often be lower than the maximum amount he or she is actually willing to pay for that unit. If this is the case, it will be in the consumer's self interest to purchase another unit. The bleary-eyed consumer, for example, may be willing to pay $2.00 for her first cup of coffee in the morning. If coffee sells for $.50 a cup, then a personal profit, or 'consumer surplus' of $1.50 is realized on this purchase. Rather than go without, in other words, the consumer would have been willing to pay an additional $1.50 for her first cup of coffee. This additional $1.50 constitutes the consumer's net WTP. Net WTP is a measure of the economic value received, over and above the cost of purchasing the good. This decision process—comparing price to WTP—is repeated until the benefits of consuming one more cup of coffee (WTP) just equal the price. At that point, no more coffee is purchased. Thus, for the last cup of coffee, price equals WTP. More specifically, the net WTP for the last unit consumed is zero.

In the case of goods supplied by the environment, e.g. wilderness, water quality, or fishing, the benefits are still measured by the user's WTP. Unlike the case of a marketed good such as coffee, where all consumers face the same price per cup, recreation has no readily observable market price. This lack of a market price does not, of course, imply that recreation is free. The "price paid" takes the form of transportation and time costs incurred en route to and from the recreation site. Depending on
where one lives relative to a particular site, different people face different "prices" for recreation. Nonetheless, the same concept of net WTP, or consumer surplus, holds for valuing recreation. The first fishing trip of the season is often valued in excess of the price paid in terms of travel costs. Therefore, a personal profit, or consumer surplus, is realized. If the first trip was valued at $25 and the travel cost was $10, the consumer would have been willing to pay $15 more than he actually paid, rather than go without a fishing trip. His net WTP, therefore, was $15. Exactly like the consumer of coffee, the angler will continue to take fishing trips until the expected benefits, i.e., WTP, from one more trip equal the travel cost of making that additional trip.

The use of WTP as a standard of economic value is recommended by an interagency committee of the Federal Government (U.S. Water Resources Council, 1979; 1983). Net WTP is the measure of value used by the U.S. Department of Interior for valuing natural resource damages (U.S. Department of Interior, 1986). Net WTP is also recommended as the measure of economic benefits in textbooks on benefit-cost analysis (Sassone and Schaffer 1978; Mishan 1976).

Discounting: Once the benefits and costs that a proposed project will create are expressed in dollar terms, the effect of time on those values must be accounted for. Time has a straightforward influence on the valuation process: a benefit received or a cost incurred in the present is worth more than the same benefit or cost in the future. Given the choice, we would rather receive $100.00 now than a year from now. This, of course, is the rationale behind the practice of charging interest. A person who lends $100.00 with the expectation of being paid back in one year would not feel justly compensated for postponing consumption or investment if he were to be given a check for only $100.00 at the end of the year. He might have to charge an interest rate of, say, 10% in order to be as well off as he would have been had he not made the loan in the first place. That would mean receiving $110.00 rather than only $100.00 at the end of the year.

The effects of time on the benefits and costs associated with a proposed resource decision are calculated by applying an appropriate interest--or 'discount'--rate to them in order to express their value
as if they were to be realized in the present. This process is referred to as calculating a project’s 'present value.' The discounting process begins when all identified benefits and costs are assigned to the periods (year, fiscal year, etc.) in which they are expected to accrue. For each period, then, costs are subtracted from benefits, in order to arrive at a net benefits value. An appropriate annual discount rate is then used to bring the net benefit figure from each period into the present (the net benefit figure is discounted once for each period that will elapse between the present, and the period in which that benefit will accrue). When all net benefit values have been expressed in present value terms, they are simply added. The result is a single net present value (NPV) figure which can be compared with NPV values from other project alternatives, or with other project proposals competing for the same pool of funds.

**Types of Goods to be Valued:** It is extremely important in performing an economic analysis that values be estimated for *all* benefits and *all* costs. That means that market as well as non-market goods must be accounted for, and that all groups who gain or lose by the project must be identified, no matter how far those groups might reside from the actual project site. One method of insuring that all necessary benefit-cost data is gathered when a watershed restoration project is to be evaluated is depicted in Figure 2. This method requires the investigator to collect 4 categories of data: (1) market goods accruing to residents of the upland watershed, (2) market goods accruing to residents of downstream areas, (3) non-market goods accruing to residents of upland watersheds, and (4) non-market goods accruing to residents of downstream areas.

Historically, financial analyses (including those that masquerade as economic efficiency analyses) have focused on the first category of outputs. The majority of these have been studies of the on-farm financial impacts of erosion control programs (see, e.g., Berglund and Michelson, 1981; Dickason and Piper, 1983; Pope, et al., 1983, and Walker, 1982). PG&E will, of course, be particularly interested in category 2, which includes hydroelectric power generation. Categories 3 and 4 contain the goods and services which are most-often overlooked in economic analyses of watershed projects: non-market goods. Although the lack of a market price renders these particular goods difficult to value, it is unwise
Figure 2: Relationship Between (a) the Benefits and Costs Associated with Watershed Management Projects and (b) the Location of Groups Experiencing Those Costs and Benefits

<table>
<thead>
<tr>
<th>Types of Costs and Benefits</th>
<th>Market</th>
<th>Quadrant I</th>
<th>Quadrant II</th>
</tr>
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<tbody>
<tr>
<td>Non-Market</td>
<td>Quadrant III</td>
<td>Quadrant IV</td>
<td></td>
</tr>
</tbody>
</table>

Quadrant I: Food crops, forage for livestock, animal products, fuelwood, pulpwood, lumber, other wood products, minerals, water, fisheries.

Quadrant II: Water for drinking, fisheries, irrigation, hydroelectric power generation, navigation, municipal and industrial supplies; flood control benefits; sediment control for avoiding losses of reservoir benefits, etc.

Quadrant III: Aesthetic values; wildlife habitat protection; recreation; health benefits of high quality water supplies; protection of aquatic ecosystems; landslide/mudslide control (minimization); preservation of gene pools (natural vegetation).

Quadrant IV: Protection of downstream riparian and aquatic ecosystems; high quality water for recreation-aesthetic values; aesthetic/recreational values; protection of migratory bird populations (for birds that stopover at project site, but then move on other sites);

SOURCE: Adapted from Brooks and Gregersen, 1986.
to simply neglect them. Despite the absence of observable markets for such goods, many studies have shown that the WTP for some of them can be quite high—often high enough to make them primary determinants of the final net benefits value. For example, fisheries, wilderness and elk hunting dominate timber in portions of the Gallatin National Forest (Loomis, 1989). Habitat preservation and nonconsumptive wildlife recreation at Mono Lake dominates the replacement cost of water and power to Los Angeles (Loomis, 1987). Recreation values of fishing outweigh soil erosion control costs in Lake Chicot in Arkansas (Osborn et al. 1981). Similarly, the benefits of wilderness preservation outweigh timber harvesting on 9 million out of 10 million acres of roadless public land in Colorado (Walsh, et al., 1984).

In general, a project benefit is defined as either a reduced cost that will occur as a result of a project, or a net WTP value for a project-induced change in the output of some good. The Water Resources Council specifies four categories of benefits (U.S. Water Resources Council, 1979; 1983):

1. **Cost avoided:** If a project will supply enough additional water to a reservoir to significantly decrease (or to remove entirely) the need to generate more expensive supplemental power, then the supplemental power that no longer needs to be generated is a 'cost avoided,' and constitutes a project benefit.

2. **Change in net income:** If a project will, say, increase livestock forage enough to significantly increase livestock production, the increase in ranching income constitutes a project benefit.

3. **Actual or simulated market values:** If a non-market good such as recreation will be supplied by a project, values for those goods can be estimated using simulated markets. Two procedures which make use of simulated markets are now in use. The travel cost method (TCM) makes use of the cost of travel to and from recreation sites as a proxy for a market price. A TCM analysis uses data on distance traveled and number of trips per year to derive a demand curve for recreation. The net WTP for a given recreation opportunity, then, can be determined from the area under that demand curve. In a contingent value method (CVM) analysis, a survey consisting of a 'simulated market' for the good of interest is conducted. A realistic 'payment vehicle' (tax, trust fund, etc.) is created, and a sample of people who are in a position to benefit from the good are surveyed to determine how much they would be willing to pay (via the specified payment vehicle) for the provision of that good.

4. **Administrative values:** In some cases, government agencies have established values that are to be used in all in-house economic analyses. The Soil Conservation Service, for example, provides a single dollar-per-animal-unit-month value that can be used in its analyses. Actual or simulated market values, however, can be used in place of these administrative values when they are available. In practice, the values established by agencies are also widely used outside of the agencies that establish them.
Sources for these types of values, or models for deriving them, will be the subject of Chapter IV, below.

Regional Analysis: Methods and Rationale

When performing a regional analysis, the economist attempts to determine the effects of a resource decision on income and employment levels within a region of interest. The regional perspective involves some significant departures from the economy-wide perspective. One of the more important of these is the manner in which labor is treated. When a project requires extensive local labor, that requirement will be counted as a project cost in an efficiency analysis, but as a generator of positive local employment benefits in a regional analysis. Another important difference is that many project outcomes that are counted as benefits in a regional context would constitute only transfers in the larger economy. If a reservoir were constructed, for example, business would increase at local restaurants, motels, sporting goods stores, and so on. This increase is clearly a benefit from the local perspective. In terms of the larger economy, however, it is probably only a transfer: The increased revenues locally would probably be offset by comparable decreases where the users of the new reservoir previously spent their disposable income. It is important to note that no new income is generated even if the reservoir user had not previously been recreating. Existing income is just redistributed from previous home-based consumption (e.g., renting video movies) to meeting expenses at the new reservoir.

In analyzing the impacts of a project proposal on a region, the analyst seeks to account for the fact that the increase (or, perhaps, the decrease) in economic activity the project will bring about will have a sort of ripple, or 'multiplier,' effect as it passes through the economy. The construction worker hired to work at the project site, for example, might use part of his paycheck to buy aluminum siding for his home. This purchase will stimulate production at the nearby aluminum siding plant, which, in order to keep up with the increased demand, will install more locally-produced machinery for handling sheets of aluminum. Thus, revenues increase at both the aluminum siding plant and at the firm which
manufactures the equipment used at the siding plant. This process will continue until the new money in the area works its way through the whole regional economy and a new equilibrium is reached. Often, the final change in income will be two or three times larger than the first-round income change.

Input-Output Models and Multipliers

In order to fully assess the regional economic impacts of a proposed project, the analyst must use what is known as a "input-output" model (Mieynk 1965, Richardson 1972, Yan 1969). An input-output model is based on a "transactions table," which is a matrix of the inputs to and outputs from all regional industries and sectors. It is arranged so that, when read along a row, the outputs of a single industry are distributed among all buyers of those outputs. Those buyers will usually be other producers who use those outputs in their own production processes, as well as final consumers. When read down a column, the transactions table shows where a single industry purchased each of the inputs it uses in its production processes.

From the transactions table, the model computes a table of input, or "technical," coefficients. These coefficients tell us how much of each input it takes to produce a dollar's worth of output. This table is then converted into a matrix of "industry multipliers" which describe how much of each input is required per dollar of final demand for goods and services in the region. The analyst's job, at this point, is to determine the degree to which a proposed project will change final demand. If the project is a major new manufacturing plant or recreational facility, final demand will probably increase by a significant amount during both the construction and operation phases. If the project happens to be the re-routing of a major interstate freeway so that it no longer passes through the region, final demand is likely to fall.

When the expected change in final demand is known, the analyst can, using the matrix of industry multipliers computed earlier, determine the effects of that change on personal income and employment over the entire region. The analyst is able to see not only how much of a change will take place as a
result of the project, but also how these changes will be distributed through different industries within the regional economy—e.g., hotels, manufacturing, agriculture, etc.

It is important to note that not all of the change in final demand acts to stimulate the local economy. Only that portion of final demand known as 'value added' actually serves to expand the region's economy. In a given sales transaction, value added is that portion of the sale price that does not simply cover costs paid to out-of-region producers, wholesalers, truckers, etc. If recreation-seekers spend $10.00 on gasoline, for example, the net gain to the local economy may be only $1.00. The other $9.00 is paid to wholesalers and truckers from outside of the region.

Input-output models and multipliers have been constructed for many regions in the United States. Two such models are referenced in this report. One is the U.S. Department of Commerce's (1986) RIM's multipliers and the other is the U.S. Forest Service's (n.d.) IMPLAN system. RIMS is nothing more than a table of income and employment multipliers for each state in the U.S. There is no breakdown available beyond the state level. The IMPLAN system does allow the user to develop multipliers for any county or group of counties in the U.S. This advantage does not come without costs, however. The user must run the entire IMPLAN program to specify counties, industries, etc. desired in the analysis. Access to this software, as well as technical assistance, may obtained from the U.S. Forest Service's Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Financial Analysis

A third perspective that can be taken when evaluating the impacts of a resource decision is the financial perspective. As pointed in the Introduction, above, a financial analysis evaluates a project proposal in terms of the anticipated cash benefits and cash costs accruing to an entity existing within the larger economy. Because financial analysis is the most commonly used (and, therefore, the most
commonly understood) method of evaluating project impacts, it will not be discussed in as much detail as the economic analysis.

