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Report to Sen. Edmund S. Muskie, Chairman, Senate Committee on Budget; Sen. Henry Bellmon, Ranking Minority Member; by Elmer B. Staats, Comptroller General.

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When the Corps of Engineers estimates costs and benefits of proposed water resource projects, it encounters uncertainty. The two basic probability approaches to analyzing uncertainty are the "relative frequency" approach which relies on past events and the "subjective interpretation" approach which depends on whether an event will occur at all.
Findings/Conclusions: The Corps is more successful in analyses of costs and benefits which depend on the "relative frequency" approach. For example, if floods have occurred at a certain frequency in the past, they can be expected to occur at similar frequencies in the future. However, predictions of events such as future development in a flood-prone area are subjective. The Corps' treatment of this type of uncertainty could be improved. For example, when an estimate of future events is based on the judgment of a panel of experts, it should reflect the degree of agreement in the panel, not just the "average" opinion.
Recommendations: The Corps should: explicitly recognize intangible benefits and costs and show what effect they have on judgments about a project, indicate the level of confidence surrounding estimates which involve uncertainty, make increased use of sensitivity analysis to show the potential impact of uncertainty on expected costs and benefits, adjust estimates to account for uncertainty, incorporate an "option" value in its analysis to reflect the fact that an irreversible action may preclude some other action whose future value could be greater than expected, and consider devoting more analysis to factors that are the greatest sources of uncertainty. (HTW)

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REPORT BY THE

RELEASED 6/9/78

Comptroller General

OF THE UNITED STATES

Better Analysis Of Uncertainty Needed For Water Resource Projects

Two types of uncertainty surround estimates of costs and benefits from water resource projects. The first involves events that are repeatable--like rainfall--and that will occur with some frequency. The second involves events that will simply either occur or not occur--a particular rate of population growth, for example.

The Army Corps of Engineers' approach in dealing with the uncertainty of repeatable events is correct. For nonrepeatable events, however, the Corps' analysis could be improved in several ways.

GAO recommends improvements designed to indicate the range of likely values that a variable might realize in the future.

This report was requested by the Senate Budget Committee.

UNITED STATES GENERAL ACCOUNTING OFFICE

PAD-78-67
JUNE 2, 1978

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-167941

The Honorable Edmund S. Muskie,
Chairman
The Honorable Henry Bellmon,
Ranking Minority Member
Committee on the Budget
United States Senate

In accordance with your August 5, 1977, request, this report discusses the use of probability analysis in calculating benefits for water resources projects, with special reference to the Corps of Engineers' feasibility studies.

At your request, we did not obtain written agency comments. We did, however, discuss portions of the report with Corps officials. We have also received informal comments from the Corps, which have been incorporated in the report where appropriate.

Generally, the Corps' analysis could be improved by giving more recognition to the possible differences between expected and realized benefits and costs. Specifying the sources, magnitudes, and likelihood of such differences would help the decisionmakers evaluate proposed water projects.

As arranged with Committee staff, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from the issuance date At that time, we will send copies to appropriate Senate and House committees; the Director, Office of Management and Budget; and the heads of departments and agencies directly involved.

Elmer B. Staats

Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE SENATE COMMITTEE ON THE BUDGET

BETTER ANALYSIS OF UNCERTAINTY NEEDED FOR WATER RESOURCE PROJECTS

D I G E S T

There is always an element of uncertainty in the estimated costs and benefits of a proposed water resource project. The Corps of Engineers does a good job of analyzing some types of uncertainty, but does less well with others. Congressional and executive branch evaluations of water resource projects could be aided if the Corps provided greater and more explicit recognition of the uncertainty in its cost and benefit estimates.

This report discusses two basic approaches to analyzing different sorts of uncertainty.

One, the "relative frequency" approach, relies heavily on past events. If, for example, circumstances leading to a flood of a certain size have occurred on the average of once every 30 years for the past century, this fact can be used to deal with uncertainty about future floods. The analysis would rely on the proposition that a flood of that size will occur, on the average, once every 30 years in the future. The Corps' analyses of costs and benefits generally handle this sort of uncertainty quite well.

The second approach is the "subjective interpretation" approach. In this case, the issue is not how often a particular event will occur, but whether it will occur at all. For example, the benefits of a flood control project will largely depend on the extent of future development in the potentially flood-prone area. If intensive development will occur, the damages avoided through flood control (the benefits of flood control) will be greater than if development were sparse.

PAD-78-67

Unlike predictions of the frequency of particular meteorological and hydrological conditions, however, predictions of the pace of development are inherently subjective. The Corps' treatment of such subjective uncertainties could be improved. For example, when an estimate of future events is based on the judgment of a panel of experts, the estimate should reflect the degree of agreement in the panel, not just the "average" opinion.

To help decisionmakers understand the extent and significance of uncertainty in its estimates of costs and benefits, the Corps should:

--Explicitly recognize intangible benefits and costs and show what effect they have on the Corps' judgments about a project.

--Indicate the level of confidence surrounding estimates which involve uncertainty.

--Make increased use of sensitivity analysis to show the potential impact of uncertainty on expected benefits and costs.

--Adjust its estimates of expected costs and benefits to account for uncertainty.

--Incorporate an "option" value in its analysis, to reflect the fact that an irreversible action taken today may preclude the Nation from taking some other action whose future value could be greater than currently expected. This possibility exists when there is uncertainty concerning the future value of the existing situation, or when the situation could be modified by new information, such as the discovery of a unique natural resource.

--Consider devoting more of its analysis to those factors (for example, economic variables) that are the greatest sources of uncertainty.

At the request of the Senate Committee on the Budget, GAO did not seek written comments on this report. However, the contents were discussed informally with Corps officials. Some of GAO's recommendations are, at least in part, already being met by the Corps--the use of sensitivity analysis, for example.

Contents

CHAPTER 1

INTRODUCTION

When the expected benefits or costs of a water resource project are uncertain, a single benefit-cost ratio provides limited assistance in deciding whether to fund the project. A decisionmaker should also know the size of other possible benefit-cost ratios and their likelihood of occurrence. Corps of Engineers benefit-cost analyses focus on the estimation of expected values and, generally, do not clearly show the degree of uncertainty inherent in particular projects.

OUR ROLE

In a letter dated August 5, 1977 (see app. I), the Chairman and Ranking Minority Member of the Senate Committee on the Budget requested that we study certain aspects of water resource programs. This report deals with one issue discussed in that letter--the use of probability analysis in calculating benefits from water resource projects.

CONTENT OF THIS REPORT

Uncertainty, as applied to water resource projects, has two distinct interpretations. One, the relative frequency approach, involves events having repeatable outcomes. The other, the subjective approach, is viewed as a quantified statement of belief.

Chapter 2 discusses the relative frequency approach and the calculation of expected benefits from flood control projects. Chapter 3 describes subjective uncertainty and presents a number of methods for dealing with it in benefit-cost analyses. Chapter 4 summarizes our conclusions and recommendations regarding Corps of Engineers benefit-cost analyses.

SCOPE OF REVIEW

Our review was made primarily at the Corps of Engineers headquarters in Washington, D.C. We examined Corps manuals and circulars, as well as the Federal Register, for policy statements. There are no written Corps policy statements covering some of the issues discussed in this report. In these cases