Financial analysis, like economic efficiency and regional analysis, is appropriate in some situations and not in others. Its purpose is to enable an individual economic entity—whether an individual, a corporation, or a government agency—to determine how a particular project proposal is likely to affect its own financial standing. An obvious danger arises if the results of a financial analysis are substituted for an economic or regional analysis as a primary decision criterion for project proposal. This could have the effect of allowing the impacts felt by a single economic entity to have an undue influence over a decision that will affect a much wider segment of the public. A watershed restoration project proposal, for example, should not be evaluated only (or even predominantly) in terms of the effects it is likely to have on the farmers and ranchers in the project area (Veloz, et al, 1985). Even if those farmers and ranchers will bear a net cost as a result of the project, that cost might be more than offset by the net benefits realized by downstream communities (in the form of, e.g., decreased costs of power generation and water treatment).

Which type (or types) of analysis is done on a project proposal depends on exactly what one wishes to know about that project's impacts. One fairly universal guideline is that a full benefit-cost analysis should be performed on all significant resource decisions involving public funds or resources. Another is that one type of analysis should not be done in lieu of or in place of another. And, finally, performing all three types (if applicable) will provide the most complete picture of a project's expected net benefits, as well as the distribution of costs and benefits among those affected by the project.

In that most watershed restoration projects involve public funds as well as off-site impacts, a full benefit-cost analysis is strongly recommended. Having a completed benefit-cost study on hand, however, makes the job of performing a financial analysis relatively simple. Since all benefits and costs are included in full benefit-cost analysis, the values one needs to perform a financial analysis can be taken directly from the benefit-cost ledger sheet. Some of those values may have to be adjusted
somewhat, since market distortions (usually the result of government intervention in private markets) are corrected for in a benefit-cost analysis, but such corrections are usually simple to make: one need only reverse the calculation that was done to remove the effect of the distortion. In sum, a comprehensive benefit-cost analysis will embody any type of financial analysis that should ever be necessary.

CHAPTER II

Literature Review

A computerized literature search was conducted using the facilities at the University of California, Davis library. Using the Dialog retrieval system, several different data bases (water, agriculture, etc.) were searched, using key words such as 'erosion,' 'water quality,' 'fisheries,' 'livestock,' and 'hydropower.' We also searched the Dissertation Abstracts database. A great deal of unpublished research was obtained through personal contact from faculty at University of California and other western land grant universities. Unfortunately, most of the current research on soil erosion and water quality/quantity is focused on agriculture or timber harvesting. Relatively little literature was found regarding the economic effects of livestock grazing on erosion. There is almost no literature presenting a comprehensive framework for evaluating small watershed projects on rangelands. Therefore we have selectively discussed papers whose methods have at least some applicability to small watershed restoration projects.

Our contention that a watershed restoration proposal is a major resource decision that must be analyzed on at least the economic efficiency level is echoed in several published studies and methodological papers (Brooks and Gregersen, 1986; Brooks et al., 1982; Strohbehn, 1986; Veloz et al., 1985; Hitzhusen et al., 1984; Gunterman, 1974; Hufschmidt, 1986; Osborn et al., 1981). Unfortunately, many of the erosion control project evaluations that we encountered did not include economic efficiency analyses, did not mention the need for such analyses, and, in some cases, actually confused financial or
regional evaluation with economic analysis (Berglund and Michelson, 1981; Pope et al., 1983; Seitz et al., 1979; Walker, 1982; White and Partenheimer, 1980).

One explanation for this apparent inability of the economics profession to follow its own methodological and theoretical dictates is offered by Dickason and Piper (1983). They reviewed 54 economic studies of erosion control projects completed between 1972 and 1981. These authors point out that constraints on the availability of government funding for actual erosion control projects strongly influenced research design for many years. Government funding for technical assistance and cost sharing was only available for projects covering small areas. Thus, most of the studies done on these projects examined only the localized economic and financial impacts.

While recognizing the need for such small-scale studies (farmers are not likely to acquiesce to erosion control programs that will entail significant costs to them), Dickason and Piper (1983) are quick to point out the problems that can arise when localized analyses that do not discuss their own inherent limitations are used as decision criteria. Readers of such studies (some of whom are presumably decision-makers) are often not alerted to (a) the existence of significant regional and national benefits and costs, (b) the possibility that the project under study might benefit one region at another region's expense, or (c) the limited generalizeability of the findings reached.

Strohbehn (1986) points out that, prior to about 1983, analysts attempting to evaluate the effectiveness of federal erosion control programs lacked the necessary data and procedures to perform full economic analyses. As a result, purely physical measures or cost-effectiveness analyses were used in program planning and evaluation. These methods were subsequently criticized in a series of program evaluations, two of which were performed by the General Accounting Office (GAO). A GAO evaluation which came out in 1983 triggered a major effort on the part of federal agencies engaged in erosion control projects to plan and evaluate their programs based on complete economic analyses. The Strohbehn study was itself a major effort to compile a full economic analysis in keeping with the 1983 GAO recommendations.
Another explanation for the existence of such a large number of localized (on-farm) studies is that, for many years, it was assumed that one of the primary impacts of erosion was loss of productivity on the farmland undergoing the erosion. Subsequent studies have shown, however, that declines in productivity due to soil loss have been obscured by the yield increases associated with technological advances (fertilizers, pesticides, and improved crop strains). From the farmer's point of view, there has been a net increase in productivity, despite high rates of topsoil loss (Walker 1986; Gunterman, 1974). This perception has acted as a disincentive to farmers considering the adoption of conservation measures, and has resulted in a backing away from the productivity loss argument on the parts of conservation proponents.

Due in part, perhaps, to the perception that erosion doesn't substantially threaten productivity on most farms, the focus in many recent studies has tended to shift toward off-farm, regional, and national impact analysis (Clark, et al., 1985; Dixon, 1987; Crowder, 1987; Brooks and Gregersen, 1986; Ribaudo, 1986; Moore and McCarl, 1987). Most such studies arrive at the conclusion that watershed restoration is a very good social investment. Among the exceptions to this rule is a study of the ability of "surface treatments" (contour plowing) and gully control to decrease the rate of sedimentation behind the Glen Canyon Dam (Workman and Keith, 1975). The benefit-cost ratio arrived at (assuming that the entire sediment inflow behind the dam originated on the treated lands) was only 0.12. This study is unusual in two respects, however: it made no apparent attempt account for all project benefits (recreation was not even mentioned), and the surface treatments used were extremely intensive, involving contour plowing and gully control on 1,280,000 acres of watershed.

Several of the on-farm studies already mentioned found that erosion control programs seldom result in net gains to farmers (Gunterman 1974; Walker 1986 and 1982; Berglund and Michelson 1981; Pope et al., 1983; Seltz et al., 1979; White and Partenheimer, 1980). Erosion control measures on farmland often called for changes in cropping and rotation regimes that decreased short-term yields. Even if the
government pays for a large part of the structural on-farm measures, the costs to the farmers often outweigh the long term discounted benefits from soil conservation.

A notable exception to the general finding that erosion control programs do not benefit farmers is found in Osborn, et al., (1981). These authors discovered a tillage regime that would actually enable the farmers in the Lake Chicot, Arkansas drainage basin to significantly decrease the sedimentation levels from their lands, while at the same time increasing their net returns per acre. The benefit-cost ratios calculated by these authors ranged from 33 to 112, depending on the type of calculation used. Not all possible project benefits were considered.

Another study describing a watershed restoration project that yielded net social benefits is Brooks, et al. (1982). These authors found, using a simplified but quite comprehensive analytical approach, that a watershed restoration project under consideration in Morocco would yield net benefits in the neighborhood of $18.8 million. The inputs to this project were more typical than the large-scale inputs to the project evaluated by Workman and Keith (1975): they included channel stabilization, reforestation, pastureland management, and the establishment of an olive orchard. The total land area affected was a relatively modest 40,000 acres. Although the project evaluated in this study was located in North Africa, the watershed restoration practices employed were probably more typical of the practices that might be implemented in California than were the practices discussed by Workman and Keith (1975).

In a similar study, Veloz et al. (1985) found that substantial net benefits could be realized from a watershed restoration project in the Dominican Republic. This study was later criticized, however, because the authors did not devote enough attention to the process of defining the physical relationships responsible for the erosion/sedimentation problem. The Veloz article describes a plan designed to extend the useful life of the Valdesia Dam in the Dominican Republic (also described in Hitzhusen et al., 1984). That plan would, reported the authors, call for erosion-control treatments on only 43% of the watershed. Only the steepest 11% of the watershed would be subject to actual changes in land use (from, say, cropland to protected rangeland). According to the authors, these relatively modest
changes would result in a whopping 86% decrease in the sedimentation rate. This translates into a NPV of $9.5 million and a benefit-cost ratio of 1.23.

Andrus (1986) took issue with these findings. He argued that the Veloz et al. study was flawed because it made uncritical use of the universal soil loss equation (Wischmeir and Smith, 1978; Wischmeir, 1976), which accounts only for sheet and rill erosion. The mountainous watershed studied by Veloz, et al. almost certainly experiences high levels of mass soil movements on steeper slopes. This is an unstable condition that will continue to contribute large amounts of sediment to the Valdesia reservoir long after the Veloz et al. plan is implemented. This and other shortcomings in the original study's definitions of the physical relationships at work render the NPV and Benefit-cost figures arrived at overly-optimistic (i.e., the benefits are probably substantially lower than the authors claim they will be).

In his response to Andrus's critique, one of the authors of the original study (Southgate 1986) agrees that the universal soil loss equation probably underestimates the actual sedimentation rate in the Valdesia watershed, but cites other sources to the effect that the resulting discrepancy is smaller than Andrus claims it is. One of Southgate's main points is that accurately defining the physical relationships involved is extremely difficult, given the complexity of the systems involved.

The debate over the projected net benefits from the Valdesia erosion control project is one illustration of the importance of attempting to accurately define the physical relationships at work in the watershed of interest. This is a point we make below ("Valuing Watershed Restoration Projects: A Hydro-Bio-Economic Approach"). Among the many other authors who echo this methodological proviso are Nelson (1984), Brooks and Gregersen (1986), Brooks et al. (1982), Fowler (1979), and Ribaudo (1986).

Recent On-farm Studies: In recent years, interest has revived somewhat in the on-farm impacts of erosion. Walker (1986) analyzed the extent to which technological progress has increased productivity in the highly-erosive eastern Washington region. He concluded that these increases would have been
significantly greater had they occurred in conjunction with deeper topsoils. In many cases, long-term yield increases due to the combined effects of soil conservation and technical progress would have more than offset any short-term costs incurred as a result of the changeover to soil conserving tillage and planting practices. Unfortunately, the discount rates employed by many farmers (as determined by a survey) are such that short-term losses are often more important than long-term gains. Thus, in cases where the off-site costs associated with farmland erosion render on-site conservation practices socially beneficial, farmers may have to be compensated to the point where they sustain no net private costs (given their private discount rates) as a result of the changeover to a conservation regime.

In a study of the costs of erosion-induced productivity losses on the prairie farmlands of Saskatchewan, Van Kooten et al. (1988) developed a non-linear stochastic dynamic programming model to estimate the marginal productivity losses that accompany decreases in soil depth. The NPV of the lost productivity in the region (assuming unabated erosion rates) ranged from a low of $24.33 million (15% discount rate) to a high of over $20 billion (3.5% discount rate). The corresponding average annualized per-hectare costs ranged from $0.87 to $168.83. The authors conclude, as does Walker (1986), that these costs provide farmers with little incentive to adopt conservation practices that are likely to reduce profits in the short run. Although their results are sufficient to substantiate this conclusion, say the authors, the cost estimates arrived at are far too uncertain (given their enormous variance) to be of use in regional cost calculations.

Stults et al. (1987) also re-examined the on-site impacts of farmland erosion. Their study focused on the on-site benefits of erosion control efforts targeted on major erosion areas located in eight counties covering four states. Although these authors did not consider off-site benefits (unlike many investigators, Stults et al. explicitly discuss the limited scope of their analysis), they discovered practices at each study site that would yield benefits in excess of costs. Accounting for off-site benefits would, say the authors, widen the gap even further.
The Strohbehn (1986) study discussed above also dealt with the on-site benefits associated with the conservation of farmland topsoils. The NPV of productivity benefits were found to range from about $1.25 to about $0.07 per ton of soil conserved. Benefits were generally greater on better soils. The Strohbehn study found that when these on-site benefits are combined with the off-site benefits associated with soil conservation, government erosion-control programs are not economically efficient (i.e., they do not begin to show a benefit-cost ratio of one or more) unless they are confined to farmland that is eroding at a rate of at least 14 tons per acre per year. Unfortunately, most of the federal money spent on erosion control is used on land eroding at rates of less than 5 tons per acre per year.

**Off-site Farm and Ranch Impact Studies:** The costs and benefits associated with livestock grazing are discussed by Kim (1984), and by Platts and Wagstaff (1984). Kim assembled a dynamic optimization model which is capable of deriving an optimal livestock forage utilization rate, given the impacts of grazing on water yield and sediment production. Although Kim does not perform a benefit-cost or input-output analysis, many of the physical parameters, prices and models he uses could be used in either type of analysis.

Platts and Wagstaff (1984) examine the relative benefits of two competing uses of a stream system--as a producer of (1) recreational fishing and (2) riparian livestock forage. Their method was to perform a limited benefit-cost analysis on a project that would improve fish production by fencing the riparian zone to exclude grazing livestock. Their conclusion was that the increase in angler-days the project would produce would not offset the costs of fencing and of foregone livestock production. The authors readily admit that a major shortcoming of their study is that it considers the increase in angler-days as the only project benefit. In general, say the authors, a fuller benefit-cost analysis could show that fencing is an efficient method of improving non-livestock-related watershed values.

**Reservoir Construction:** The benefits and costs associated with reservoir construction are discussed in the following three studies. In the first, Miltz and White (1987) develop a methodology for selecting a least cost reservoir size, taking into consideration sedimentation rates. This methodology
can produce reliable results in a cost-effectiveness study. Reservoir size (including the sediment storage basin) are taken as functions of sedimentation rates, dredging costs, construction costs, and the interest rate.

In the second reservoir study, Hanson and Millham (1976) develop a computer simulation model to predict the economic consequences of changes in the storage and release regimes for hydroelectric dams and storage reservoirs along the Snake and Columbia Rivers. Their model was constructed to provide answers to questions concerning the changes that would have to be made if existing generation and drawdown schedules were altered to accommodate minimum instream flow requirements, interregional water transfers, or the like. A primary factor in their analysis is the cost of alternatives to hydropower, should reservoir storage become too low to sustain peak power demand.

Finally, Crowder (1987) calculates the estimated costs of cropland-induced reservoir sedimentation. His estimates are regional in scope. When all regions are considered, 0.22% of the nation's storage capacity is lost annually. Of this loss, 24% can be attributed to erosion from cropland. The overall dollar value of this damage is between $144 and $197 million. When all sources of sedimentation are considered, the damage figure is between $597 and $819 million.

**Water Yield:** Because one of the final outputs associated with many erosion control projects is increased water yield, an important part of analyzing the economics of such a project is determining the value of any increments in water yield realized. Romm, et al. (1986) estimated the value to agriculture and to hydroelectricity generation of water from California watersheds. Hydroelectric values are estimated for a given stream system using an ordinary least squares regression model which predicts on the basis of the elevation of the highest hydroelectric generator through which the water in the system passes. This independent variable is a proxy for the total number of generators through which the water runs: on average, the higher the first generator is, the greater the number of downstream generators that will be present. The value of water to agriculture is determined using a cost-avoided method: the costs that are avoided when surface water is available are the costs of the next cheapest water source.
(groundwater pumping is often the next cheapest source). The findings of this study are discussed at greater length in Chapter IV, below.

A method for valuing water yield which may be less fruitful is the use of prices from existing water markets. Saliba, et al. (1987) found that none of the markets that currently exist are free from significant distortions (subsidization of water prices and use of historic accounting costs rather than marginal costs to set prices). Thus, if prices from such markets are to be used, great care must be taken to adjust them to correct for the distortions present.

**General:** The Forest Service recently published a compendium of economic analyses of watershed maintenance projects (USDA Forest Service, December 1987). A great many examples are outlined, but few details are provided, and the level of sophistication is generally modest. An lengthy bibliography is provided, however. Of particular interest is the example of a restoration project on Poco Creek in the Beckwourth Ranger District of the Plumas National Forest. A main component of one of the alternatives considered for this project was the construction of a series of rock check dams in the stream bed. This alternative also included livestock exclusion fencing.

**SUMMARY:** The most important themes gleaned from the literature reviewed in this section are as follows:

1. Although there is not a large body of literature on the economic evaluation of watershed restoration projects, the literature that is available includes some excellent studies. The best of these stress the need for comprehensive economic efficiency analyses that consider on- as well as off-site impacts, and describe methods that can be employed to meet this need. Very illuminating applications of these methods are often included. Some of these studies have shown that off-site impacts—fisheries, hydropower, water treatment costs, etc.—often have a substantial effect on the outcome of the analysis. The overall message of these studies is that projects can be justified on economic efficiency grounds only when all the benefits of reduced erosion are considered.

2. The 'second tier' of watershed restoration studies include analyses that either do not attempt to consider all conceivable impacts, or that analyzed costly (and environmentally questionable) restoration projects (e.g., contour plowing large amounts of the watershed).

3. By far the largest body of literature on erosion control is concerned with agricultural lands. These studies are interesting in that an evolution of sorts is evident in them. Erosion control on agricultural lands was originally undertaken out of a desire to protect the productivity of the land. Subsequent productivity studies revealed, however, that, due to increased use of
fertilizers and other inputs, yields rose even as erosion continued or increased. Because this finding seemed to indicate that the on-site value of erosion control projects was negligible, the focus shifted to assessing the value of off-site erosion impacts. Subsequently, it was shown that substantial on-site impacts have been masked by the use of fertilizers, pesticides, and improved crop strains. The result has been a renewed interest in on-site impacts. The overall trend has been toward a comprehensive approach which considers all significant impacts. The necessity for such an approach has been underscored by federal studies evaluating the performance of federal erosion control programs.

(4) Most studies dealing with on-site impacts tend to employ some form of farm or ranch budget method to evaluate erosion control projects. The methods used ranged from straightforward ledger sheet analyses to sophisticated optimization modeling. More comprehensive studies tended to use the methods of benefit-cost analysis.

CHAPTER III
Valuing Watershed Restoration Projects:
A Hydro-Bio-Economic Approach

A necessary preliminary step in preparing an economic analysis of a watershed restoration project is to define as accurately as possible the physical relationships the project will affect (Brooks and Gregersen, 1986; Gregersen and Brooks, 1980; Hufschmidt, 1986; Moore and McCarl, 1987; this fact is also acknowledged—albeit implicitly—in numerous studies based on the universal soil loss equation, e.g., Osborn, et al., 1981). Although these relationships can sometimes be straightforward and rather easily defined, they are often complex and far-reaching, requiring that the project planner work closely with soil scientists, hydrologists, range scientists, foresters, hydroelectric power producers, and other experts.

One extremely effective method for recording and summarizing the results of these consultations is to draw up a preliminary working model of the project’s effects. Probably the best format for such a model is the flow chart. A preliminary flow chart can be circulated, revised, and recirculated among the various experts involved until a consensus is reached that the physical relationships depicted are reasonably accurate. A useful flow chart should have the following characteristics:
(1) It should clearly define the distinction between inputs, intermediate outputs, and final outputs. This will ensure that the common and troublesome confusion of intermediate outputs with final outputs can be avoided early on. A final output is a good that somehow increases the 'utility' (well-being) of one or more human beings (and, thereby, has economic value). Utility is increased if new goods (broadly-defined), are made available, if the same goods are made available in historical quantities but at lower cost (the 'cost avoided' type of benefit discussed above), or if the same goods are made available in larger quantities (larger quantities are assumed to lead to lower price). An output need not have an observable market to qualify as a final output, but it does have to have demonstrable value to at least one person. The most important implication of this definition is that outputs such as 'increased riparian habitat,' 'increased meadow productivity,' and 'higher waterfowl populations' have no direct economic value. Because these outputs are intermediate rather than final, they must be translated into final outputs before dollar values can be found for them. 'Increased riparian habitat' must be translated into a final output such as 'higher property values' before its economic value can be determined. 'Higher meadow productivity' must be translated into 'increased meat production' and 'higher rancher incomes.' 'Increased waterfowl populations' must be converted into additional days of hunting or wildlife viewing (or a higher quality hunting/viewing experience for the same number of hunters/viewers). Thus, to qualify as a final output, a project effect must meet two criteria: (1) there must be a direct link between the effect and human consumption, and (2) there must be enough demand for the additional output to insure that it will actually be consumed (lacking this demand, the added output has no immediate economic value).

(2) A flow chart should, to the extent possible, quantify the relationships involved. It should quantify reduced sediment loads, both on-site, and downstream, in terms of cubic yards (or tons) per acre per year (or other appropriate units); it should report the expected increase in animal-unit-months of forage; it should show the magnitude of the anticipated rise in local wildlife populations; it should specify the dollar investment per unit of reduced sediment delivery. Ideally, each time one box is connected to another in the flow chart, some type of coefficient which defines the relationship would appear. A full-scale systems model of this kind is usually impossible, of course, but one should approach the flow charting task with a model of this sort in mind—getting as close as possible, given the constraints facing the project.

A flow chart summarizing the likely effects of small watershed projects such as the Interagency Red Clover Creek demonstration project was prepared as part of this report. That chart is included as Appendix A. The major project inputs this chart specifies are planning and design, structural features (such as check dam construction or dikes) or nonstructural measures (better regulation of grazing). These inputs lead to a variety of intermediate outputs, including increased meadow productivity, increased livestock production, increased fish populations, increased wildlife populations, decreased downstream flood hazard, increased water quality, and decreased downstream siltation problems. These intermediate products arise from an very complex set of interrelationships, exemplified by the cluster of boxes describing the effects of the structural measures (lower left corner of the chart). These structural measures cause the water to slow and pool, which causes much of the sediment load in the stream to
drop out. Provided this deposition of sediment is significant, this deposition causes the stream bed to rise, and the stream's gradient to decrease. This may result in an increase in the adjacent water table. Also as a result of slowing the water flow, downcutting of the river bed and bank erosion is reduced. The pooling of water in the stream bed also causes the water table to rise, which will lead to improved riparian and meadow plant communities. A slower, deeper, more shaded river will result—an outcome which will increase fish populations. As shown in the flow chart, some of these processes tend to feed back onto and enhance one another, magnifying the overall effect. As the stream bed and water table rise, for example, bank erosion will be slowed. Riparian vegetation will also be stimulated, however, further decreasing bank erosion.

These complex interactions lead to a fairly well-defined set of final outputs: decreased hydroelectricity costs, increased property values, increased provision of government services (due to additional tax revenues), increased agricultural incomes, and increased recreation. The levels of at least some of these outputs can be estimated with reasonable accuracy using coefficients derived from direct measurement, from models, from similar projects, or from the literature. Examples will be provided in subsequent sections of this report.

The Role of Economic Analysis in Project Planning

Economic analysis is sometimes used only to determine the probable impacts of a project that has already been designed by engineers and planners. If it is used earlier in the planning process, economic analysis can often lead to substantially better decisions concerning project feasibility and design. By accepted practice, and, sometimes, by law, most projects are preliminarily designed in two or more alternative forms. If each alternative can be subjected to economic analysis and the results compared, a powerful criterion for choosing among the various alternatives will exist. The power of this criterion depends to a large extent, of course, on whether or not the range of alternatives analyzed covers the full spectrum of possible responses to the original problem (e.g., structural as well as non-structural
responses to a flood problem). Because the alternative with the greatest economic benefits is not always the alternative preferred on engineering or planning grounds, the additional information provided by the economic analysis can become very important in the decision process.

When projects contain two or more separable elements (e.g., an erosion control project consisting of check dams, stream bank rehabilitation, gully control, and livestock exclosure fencing), economic analysis can reveal not only the net benefits associated with the whole package, but also the benefits associated with each element. It is sometimes the case that the combination of elements that is originally proposed does not turn out to be the most efficient combination. Economic analysis can tell the decision-maker which combination of elements yields the highest net benefits.

Economic analysis can also be used to compare the benefits of unrelated projects which compete for the same pool of funds. The U.S. Department of Agriculture, for example, might want to know how best to allocate its erosion control budget. The money might go to public lands agencies for watershed restoration projects, or it might go to the Soil Conservation Service where it would be used to reduce erosion from private lands—or it could be divided up between these two programs. An important consideration in deciding how to allocate these funds would be the net benefits of the projects that would be completed in each area. The combination of projects across both areas that yields the highest net benefits can be determined through economic analysis. Again, this is valuable information to a decision-maker who must make an allocation decision.
CHAPTER IV
Quantifying Benefits

Introduction

Before the economic benefits of a watershed restoration project can be quantified, all significant physical changes that will occur as a result of the project must first be identified and quantified. The analyst must determine how much additional water, forage, fish, wildlife, and so on the project will bring about. Before these changes can be measured, however, baseline relationships must be arrived at: the relationships between water table depth and forage production, between forage production and stocking rates, between water temperature and fish production, and so on, must be known or accurately estimated. Once all physical relationships have been defined, with- and without-project output levels can be quantified. A variety of techniques can then be employed to estimate the dollar value of these known output levels.

It is during this stage of the analysis that a reliable flow chart is all but essential. Because the chart depicts all of the physical relationships involved, the analyst is less likely to overlook any project effects, or neglect to account for interacting forces that might cause a larger net change than either force acting singly. The discussion that follows is based on a flow chart we originally developed for the Red Clover Creek Demonstration Project, but which has since been generalized to take in a broad range of watershed restoration projects (see Appendix A). Each section that follows refers to one relationship, or one set of interacting relationships, that appears on this chart.
Increased Vegetative Productivity

The increased vegetative productivity that watershed restoration projects usually bring about results from a complex interaction between several factors: the establishment of a regime of regular meadow flooding, a rise in the water table, and a change in the distribution of livestock. The current without-project and the anticipated with-project total forage production should be determined. Although the relationship between stocking rates, timing/seasonality of grazing, and forage production has been studied fairly extensively, it appears that more work is needed before consistently reliable predictions can be made over a range of geographical, climatic, and biological conditions—especially in the riparian zone (Platts and Nelson 1985a; Platts 1982; Kauffman and Krueger 1984). Moreover, much of the work done in this area consists of case studies in which the issue of generalizeability of results to other systems is not addressed (Kauffman and Vavra 1983; Platts et al. 1983; Bryant 1985; Cox and Morton 1985). An exception to this rule is a case study by Platts and Nelson (1985b) that aspires to generalizeability by way of using numerous and diverse study sites and careful controls.

The U. S. Soil Conservation Service relies mainly upon site-specific analyses of range conditions in order to characterize vegetation-livestock-wildlife relationships (King 1989). SCS range specialists prepare "Range Site Descriptions" to be included in Range Reports. These descriptions focus on the plant communities and soil types present on the site. They describe the site's potential forage production under a good management regime, as well as the likely consequences of poor management. Rough animal-unit-month (AUM) per acre estimates are made for these management scenarios. When possible, these estimates are based on actual use records at the site, or at similar sites. Otherwise, AUM-per-acre estimates are based primarily on determinations of the amount of palatable forage present, the amount of vegetative residue that must be left to avoid degrading the site, and the amount of available forage consumed by wildlife.

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A preliminary estimate was made by the Soil Conservation Service concerning the increase in forage that is likely to result from the Red Clover Creek restoration project (Murray August 25, 1988). That estimate foresees a two AUM per acre increase (from two to four AUMs per acre) in the amount of forage produced at The Red Clover site. The value of the forage produced was estimated to increase by ten percent.

The effects of meadow flooding and of a rising water table on vegetative production are less well studied. A review of the studies that are available appears in Branson et al. (1981). Unfortunately, no off-the-shelf models designed specifically to predict the response of vegetation to these factors appear to exist. A simulation model that predicts biomass production (as well as other system parameters) based on inputs that include water table depth and soil moisture has, however, been developed (Fogel and Pfolliott 1985). This model may be capable of projecting post-project vegetative production with enough accuracy to enable an economic analysis to be performed. If the Fogel and Pfolliott model cannot be used, however, the best source of estimates will usually be the professional judgement of specialists in range management and ecology.

Valuing Forage

Once a reliable estimate of the increase in vegetative productivity has been arrived at, forage utilization patterns must be determined. Total forage production must be adjusted for the percentage of desirable grass species (to both livestock and wildlife) in both the without and with project case. The available vegetation must be allocated between grazable forage (to livestock and wildlife) and erosion control (residue). The economic value of the wildlife and livestock forage allocations can then be determined. It should be noted that the contribution of forage residue to reducing erosion will be captured by the increase in erosion-sensitive outputs or the reduced costs of production associated with reduced erosion. However, the analyst should keep in mind that utilization of the forage may be limited
due to a simple lack of demand (due, e.g., to lack of access to the site, or to distance from cattle operations).

Several methods exist for valuing the increase in livestock forage. These can be grouped into approaches that look at private transactions for forage in the market and those that attempt to derive a value from a model of rancher operations.

**Private Market Data:** One method of valuing forage is to use market prices for similar sources of forage. Potentially useful market prices exist for private rangeland leases, and for grazing rights on state lands. When grazing rights on state rangelands are purchased through a competitive bidding process, the prices paid are often good indicators of forage values on comparable federal lands. Tittman and Brownelly (1984), for example, found that the average private land lease rate for mature cattle in the region which takes in most of California (including Plumas County) was $6.75 per head-month, or pair-month (i.e., cow-calf). For yearling cattle, the lease rate was $4.75 per head-month.

Another approach to valuing forage is to use market prices for 'substitute feeds.' The common substitute for forage is, of course, hay. Using hay prices as a proxy (or a 'shadow price') for forage has, unfortunately, proven unsatisfactory. Hay prices are often inflated due to strong demand (e.g. from the dairy industry) and limited supply. As a result, the forage value estimates arrived at using this method have generally been substantially higher than comparable values arrived at by other means.

One of the more reliable market prices available for this use is the capitalized value of public lands grazing permits. Markets for grazing permits exist because the grazing fee attached to them is lower than the actual market value of the forage to which they provide access. Thus, when the private ranch land associated with the permitted public land is sold, the sale price will reflect the capitalized value of the public land forage. The market value of the forage covered by the permit, then, consists of the annualized differential value for the land plus all fee and nonfee costs. This value is considered to be a reliable estimate of WTP for forage.
Values of Forage from Ranch Operations Models: The U. S. Forest Service and the Bureau of Land Management charge a per animal-unit-month (AUM) grazing fee, but those fees are considerably lower than the actual market value of the forage present (this and the following is from Wagstaff and Pope, 1987). One approach to more accurately valuing forage on federal lands is the ranch budget method. The general approach is to attempt to value every input into the ranch production process, and then designate all or part of the 'residual'--the difference between all costs accounted for and gross income--as the value of the forage. Because this method involves some uncertainty (e.g., the value of unpaid family labor and management), the results obtained depend on assumptions made about whether ranchers assign a short- or a long-run value to forage. In general, the long-term value, from which all costs (including labor and management) have been netted out, should be used for planning purposes.

A variant of the straightforward budget method is the budget optimization method, which uses a linear programming (LP) model. An LP model uses production and budget constraints (i.e., maximum and minimum amounts of such inputs as forage, labor, water, and so on) to arrive at input levels which either maximize profits, or minimize costs. The user specifies all pertinent constraints, and the model will specify optimal input levels, as well as the overall profit (or cost) that these levels will yield. The interested reader should see Gee (1981) for a thorough explanation and application of this method.

An LP model can be used to value forage in the following manner: the model is run several times with all but the forage variable held constant. The resulting changes in net returns (income minus costs) after each run is, since that net change is associated only with changes in forage levels, an indication of the marginal value of forage in the production process.

Although LP models do produce credible estimates, they have a couple of major drawbacks. The first is that they require extensive budget data from ranches in the area. Such data is often difficult to gather, or simply unavailable. The second drawback is that the values yielded by the model are values to the optimal ranch operation. Not all ranchers will necessarily employ optimal management strategies.
Because the values yielded by this method are optimal, they are usually considered to comprise an upper bound on actual forage values.

**Available Estimates of the Value of Forage:** Tittman and Brownelly (1984) prepared forage value estimates for the U. S. Forest Service and the Bureau of Land Management based on ranch appraisal data. For much of California (including Plumas County), forage on public land was valued as follows:

- Cattle and horses over 18 months old ............... $6.40 per AUM
- Yearling cattle under 18 months old ............... $4.50 per AUM
- Sheep .................. $1.05 per AUM

For Comparison, the U. S. Soil Conservation Service's administratively-set advisory value is $10.00 per animal-unit-month for cattle.

A simple approach for implementing the private market data approach is to contact a farm advisor or county extension agent regarding private land lease rates at similar properties. Such comparison properties should have similar plant species present, as well as similar grazing regimes.

The value of forage for wildlife, especially when there is competition between wildlife and cattle, has been less well studied. One effort in this direction used a variation of the travel cost method (described below) to arrive at a forage value for deer and elk in Idaho (Loomis, Donnelly, and Sorg, 1989). The travel cost models used in this study included "site quality" variables consisting of numbers of deer and elk harvested. The values per AUM for deer turned out to be between $6.33 and $15.83; for elk, they ranged from $6.65 and $8.25.
Decreased Sediment Loads

As shown in the project evaluation flow chart (Appendix A), the overall goal of a watershed restoration project is to reduce erosion and sediment loads by promoting hydrologic regimes that encourage the establishment of riparian and upland vegetation. Riparian vegetation increases channel roughness (Parker et al. 1985; Branson et al. 1981). As roughness increases, water velocity and, in turn, erosional energy, are reduced. The result is sediment deposition and erosion reduction. Upland vegetation enhancement reduces erosion by promoting greater soil infiltration rates—a process which decreases the overland flow of water, and reduces the amount of sediment delivered to the stream.

Because the primary causes of erosion will vary from site to site, the treatments applied to a particular site must be tailored to the specific erosion problems present there. Thus, the first step in the restoration process is to identify primary sediment sources. Sediment can originate from either instream or upland sources. Instream sediment is produced by erosion of either the streambed (downcutting) or the streambanks (lateral migration). Sediment from upland sources usually originates with disturbances such as overgrazing or roadbuilding. Upland sediment is transported to the stream via sheet, rill, or gully erosion. Determining the relative contributions of instream and upland sources is important in prescribing the appropriate erosion control measures that most effectively meet restoration objectives.

One of the more common treatments for eroding channels is the check dam. Check dams reduce downcutting by reducing the channel gradient and water velocity, causing sediment deposition. These structures protect the streambed from further downcutting, and the deposited sediments raise the streambed elevation and provide a water-laden substrate for vegetation establishment (Branson et al. 1981; DeBano and Schmidt 1988; Groenveld and Griepentrog 1985; Stabler 1985; Szaro and DeBano, 1985; for a useful discussion of comparable processes as caused by beaver dams, see Parker et al. 1985).
Because check dams and sills create depositional sites, their immediate effect is to decrease channel capacity. A decrease in channel capacity will cause an increase in lateral migration and, therefore, bank erosion. Bank stabilization measures such as willow plantings, riprap, or revetments are usually necessary to control bank erosion or changes in the channel alignment (i.e., meander pattern). In some situations, a combination of these measures may be necessary to promote a hydrologic balance.

To treat upland erosion, measures that enhance vegetation growth or control vegetation use are commonly employed. These measures include livestock management, control of off-road vehicles, and seeding. Because they can cause the shallow floodplain water table to rise high enough to increase vegetative growth, instream check dams may also act to decrease upland erosion. This increased vegetative growth can substantially augment the amount of forage available to livestock and wildlife. As the trend toward stream stabilization continues, the frequency of overbank flooding may increase—a process which also acts to recharge subsurface aquifers and to stimulate vegetation growth in the floodplain.

In order to estimate the value of final project outputs that are a function of changes in sediment yield, the magnitude of sediment yield changes must first be determined. Unfortunately, the methods currently available for making such prospective estimates are either inaccurate, or not applicable to many individual projects. For a thorough discussion of available methods and related studies, see Branson et al. (1981). The two methods in most common use are:

(1) The use of a control site. Pre-project sediment production rates can be compared with production rates at a control stream that has not been impacted by man's activities. Control sites will not be available in every case, of course, and, when they are, they will never perfectly reflect the restored condition of the project watershed. This method will entail potentially significant monitoring costs if sediment production data for the project site, the control site, or both, is not already available from stream gauging stations operated by either the U. S. Geologic Survey or the U. S. Forest Service.

(2) The use of the universal soil loss equation (USLE) (Wischmeir 1976; Wischmeir and Smith 1978; Branson et al. 1981). This equation (and its many variants, including the modified universal soil loss equation, used to measure the sediments produced by storm events) were designed to estimate sheet and rill erosion on relatively flat midwestern farmland. As a result, they generally yield unsatisfactory estimates when applied to western rangelands where topography and vegetation make mass wasting a significant factor (Branson 1981; Andrus 1986). Modifications

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have been made to the USLE to improve its usefulness west of the Rocky Mountains (Branson 1981). In that the USLE is often the only tool available for estimating sediment production, some agencies, including the U. S. Soil Conservation Service, use it to make estimates on a variety of terrain, vegetation, and soil types.

A more accurate method of determining erosion and sedimentation rates is currently under joint development by the U. S. Forest Service and the U. S. Soil Conservation Service. The Watershed Erosion Prediction model (WEPP), as this new method will be called, is scheduled for release in 1992 (USDA Agricultural Research Service, et al., 1987). It will consists of a series of computer modules which will estimate erosion and sediment delivery rates based on fairly specific information (as supplied by the user) about the particular watershed under study.

Total sediment yield (sediment from instream sources [bed and bank erosion] plus sediment from upland sources [sheet, rill, and gully erosion]) is also affected by changes in the stream bed itself. When a stream bed is raised and its gradient reduced through a given reach, sediment yields from that reach may fluctuate until a new equilibrium state is reached. If appropriate measures (as described above) are taken to control bank erosion due to decreased channel capacity, total sediment yield from that reach will probably decline over the long term. Since predicting sediment yield changes from even relatively straightforward projects is difficult, predicting short-term (preferably annual) fluctuations resulting from stream-bed modifications may not be possible, given the current state of the art in sediment yield modeling. For a thorough discussion of the 'state of the art' as of 1981, see Branson et al. (1981).

A quick and admittedly crude method used by the Soil Conservation Service to estimate total sediment yield can be helpful, however (Water Management Subcommittee 1968; Branson et al. 1981). To use this method, an experienced geologist or soil scientist assigns the study area a rating in each of the following nine categories: geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport. These ratings are then added together. The sum is then translated (using a table) into a total erosion yield figure (in units of acre-feet per square mile). To use this method to estimate the change in sediment yield that might result from anticipated
changes in channel configuration, the pre-project study area is first rated by an appropriate specialist. The dimensions of the post-project stream bed are then given to the specialist, who is then asked to revise his rating based only on that information. The difference between the pre- and post-project yield estimates, then, will constitute a rough estimate of the changes in sediment yield attributable to changes in the configuration of the channel.

Unfortunately, this method is subjective and imprecise, and may, therefore, be unable to detect small (or even moderate) changes in yield. Thus, the judgement of the specialist who rates the study area will be crucial in arriving at a good estimate.

Before leaving the subject of estimating sediment production, three other potentially useful approaches deserve mention. Rosgen (1985) has developed a stream classification system which can be used to estimate sediment production based on the category into which a stream falls. Fogel and Pfolliott (1985) have constructed a computer simulation model which is capable of predicting runoff volume, sediment volume, and biomass production based on meteorological data, land use decisions, and the initial state of the system. Parker et al. (1985) have modeled the ability of beaver dams to decrease erosion by (a) decreasing the energy in flowing water and (b) enhancing vegetative establishment (thereby increasing channel roughness). Insofar as check dam treatments produce effects similar to beaver dams, this model—or a modified version of it—may prove useful in projecting post-project sediment production.

Because not all of the material that is disturbed by erosion ends up in water bodies, a 'sediment delivery ratio' must be calculated before the physical impacts of erosion can be fully accounted for (Clark, et al. 1985). Branson et al. (1981) describes the methods in current use for predicting sediment delivery. The Soil Conservation Service has modeled the routing of sediment through a stream system using an electronic spreadsheet program which breaks a watercourse up into a series of reaches, each of which is characterized in terms of the factors which affect transport and deposition (White, 1986). The model is iterative in that it calculates the yield of each reach individually, using as input the just-
calculated yield of the adjacent upstream reach. Sediment delivery can be recalculated relatively quickly if new, more accurate information about one or more reaches becomes available.

The amount of suspended sediment that will be carried out of the project area after the project is completed can be estimated using a variety of methods. A commonly used method is the U. S. Soil Conservation Service's dam trap efficiency model (USDA Soil Conservation Service, 1972). This model is used to arrive at an estimate for the amounts of sediment that drop out and that remain suspended when a stream encounters a dam, or a series of check dams. Before this model can be used, of course, pre-project sediment production and delivery rates must be known.

Economic Benefits of Decreased Sediment Loads

A primary benefit of decreased sediment loads downstream is decreased reservoir dredging costs. When the reduction in sediment inflow is great enough, dredging is required less frequently, resulting in a significant savings. Because most reservoirs are fed by more than one stream, however, a large decrease in the sediment contribution of a single stream may or may not result in a significant decrease in the sediment load reaching the reservoir. It is entirely possible that a large decrease in the sediment carried by one stream will have no effect on the dredging frequency required to keep the reservoir functional: the total contribution of the restored watershed may be negligible in relation to the contributions made by the other streams feeding the reservoir. It could also be the case if the restored watershed is a great distance from the reservoir. When watershed and reservoir are far apart, there is a greater chance that a large proportion of the sediment leaving the watershed settles out before reaching the reservoir. This would mean the original sediment contribution of that watershed was never very high, and the net decrease brought about by the project is quite small. Even with dredging, however, high levels of suspended sediment can damage dams, gates and equipment. Thus, if the amount of suspended sediment reaching the dam can be reduced by the restoration project, damage to the dam can be reduced. A potentially significant cost savings can result.
Reservoir design must also be taken into consideration. Even if a watershed restoration project removes a substantial proportion of the total sediment load entering a reservoir, the dredging frequency may not be affected if other streams deposit their sediment loads closer to the dam. The reason is that the sediment deposited closest to the dam tends to be the first to impinge upon the turbine intakes, gates, and other mechanical parts. This sediment must be dredged before it can cause mechanical damage to the dam. The frequency with which it must be dredged may not be affected by changes in the sediment loads deposited further away from the dam by other streams.

Dredging costs vary considerably from site to site. If a suction dredge, which simply pumps its spoils to an onshore disposal site, can be used, costs will be relatively low. If a clamshell or dragline dredge must be used, costs will be higher. The further away the from the project area the disposal site is, the higher the costs will be. Additional costs will be incurred if a new disposal site must be located and prepared.

The estimated cost of dredging Rock Creek Reservoir is between $10.00 and $20.00 per cubic yard (Harrison Aug. 19, 1988). About 2 million cubic yards of sediment would be removed in a complete dredging operation.

Another benefit associated with decreased downstream sediment loads is Improved water quality. Water quality improvements can result in (a) increased fish populations, (b) more satisfying viewing (hiking, wildlife viewing), (c) increased demand for swimming, (d) a greater demand for some or all forms of boat-related recreation (canoeing, rafting, water skiing, etc.), (e) fishing (even if fish populations do not change), (f) increased property values, and (g) higher quality or lower cost water to municipal, industrial, and agricultural users. All except the last two of these benefits can be estimated using either the travel cost method or the contingent valuation method. These techniques, as they relate to water quality as well as other project benefits, are discussed below, under "Valuing Changes in Site Quality." Project outputs which might affect property values are discussed below (p. 50).
The reduction of sediments in water destined for municipal or industrial consumption can result in significant savings (Loomis, December 1988). When water which enters the municipal treatment process contains high sediment levels, the color, taste, and safety of the treated water produced can be adversely affected (safety is affected when, for example, high turbidity levels reduce disinfection effectiveness). As a result, the Environmental Protection Agency has drafted standards governing the quality of the water which enters the intakes at municipal treatment facilities. Filtration must be a part of the treatment process if these standards are not met. The turbidity standard requires filtration if the monthly average turbidity level rises above one nephelometric turbidity unit (NTU), or if any two-day turbidity level rises above 5 NTUs. When municipal water supplies are derived from forested watersheds where logging is allowed, this turbidity standard can only be met if environmentally sensitive logging practices (careful road design, post-harvest rehabilitation, and generous streambank and lakeshore buffer zones) are observed. Logging must be discontinued if (1) soil and slope conditions indicate that residual soil erosion will cause the 5 NTU standard to be exceeded, or (2) The safeguards necessary to insure compliance with turbidity standards will render the timber harvest uneconomical. The turbidity of unfiltered municipal water supplies must either be monitored continuously, or sampled six times daily. If this, and the EPA’s other standards can be met, a municipal water supplier (and, in most cases, the consumers of the water supplied) can avoid filtration costs (though incurring monitoring costs, which are presumably lower than filtration costs).

The value to a municipal water supplier of preventing excessive turbidity in its water supply is illustrated by recent actions on the part of the Plumas County, California Board of Supervisors. When it was determined that logging on private land in two watersheds which provide water to the City of Quincy, would result in significant increases in the turbidity of the water entering the City’s treatment plant, the County initiated a study to determine the benefits of purchasing 180 acres of the watershed (Loomis, December 1988). That study determined that the savings to the residents of the City of Quincy, measured in terms of groundwater pumping costs avoided, would be approximately $25,000 a year. Given the City’s 700 household and business water hook-ups, this translates into a savings of $35.70 per
year, per customer. On a per-month basis, the cost of purchasing the affected private lands would be $1.52. The purchase of the watershed, then, would result in direct benefits of $2.98 per month. The rate of return to the City and County on such a purchase would be almost 100%. The affected lands were eventually purchased.

An example of a study in which reasonably accurate values for many of these water quality parameters were found is Moore and McCarl (1987). The values arrived at are, in most cases, specific to the Willamette Valley area of Oregon, but the methods employed by these authors are quite sound, and could serve as a blueprint for similar studies elsewhere.

For projects in which sophisticated modeling of the economic effects of changes in water quality is desired, Gutema and Whittlesey (1983) should be consulted. These authors have developed a multiple parameter analytical procedure for estimating the benefits of water pollution abatement. This model is capable of measuring the effects of reduced sediment levels.

**Increased flows Later in Summer**

The degree to which a watershed restoration project can affect the amount and the timing of streamflows is a function of (a) the degree to which increased vegetative cover in the watershed allows what were once overland runoff flows to infiltrate into the ground, (b) the rate at which water from the stream bed can, when conditions permit, migrate laterally into the water table, and (c) the degree to which sediments stored in channels retain water runoff. Precipitation is more likely to infiltrate because improved vegetative cover acts to increase soil permeability, thereby allowing a larger proportion of that precipitation to infiltrate rather than flow overland into the stream course. Water from the stream bed can enter the water table when stream flows are relatively high, and the water table relatively low. When this happens, the normal downward gradient between the water table and the stream is reversed.
(Discussions of these processes from varying perspectives can be found in Branson et al. 1981; DeBano and Schmidt, 1988; Stabler 1985; Parker et al. 1985).

Among the more important variables affecting streamflow increases resulting from watershed restoration projects are the following:

(1) The added volume of groundwater that will be stored in the watershed at the end of a water-year. This amount depends, as mentioned, upon changes in vegetative cover, and changes in the stream-to-ground recharge regime. The Soil Conservation Service relies on water table sampling to determine the hydraulic conductivity of the aquifer (Hanes 1988). Other potentially useful methods for predicting water table effects are discussed in Branson et al. (1981). This information—along with data on the change in the depth of the water surface in the stream channel—makes it possible to compare pre-project and post-project water table volumes.

(2) The rate at which groundwater leaves the watershed (either by descending to a deep aquifer, or by flowing into stream courses). This rate will be a function of the hydraulic conductivity of the aquifer (see item #1, above).

(3) The extent to which the augmented streamflows in the project area will result in increased flows downstream. Certain stream characteristics (coarse, sandy soils which allow much downstream infiltration; broad shallow reaches combined with summer heat causing high rates of evaporation along the stream course) may cause a significant flow augmentation in the immediate project area to diminish substantially, or disappear altogether, at an important downstream location (e.g., a reservoir) (Branson et al. 1981).

(4) Losses to transpiration, given the increased post-project vegetative cover in the riparian zone and the floodplain.

According to Branson et al. (1981), many rangeland watershed hydrologic models are currently in use. The model one chooses for a particular application depends upon the physical characteristics of the project area, and the specific objectives of the modeling effort. For guidance in choosing a model, see Branson (especially pp. 289 - 331, and pp. 73 - 106).
Economic Value of Augmented Flows
for Hydroelectric Generation

Ideally, the value of water for use in hydroelectric generation would be determined as would the value of any other commodity: The commodity price which balances supply and demand is the value of that commodity. Unfortunately, this type of analysis can only be used when the market in question is relatively free of ‘distortions’ (regulations and other constraints on competition). Because hydropower is heavily price-regulated, other methods must be employed to discover the value of additional units of water to be made available for the generation of electricity (Gibbons, 1986).

In most cases, the only practical means of arriving at a value for water to be used in hydropower generation is to find out how much it would cost to generate power in some other way. The value imputed to the water is the cost of the alternative generation method minus the cost of hydropower generation. This method is based on the fact that the utility would generate enough electricity to meet demand in any case, but when it uses water to generate that electricity, it can produce the power its customers demand at a lower cost. The value of the water used to generate electricity, therefore, is defined as the savings the utility and society realize by substituting a lower-cost input (water) for high-cost inputs (oil or coal).

A possible pitfall with this method, however, is that it uses input costs as a proxy for value. This can present a problem in that it ignores the forces which shape the demand for the output. As long as future demand trends do not depart too radically from past trends, this flaw will not affect the analysis. If, however, demand either increases or decreases significantly—in response to changes in electricity prices, or to unexpected changes in the local economy—the value of the electricity generated will change. Any analysis based solely on input costs will, under these conditions, be rendered inaccurate.
The evaluation method which most effectively avoids this pitfall is the short-run marginal value method. As is the case in any 'short-run' analysis, long-run costs (capital outlays, depreciation, taxes, etc.) are considered to be 'fixed.' As such, they are ignored in cost calculations. Only 'variable' costs—primarily fuel costs, but including some operation and maintenance expenses, and other production costs—are used. Once these costs are compiled, the value of newly-available water is arrived at as follows: The cost of generating electricity with the additional water is subtracted from the cost of generating the same amount of additional electricity by the most likely alternative means.

It is important to use marginal values when performing this analysis. A "marginal" value is simply the value (in terms of cost avoided) of the last unit to be produced or consumed. In most cases, the first units produced or consumed are more highly valued than later units. In economic jargon, this phenomenon is referred to as 'diminishing marginal value.' It is important because, when value is not constant for all units, it can be a mistake to assume that the average value of all units represents the value of the last unit. Because value declines as more units are produced or consumed, the value of the last unit can be quite different from the average value of all units.

It is also possible to use two 'long-run' methods to arrive at a value for additional water for use in hydropower generation. In these, and all long-run calculations, capital costs are assumed to be variable (since, in the long run, machinery, and even entire plants must be renovated and replaced). Thus, capital costs, depreciation, taxes, etc. are included in such calculations.

The long-run method which corresponds to the short-run marginal value method is the long-run average method. The long-run average value of water used in hydropower generation is defined as the difference between the total (capital plus production) costs of alternative generation and the total costs of hydroelectric generation. One important long-run variable cost faced by a hydroelectricity producer is the cost of periodic dredging. This cost is discussed above (p. 38). All other capital and production costs must be obtained from the utility (or utilities) which generates electricity in the region, or from the Public Utilities Commission with jurisdiction over that utility.
The second long-run method can only be used if some restrictive assumptions can be made. The long-run replacement capacity value method assumes (1) that hydropower generating capacity is fixed, and that alternative generation capacity is variable, and (2) that all water removed from a river on regular basis reduces hydropower capacity and necessitates an increase in alternative generating capacity. It is calculated as follows: the value of water removed from hydropower generation is equal to the cost of enough new thermal generation capacity to replace the foregone hydropower, minus the production costs of that lost hydropower. If augmented rather than curtailed supplies are to be evaluated, the analysis is done in the same way. The analyst simply carries out the calculations as if the additional water were already in use. The long-run replacement cost of that water, were it to become unavailable for hydroelectric generation, is then calculated. Because this method requires that restrictive assumptions be made, and because it is very vulnerable to the problems associated with ignoring the potential for changes in demand (discussed above), it is generally not recommended.

Four important points must be kept in mind when using any of these methods:

1. Much of the additional water produced by a watershed restoration project will pass through more than one hydroelectric dam. Many of California’s rivers are routed through two or more hydroelectric developments. The value of any additional water added to such a river system, therefore, is the sum of that water’s value at every hydroelectric generator it passes through.

2. Many utilities generate base and peak load power differently. Hydropower is often reserved for peak power generation only. Since peak power is more valuable than base load power, it is important to avoid the pitfall of determining the value of water to be used for peak power generation in terms of a base load value from an alternative facility (or vice versa).

3. Calculating the value of water in hydropower generation is made simpler by the fact that its marginal productivity is constant—that is, all units of water that pass through the turbines produce the same amount of hydroelectricity, regardless of whether they are the first or the last units supplied. Thus, in the case of hydropower, the marginal and average productivities are equal. The standard value used is 0.87 kilowatt-hours per acre-foot of water per foot of head.

4. Once enough water is available to meet both base and peak load demand, additional water added to the system has no electrical generation value.

A good source of current price and cost information for electricity generation is Pacific Gas and Electric Company’s Co-generation and Small Power Project Quarterly. This publication reports the
prices paid by Pacific Gas and Electric to small power producers. In keeping with California Public Utilities Commission policy, a utility must pay small producers of electricity an amount equivalent to the cost the utility avoids by not supplying electricity to that producer. The Public Utilities Commission determines how much the utilities must offer small producers. Copies of current contractual offers, as well as the methods and calculations used by the Public Utilities Commission to arrive at the amounts offered are published in the Co-generation and Small Power Project Quarterly, which can be obtained either from Pacific Gas and Electric Company or the California Public Utilities Commission.

A per acre-foot estimate of the value of water in the generation of electricity can be obtained from a regression model constructed by Romm et al. (1986). This model uses the elevation of the highest power plant on a river as a proxy for the number of plants on the whole river system. Water is valued in this model according to the short-run marginal value method. The model is specified as follows:

\[
\text{Value ($/acre-foot)} = 4.04 + (0.0076) \times \text{(Elevation)}
\]

This model has an \( R^2 \) of 0.6822 and a standard error of $16.52 for the value estimate. The following table reports some of the values this model predicts:

<table>
<thead>
<tr>
<th>Elevation (ft.)</th>
<th>Predicted Value ($/acre-feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>$19.20</td>
</tr>
<tr>
<td>4000</td>
<td>$34.35</td>
</tr>
<tr>
<td>6000</td>
<td>$49.51</td>
</tr>
<tr>
<td>8000</td>
<td>$64.66</td>
</tr>
</tbody>
</table>

The highest powerhouse on the North Fork, East Branch of the Feather River is at the Rock Creek dam—elevation: 2205 ft. As the table, above, shows, the Romm et al. model would predict that the value of the water used for hydroelectric generation at the Rock Creek dam would be about $19.20 per acre-foot of water.
As shown by a recent hydropower bypass transaction in El Dorado County, however, reported values can vary considerably: that transaction was reportedly valued at $65.00 per acre-foot (Lambert 1988).

Economic Value of Augmented Flows

For Irrigated Agriculture

Two primary methods exist for estimating the value of water to irrigated agriculture (Gibbons, 1986). The first is the production function method, in which the marginal physical productivity of water (increase in crop yield per unit increase in water application, all other inputs held constant) is multiplied by crop price to arrive at the marginal value of water. If the marginal productivity of water is not known, however (as it quite often is not), it must be determined by controlled experimentation. Thus, the production function method is seldom practical to use in an economic analysis of a watershed restoration project.

The more practical method is the farm budget analysis technique, which is virtually identical to the ranch budget method for valuing forage, described above. When the cost of all non-water inputs are subtracted from a farm’s total revenues, the residual is the maximum value that water has to the farm operation. Subtracting procurement and storage costs from this figure yields a value comparable to in-stream water values. Divided by the total quantity of water used, this value becomes the maximum average value—or WTP—of water to the farm. A short-run, or long-run value can be obtained in this way, depending upon whether or not fixed costs are included. Data on representative farm budgets can often be obtained from county extension agents.

Farm budget data can also be analyzed with a linear programming (LP) model (for more information, see "Valuing Forage," above). Once the model (objective function) has been defined for the farm of interest, a series of solutions over a range of water costs are derived (all other variables held constant).
The result is a water demand schedule for that farm (assuming optimizing behavior on the part of the farmer, since LP models yield optimal solutions, given a set of constraints).

Representative values for California agriculture obtained through the use of these methods are included in Gibbons (1986). Because the values reported were either national averages, or obtained from the west side of the San Joaquin Valley, they probably should not be used to value northern California crops.

Another method that has been used to estimate the value of surface water to irrigated agriculture is the pumping cost avoided method (Romm et al., 1986). This technique makes use of the cost of pumping irrigation water from the groundwater table as proxy for the value of an equivalent quantity of surface water. Transportation and facility costs were deducted from the gross pumping costs in order to obtain the approximate in-stream value of the water used. This method yielded a average value of $20.63 per acre foot for water from national forests in California. Water originating in the upper Feather River watershed was valued at $23.88 an acre-foot.

**Increases in Desirable Fish Populations**

Several of the changes brought about by a watershed restoration project can have an affect on fish populations. Two of the most important of these are a direct result of the increase in riparian vegetation which such a project usually entails. Riparian vegetation acts to shade and cool a stream course. This cooling improves the habitat quality for the most economically important fish species likely to be present, the salmonids. Increased riparian growth also contributes insects and other nutrients to the stream ecosystem (for discussion of the importance of vegetative cover to fish populations, see Wesche, et al. 1985). The decreased sediment loads brought on by a restoration project also improve salmonid habitat, primarily by increasing the abundance of suitable spawning gravels (Tappel and Bjornn 1983; Sigler and Bjornn 1984).
Unfortunately, we were able to locate very little in the way of biological models capable of predicting the effects of watershed restoration projects on fish populations. One possible exception was Wesche et al (1985), who developed a regression model which predicts brown trout standing crop based on vegetation cover variables. The authors found, in one application of their model, that percent overhead bank cover explained the most variation in brown trout populations. They anticipate, however, that other cover variables might be more important in other settings. The authors are all researchers at the Wyoming Water Research Center, University of Wyoming, Laramie, Wyoming.

Frissel et al. (1986) and Lotspeich and Platts (1982) describe habitat classification methods which might make it possible to estimate fish populations by reference to a comparison stream. The class into which the restored project stream will fall is first determined. Then, a similar stream—in the same habitat class is located. The comparison stream might be in relatively unaltered condition, or it might have been restored by a project similar to the one being contemplated. Fish populations in the comparison stream can then be used as estimates of post-project fish populations. Because this method has the potential of introducing considerable error into the population estimates, it should only be used with care by a competent fisheries biologist.

Perhaps the two most widely-used fisheries models—the Habitat Evaluation Procedure (HEP) and the Instream Flow Incremental Methodology (IFIM)—do not permit the user to directly predict actual fish populations (Armour et al., 1984). The output of both models consists of habitat suitability ratings. Some efforts have been made, however, to correlate IFIM output with population numbers (see, for example, Milhouse 1983).

For information on these models, and how the output they are capable of producing can be translated into fish population figures, contact the Western Energy and Land Use Group, U.S. Fish and Wildlife Service, Creekside One, 2627 Redwing Road, Fort Collins, CO 80526-2899. For specific
information on HEP, call (303) 226-9424. Information about IFIM is available from the Instream Flow and Aquatic Systems Group at (303) 226-9331.

**Increased Wildlife Populations**

A set of habitat models designed specifically for predicting changes in riparian wildlife populations was developed by Anderson and Ohmart (1985). These models are intended for use in improving the management of the Colorado River riparian zone. These models grew out of over seven years worth of monthly data gathered at study sites along the Colorado River. Although the authors warned that the 1985 version of their models were not readily generalizable to other riparian areas, they reported that they were currently working on models applicable to a broader range of such habitats. Both authors can be contacted through the Center for Environmental Studies, Arizona State University, Tempe, Arizona.

**Valuing Increased Fish and Wildlife Populations**

The economic value of increased fish and wildlife populations is usually estimated by applying either the travel cost method or the contingent valuation method. The application of these techniques to increases in angler-days, along with their application to other project outputs, is discussed below.

**Valuing Changes in Site Quality:** A watershed restoration project has the potential to substantially improve many components of what can collectively be referred to as overall "site quality." These components include the presence of both game and non-game wildlife populations, the occurrence of catchable fish, viewshed quality, and water quality. If some or all of these changes take place on private land, and markets for any of the 'commodities' in question exist, then the fee charged for them can be used to calculate the benefit (by simply subtracting expected post-project fee revenues from known pre-project fee revenues). Because no market exists for the consumption of these site quality 'goods' on
public lands, however, their value must be estimated using either the travel cost method (TCM) or the contingent valuation method (CVM).

**The Travel Cost Method:** Before attempting to construct a travel cost or a contingent value model, the analyst should make certain that a usable model does not already exist. Using an already-constructed model can save considerable time and money. To search for a model, the analyst would begin by reviewing the following journals: *North American Journal of Fisheries Management, Transactions of the American Fisheries Society, Transactions of the North American Wildlife Conference, Land Economics, Western Journal of Agricultural Economics, American Journal of Agricultural Economics, Journal of Leisure Research,* and *Dissertations Abstracts.*

Because the basic TCM method is used to arrive at one value for a single recreation site, it is not well-suited to the job of estimating the value of changes in site quality. With certain modifications, however, the basic model can, in some cases, be made to produce reliable marginal site quality values. Marginal values can then be used to calculate the value of changes in site quality. Both the standard model, and the modified versions will be described in this section.

TCM is based on the theoretical assumption that the aggregate round trip travel cost faced by the visitors to a recreation site is (with a few necessary adjustments) an accurate approximation of the price of the recreation to be had at that site (Dwyer, Kelley, and Bowes, 1977). When constructing a travel cost model, the analyst is, in effect, estimating the extent to which the number of trips taken varies with the distance people must travel in order to use the recreation site of interest. Distance traveled is, on average, proportional to the travel cost incurred. This relationship between price (travel cost) and quantity (number of trips taken) results in a demand curve for the recreation available at that site. The area beneath this curve, but above the actual price paid, is an approximation of the value of the site in question.
In order to construct a travel cost model, the analyst needs to know where the visitors to the site under study came from. For many parks, national forests, etc., this information can be taken directly from campground fee receipts, visitor registers, etc. If such records do not exist, visitors to the site must be sampled, and statistical inference used to estimate the number of visits originating from each of several cities, counties, or regions. If possible, other types of potentially useful data should also be gathered. Income and education levels are often useful, but other indicators of a visitor's level of commitment to the activities available at the recreation site under study (e.g., equipment expenditures) should also be collected when feasible. If hunting, fishing, or viewing sites are being evaluated, catch, bag, and sighting rates are usually important variables.

Using this information, the analyst constructs a first stage demand equation—usually an ordinary least squares regression model—which predicts visits per capita based on the other variables for which data is available. One independent variable that must be used is round-trip travel cost. Travel costs can be obtained either by asking the visitor (via on-site interviews, or some other survey method) or by referring to variable cost data for operating motor vehicles. This data is published annually by one of two entities: the Hertz Corporation (1981-1986) or the Automobile Association of America (AAA) (1988). When using either the Hertz or AAA data, only the variable vehicle operating costs should be used. Fixed costs such as depreciation, insurance, etc. should not be included. The most recent published costs range between 7.5 and 17 cents per mile, depending on age and size of vehicle.

These per-mile vehicle operating costs are normally adjusted to reflect the opportunity costs of travel time (usually some proportion of earnings foregone), and then multiplied by the round-trip distance from each area of origin to the study site. Any other independent variables that turn out to be significant are also included in the first stage model.

The first stage curve is then used to construct demand curves for each zone of origin. For each origin zone, the analyst simply varies the travel cost variable between zero added cost and some appropriate upper bound (a value that either crises the trips variable to zero, or is equal to the highest
observed travel cost) while holding all other zonal variables constant. In this way, a per capita trip value for each travel cost increment is derived. Then, all per capita visitation values are converted to their corresponding total visits values. When these values are plotted against their respective dollar increments, a zonal demand curve results. When this process is completed for each origin zone (using the same increments in travel cost for each zone), all zonal visits values are summed across each travel cost increment. In economic terms, the analyst is "horizontally summing the zonal demand curves." The resulting values are then plotted against the travel cost increments used. This plot is known as a "second-stage demand curve." Integrating this curve (or otherwise estimating the area beneath it) yields an approximation of the recreation benefits of the study site. Example first and second stage curves are shown in figure 3.

If TCM is to be used to evaluate changes in a component of site quality, a regional model must be used (Loomis, Donnelly, and Sorg, 1989). A regional model will take in more than one recreation site, and the sites covered will vary somewhat in quality. Without some quality variation from site to site, it would not be possible to derive values for incremental ("marginal") changes in site quality. Site quality variables are then entered into the first stage model much as the education, income, and other non-travel-cost variables were in the straightforward model described above. These variables can be transformed in a number of ways in order to achieve statistical significance while continuing to conform to economic theory, but the final functional form used will vary from case to case.

The second stage curve is generated as described above for the straightforward model. Then, new second stage curves are generated for each zone by holding all but the site quality variable constant. That variable is incremented by some appropriate amount, and a new curve generated for each zone. The marginal value of the increment in improvement at each site is represented by the area between the original curve and the new one.
Figure 3: Example First and Second Stage Demand Curves
Loomis and Cooper (1988b) are currently constructing a regional travel cost model for fishing on the North Fork of the Feather River in California. Both time-series (1981-1985) and cross-sectional (multiple fishing sites) data were used in this study. The trips per capita (or, in this case, trips per thousand) curve is plotted in Figure 4. Combining this information with data on catch rates, the following first-stage demand model was constructed:

\[ \ln(\text{TRIPC}) = -8.93358 - 2.2786(\ln(\text{TC})) + 0.989(\ln(\text{WILDTRT})) \]

\[ (-1.44) \quad (-1.6) \quad (1.3) \]

Where: \( \ln(\text{TRIPC}) = \) the natural log of trips per capita  
\( \ln(\text{TC}) = \) the natural log of travel cost  
\( \ln(\text{WILDTRT}) = \) the natural log of number of wild trout caught

t-scores appear beneath each coefficient; \( R^2 = .43; N = 285 \)

The second-stage demand curve this model yields appears as Figure 5. Integrating this curve, we find that the consumers' surplus (net WTP) for fishing along the North Fork of the Feather River is $57,684 for the sample of anglers surveyed. This figure must be expanded upward to reflect the entire angler population using the North Fork of the Feather River.

In order to illustrate how a travel cost model can be used to estimate the value of a change in site quality, the Feather River model was re-run after increasing the number of wild trout caught by all anglers by 100. The consumers' surplus increased by $1874—which, when divided by number of additional trout (100), yields a value of $18.74 for a single additional trout caught.

TCM has also been used to derive other site quality values that can be used in evaluating a project such as the Red Clover Creek Demonstration Project. Loomis and Cooper (1988a), for example estimated that waterfowl hunting in California is worth about $62.00 per hunter-day. The number of trips and total hunting benefit increase by about 2.5 percent for every 10 percent increase in waterfowl harvest.
Figure 4: First Stage Demand Curve for the NFFR Travel Cost Model
NORTH FORK FEATHER RIVER
WILD TROUT FISHING DEMAND CURVE

Figure 5: Travel Cost Model (TCM) Second Stage Demand Curve
The Contingent Valuation Method: Willingness to pay (WTP) for improvements in site quality can also be estimated using the contingent valuation method. When using this method, the analyst creates a hypothetical market for the good of interest (e.g., site quality), and then surveys consumers of that good to see how much they would be willing to pay for the provision of additional quantities (or, in some cases, how much they would be willing to accept for the provision of lesser quantities).

The most direct way to obtain a WTP figure in any given setting is simply to ask visitors to state their maximum WTP. In practice, however, this straightforward approach has been refined and elaborated in the hopes of eliciting ever more reliable WTP estimates. Most CVM studies now attempt to set up a hypothetical market based on a credible financing scheme (or "payment vehicle") such as a hunting license surcharge, a trust fund, a bond issue, or an appropriate tax. A "bidding game" approach can be employed in personal or telephone interviews to bid each respondent up to his or her maximum WTP (or minimum WTA--willingness to accept). One of the more commonly-used approaches in mail surveys is the "dichotomous choice" method: the respondent is asked whether he or she would be willing to pay amount \( \$A \) for increment \( X \) in the provision of the good in question. The value taken on by \( \$A \) varies among respondents. WTP is inferred statistically using a type of regression model known as "logit." Logit allows a regression to be run with a dependent variable that can only take on two values (the "dichotomous choices" made by respondents).

Contingent valuation surveys can be conducted by telephone, through the mail, or in person (usually at the recreation site). CVM surveys include Willingness-to-pay questions, but usually contain other types of questions as well. One reason for inquiring into areas not directly related to WTP is that the survey results will be used to construct a demand model--much as the TCM results discussed above were used. Another reason is that some questions can be used as checks on internal consistency: since CVM respondents aren't usually involved in actual monetary transactions, questions are included in the survey which will help the analyst to identify cases in which strategic or otherwise invalid WTP values might have been given. Such consistency check questions might ask the respondent how often he participated in the type of recreation available at the study site, how much he has invested in equipment,
whether he belongs to clubs that pursue that form of recreation, and so on. Data is also gathered on demographic variables. Income often acts as the most efficient consistency check of all: respondents who are willing to pay more than their incomes will reasonably allow are probably not answering honestly.

If the analyst is interested in water quality, for example, he or she might construct a CVM survey in which visitors to a recreation site are asked to view two or more pictures which are similar in every way except the clarity and color of the water in a lake or reservoir. Respondents might also be asked to read a brief, concise description of the levels of water quality in each photo. They would then be informed of the hypothetical payment vehicle that will be used to finance water quality improvements at the recreation site they are currently visiting. The actual bidding would then begin. The respondent would be asked if he or she would be willing to pay a certain amount to see the quality of the water in the lake increased by an increment equal to that depicted in the first two pictures viewed. If the answer is "yes," the amount is raised, and the process repeated. This bidding procedure would be repeated for each increment in water quality shown in the original series of pictures. After the respondent answers some additional questions concerning income, recreation preferences and commitment, and so on, the session ends. There are, of course, many variations on this approach, but this one is commonly used, and serves to illustrate how the survey process works.

Once all the CVM data has been gathered, it can be used to calculate a single net benefits figure (average per person WTP multiplied by the estimated number of people who would be willing to pay for the site quality component of interest), or it can be used to derive a demand curve for that component. The ordinary least squares regression method is used to derive a demand curve. The coefficient on the site quality variable in the CVM demand curve model allows the analyst to quickly derive the marginal WTP for increments in the level of provision of the site quality component of interest.

CVM was used to obtain one value that could prove useful in evaluating the benefits associated with a watershed restoration project such as the Red Clover Creek Demonstration Project: Loomis (1988)
obtained a value of $37.33 per trip for bird viewing in California. That figure rises to $44.00 as the number of birds seen rises from 28 to 42. With an increase from 42 to 56 birds seen, the value per trip rises to $46.67. Increases in the number of birds seen can also increase the number of birding trips taken—a fact that must not be neglected in the analysis.

In a review of pertinent TCM and CVM studies, Walsh et al., (1988) found that small game and upland bird hunting is valued at $31.22 per hunter-day. This value is an average of 9 studies—6 of which used TCM, and 3 of which used CVM.

Some Non-CVM Survey Results: Loomis and Fitzhugh (in press) surveyed private ranch owners in California regarding the value of deer hunting on their land. The average value of a deer hunting lease in California is $706.50 per hunter, or $2.66 per acre. The value of a lease was found to rise by $130.00 with a 10% increase in the hunting success rate. If that 10% increase includes a corresponding 10% increase in the number of trophy deer bagged, another $106.00 can be added to that $130.00 figure.

Loomis and Fitzhugh (in press) also found that the value of hunting for non-deer game species on private land is about $1.16 per acre. Thus, the value of hunting for all species comes to $3.82 per acre.

The value of deer viewing in the Sierra Nevada Mountains was estimated by Loomis, Updike, and Unkel (in press). Under existing conditions, deer viewing is worth $15.00 per visitor-day.

Property Values

Certain project outputs may affect the value of private property in, near, and, in some cases, some distance away from the project. The primary ways in which property values might be influenced are the following:

(1) Improved forage production might increase the value on one or more ranches.
(2) Increased wildlife abundance might increase the value of second homes, 'ranchettes,' and similar properties.

(3) Significant decreases sedimentation rates would improve water quality in downstream stream reaches, lakes, and reservoirs. Property abutting such water bodies might increase in value as a result of the improved water quality. This increase would be a function of some or all of the following factors: improved aesthetic quality, improved conditions for water-contact sports, and improved fishing.

In most cases, the only feasible way in which to determine how much value will accrue to properties likely to be affected by the project is to locate, and then determine the value of, property exhibiting conditions similar to anticipated post-project conditions. These values can be determined either by checking with the assessor's office, or by having an appraisal done. The differential between the current value of the affected properties, and the value of the comparison properties can be used in benefit-cost, or other financial or economic analyses.

CHAPTER V
Recommendations

In the sections above, we have attempted to survey the various techniques and sources of information that can be used to determine values for the individual components of a watershed restoration project (these components, and the relationships between them, are depicted in the flow chart, included as Appendix A). In this section, we will attempt to recommend, where possible, which technique, or which source of information we feel is best suited to the task at hand. In a few important cases--most notably, vegetation response, changes in fish populations, and sediment production rates--reliable methods for predicting project outputs are not widely available. An inability to objectively predict the levels of these key outputs may make the analysis process somewhat dependent on professional judgement. The values arrived at in this way may have wide margins of error. In such cases, our recommendation must necessarily focus on the additional data collection, analysis, and model-building
may exist. Lease rates for private rangelands are often reliable indicators. If private rangeland similar in condition to the anticipated post-project condition of the lands in the restoration area can be located, the lease rates for that land can be assumed to reflect the value of the forage to be produced in the project area. If grazing rights on state lands are sold in a way that approximates an open market, the price paid for these rights can also serve as an indicator of forage value on comparable project lands. Finally, the capitalized value of federal grazing rights is considered to be a reliable indicator of forage value. The transfer of base property and associated federal permits (which is almost invariably higher than the federal grazing fees charged) reflects the value of the forage present on those federal lands.

Only when usable market prices such as these are unavailable should one resort the generally less-accurate ranch budget methods. Such methods can provide reliable estimates, but the values they yield are very sensitive to crucial assumptions made about ranch management behavior.

If data is needed very quickly, or if the funds available to the analyst are limited, forage values from Tittman and Brownelley (1984) can be used. These ranch-budget-based values are averages over wide geographic areas, and may not reflect actual conditions at specific sites within those wide areas.

The value of forage for wildlife can be determined using the travel-cost-method, as modified by Loomis, Donnelly, and Sorg (1989). If the resources needed to perform such an analysis are not available, the figures arrived at by these authors can be used or adjusted, as needed.

**Changes in Sediment Loads:** Predicting changes in sediment yields with an acceptable degree of accuracy appears to be a problem. Until the U.S. Forest Service and Soil Conservation Service release their joint Watershed Erosion Prediction model (WEPP—expected in 1992), no method for accurately projecting sediment yields from most western rangeland exists. The commonly-used Universal Soil Loss Equation (USLE) can be used with confidence on lands similar to the flat midwestern farmland where it was developed, but it yields less satisfactory results when applied to different soil and terrain types. For a comprehensive review of pertinent work and modeling efforts, see Branson et al. (1981).
An added complication is that the sediment yields from some watershed restoration projects may not simply drop off at some predictable rate following project completion. An initial rise or fluctuation may occur before any decline is realized. Predicting the course of these short-term effects does not appear to be possible, given the tools currently available. This presents a serious obstacle to any analysis that attempts to value project benefits on an annual basis. Since benefit-cost analysis depends upon relatively accurate year-by-year estimates of project benefits and costs, there is an obvious need for more research in this area.

If an estimate of the anticipated long-term average sediment yield is desired, and the use of the USLE would clearly be inappropriate, it may be possible to locate another watershed which, in the judgement of pertinent experts, approximates the anticipated post-project condition of the watershed slated for restoration. Sediment yields from that comparison watershed can be obtained either from gauging records, or from a monitoring program.

If a comparison watershed is not available, the method described by the Water Management Subcommittee (1968) can be used to arrive at a sediment yield estimate. Because this method relies heavily on the judgement of experts, it is only capable yielding very rough estimates. This method is discussed in detail beginning on page 36 above.

Other potentially useful models are presented on page 37. Since we have no authoritative information on the usefulness or accuracy of these methods, they should be used only advisedly. We recommend contacting the originators of these models before any attempt is made use them.

For an overview of current approaches to the problem of predicting sediment delivery (as opposed to production), see Branson et al. (1981). Two approaches are discussed in the main body of this report. The Soil Conservation Service's 'dam trap efficiency' method (U. S. Soil Conservation Service 1972) appears to be a suitable approach for determining sediment yield along short reaches (e.g.,

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behind a check dam), while the spreadsheet method developed by White (1986) is more appropriate for estimating sediment delivery over several reaches.

**Economic Benefits of Decreased Sediment loads:** Decreased sediment loads can result in a variety of tangible and intangible benefits. Reservoir dredging costs might be reduced, recreational opportunities might be improved (via improved site quality), and treatments costs for municipal and industrial water supplies might be decreased. In each case, cost savings must be determined by straightforward accounting methods. The main body of this report points out some pitfalls that should be avoided when assembling cost-avoided data (e.g., it may not always be true that decreased sediment delivery will result in a decreased dredging frequency), but, otherwise, the approaches discussed are straightforward.

If a restoration project warrants sophisticated modeling of the economic effects of changes in water quality, Gutema and Whittlesey (1983) should be consulted. The multiple parameter analytical procedure developed by these authors is capable of measuring the economic effects of reduced sediment levels, as well as reductions in several other types of pollutants.

Estimates are given in the main body of this report for dredging costs at Rock Creek Reservoir, and for treatment costs avoided in the town of Quincy California. If resources are not available to ascertain more precise estimates, these values might provide a starting point for estimating the needed values.

A good example of an attempt to determine the value of many of the benefits of decreased sediments loads is described in Moore and McCarl (1987). Although most of the values presented in this study are specific to the Willamette Valley area of Oregon, the methods employed by these authors could serve as a blueprint for similar studies conducted elsewhere.
Increased flows Later in Summer: Many models exist for predicting rangeland hydrologic responses. The best resource we know of for deciding which model is most appropriate for a given application is Branson et al. (1981). Pages 269 - 331 and 73 - 106 are especially helpful.

Economic Value of Augmented Flows for Hydroelectric Generation: Because the utilities which produce electricity are regulated, actual market prices paid for the electricity generated is usually not an accurate indicator of the actual value to society of that electricity. Thus, the value of electricity is usually calculated in terms of generation costs. The value of the water used to generate hydroelectricity is usually valued according to the costs avoided by not having to generate that electricity in other, usually more expensive ways. Three methods for calculating this value are described in the main body of this report (and more completely in Gibbons 1986). Of these three, the short-run marginal value method is most likely to avoid the pitfalls of using cost as a proxy for value. If a long-run method is desired, the long-run average cost method will usually be the most reliable (though it, and any long-run method, are relatively vulnerable to inaccuracies introduced by changes in demand). A good source of cost and price information useful in calculating the value of water in the generation of electricity is Pacific Gas and Electric Company's Co-generation and Small Power Project Quarterly.

A possibly less accurate, but much cheaper method of determining the value of water for electrical generation is to use the regression model developed by Romm et. al. This model predicts value based on the elevation of the highest power plant on the stream in question. It appears to be a very useful tool in situations where the resources are not available to perform a more involved analysis.

Economic Value of Augmented Flows for Irrigated Agriculture: If irrigated agriculture will receive an increased supply of water as a result of a restoration project, we recommend that the value of that increment be determined using the 'farm budget' technique, described in the main body of this report. The method calls for subtracting all non-water inputs from a farm's total revenues. The residual is the maximum value of water to the farm operation. If procurement and storage costs are subtracted also, an estimate of that water's value in-stream is the result.
Similar results can be obtained using a linear programming model, but the resources to construct such a model are not often available to the analyst. LP models also assume optimal management behavior on the part of the farmer—an assumption that is not always borne out.

A less expensive, yet quite reliable method of determining the value of water to irrigated agriculture is the pumping-cost-avoided method. The per-unit cost of groundwater pumped in a given region is considered to be the value of an equivalent unit of surface water. Subtracting transportation and facility costs yields an in-stream value. Using this method, Romm, et al. obtained an average value of $20.63 per acre-foot for water from all California national forests, and a value of $23.88 per acre-foot for water originating in the upper Feather River watershed. These values can be used, with appropriate adjustments, if the resources to perform a complete analysis are lacking.

**Increases in Desirable Fish Populations:** Although we did find references to two methods that can be used to predict the impact of a project on fish populations, we cannot vouch for their accuracy. The habitat classification methods of Frissel et al. (1986) and Lotspeich and Platts (1982) are capable of yielding relatively rough estimates. The method developed by Wesche et al. (1985) may also have potential. We recommend, however, that the authors themselves be contacted regarding the usefulness, accuracy and limitations of this method. The authors are all researchers at the Wyoming Water Research Center, University of Wyoming, Laramie, Wyoming.

The two commonly-used fish habitat models—the Instream Flow Incremental Methodology (IFIM) and the Habitat Evaluation Procedure (HEP)—yield indices of habitat suitability, but stop short of translating those values into population values. We do not know how successful the creators of these procedures have been in developing a reliable way to translate the habitat indices they yield into population numbers. That information can be obtained at the addresses and phone numbers appearing in the main body of this report.
Increased Wildlife Populations: We were only able to locate a single predictive model that might be useful in estimating the impacts of a project on wildlife. Unfortunately, this model is based on and designed for the Colorado River riparian zone (Anderson and Ohmart 1985). Although the authors warn that the 1985 version of their models were not readily generalizable to other riparian areas, they reported that they were currently working on models applicable to a broader range of such habitats. Both authors can be contacted through the Center for Environmental Studies, Arizona State University, Tempe, Arizona.

A need exists for a method which will reliably predict changes in wildlife populations. In the interim, the analyst will have to rely on the professional judgement of wildlife specialists.

Valuing Increased Fish and Wildlife Populations, and Other Changes in Site Quality: These values can all be estimated using the travel cost method (TCM) or the Contingent Valuation Method (CVM). Before attempting to conduct a TCM or a CVM study, one should check the literature to see if a usable study has already been completed for the site of interest (or one sufficiently similar to it). The main body of this report contains a list of journals which are likely to contain the results of such studies.

In most cases, TCM and CVM should provide nearly equivalent estimates. Which method one should use in a given study, however, depends upon several factors. These are summarized in Table 1.

In order to evaluate changes in site quality (increased fish or wildlife populations, improved water quality, etc.) using TCM, a regional travel cost model which takes in more than one site is recommended.

Each of these methods is summarized in the main body of this report. Some potentially useful examples are also given. If resources are limiting, some of the models or actual values provided with these examples can be used or adapted for use in other analyses.
Table 1: The Travel Cost Method Versus The Contingent Valuation Method: Deciding Which to Use

<table>
<thead>
<tr>
<th>Consideration</th>
<th>TCM</th>
<th>CVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the site the only site visited?</td>
<td>Only site</td>
<td>One of more than one site</td>
</tr>
<tr>
<td>Option, existence, and bequest values?⁴</td>
<td>Low values</td>
<td>High values</td>
</tr>
<tr>
<td>Congestion levels at the site</td>
<td>Uncongested</td>
<td>Congested or Uncongested</td>
</tr>
<tr>
<td>Resources available to analyst.</td>
<td>Relatively limited</td>
<td>Less limiting</td>
</tr>
<tr>
<td>Site characteristics</td>
<td>Relatively small; discrete entry points; Regional TCM for very large area</td>
<td>Larger; relatively unrestricted entry</td>
</tr>
<tr>
<td>Site &quot;existence&quot;</td>
<td>Site currently exists</td>
<td>Site currently exists, or is only proposed</td>
</tr>
<tr>
<td>Variation in distance and travel cost</td>
<td>Variation Essential</td>
<td>Variation not necessary</td>
</tr>
<tr>
<td>Existence of visitation data prior to study</td>
<td>This data can be used; more data may not be necessary</td>
<td>Some type of survey necessary regardless of data availability</td>
</tr>
<tr>
<td>Site quality and need for marginal values</td>
<td>Multiple site or regional TCM model needed</td>
<td>Can be obtained at single site, or over multiple sites</td>
</tr>
</tbody>
</table>

⁴Option value: the value of one's option to visit a site, regardless of whether or not such a visit ever takes place; existence value: the value of simply knowing a site exists, given that one is unlikely to ever visit it; bequest value: the value of knowing the site will be available to one's offspring. These values are highest when rare or endangered entities are present on the site.
**Property Values:** Anticipated changes in property value resulting from a restoration project should be evaluated using the 'comparison' method. Property exhibiting conditions similar to anticipated post-project conditions should be located, and its value determined. Property assessments are available in the County Assessor's office. Should these assessments be outdated, or otherwise unsatisfactory, an independent appraisal can be conducted. The differential between the current value of the affected properties, and the value of the comparison properties can be used in benefit-cost, or other financial/economic analyses.

**Financial Analysis:** If the cash costs and benefits that will accrue to private entities as a result of a restoration project must be calculated, we recommend performing the necessary calculations only after all other phases of the analysis are completed. We make this recommendation because most watershed restoration projects—because they involve public funds as well as off-site impacts—will probably require the completion of a full benefit-cost analysis. If the benefit-cost analysis performed is comprehensive and accurate, it will include all the values one needs to perform a financial analysis. Some of those values may have to be adjusted somewhat, since market distortions (usually the result of government intervention in private markets) are corrected for in a benefit-cost analysis, but such corrections are usually simple to make: one need only reverse the calculation that was done to remove the effect of the distortion. In sum, a comprehensive benefit-cost analysis will embody any type of financial analysis that should ever be necessary.

**Regional Analysis:** There is really only one widely accepted technique for evaluating the impacts of a project on a specific region’s economy: input-output analysis. Input-out analysis permits the analyst to estimate the full effects on the regional economy of an infusion of new funds, or the loss of existing funds. Included in this "full effect," are the secondary, tertiary, etc. effects of an economic stimulus as it passes through the local economy. These effects are felt, for example, when new money in the region passes from the wage-earner who first receives it to a local merchant, who then uses it to buy make a purchase from another local supplier, and so on. The steps one goes through to perform an input-
output analysis, as well as sources of needed information, are summarized in the main body of this report.

**Recommendations for Future Analysis**

Applying the framework developed in this report to Red Clover Creek, or similar watershed restoration projects, will involve assembling an interdisciplinary team. The first job of this team would be to decide upon, or actually develop appropriate predictive methods (e.g., models). The baseline data required by these models would then be collected. Once all data is collected, and all predictions are made concerning the long-run time path of all key biological and physical effects, economists can collect additional site-specific values on the resource outputs generated from the vegetation and hydrologic changes specified by the other team members. With all of the data and models brought together by the team, a comprehensive benefit-cost analysis and regional economic analysis could be performed at Red Clover Creek. This analysis could answer still outstanding questions concerning whether the economic benefits of a hydrologically and biologically successful demonstration project would warrant more such projects, similar, but redesigned projects, or a re-thinking of the current approach to watershed management.

Such an interdisciplinary team could be assembled by drawing from all interested parties. However, getting a long-term, serious commitment to this effort from such a disparate group may present a challenge. Alternatively, a team assembled from the University of California and/or Pacific Gas and Electric Company might be more focused and face fewer coordination costs in performing such a comprehensive, interdisciplinary study.

The lessons learned from such a study would be beneficial to future Soil Conservation Service projects, as well as other coordinated resource management projects.
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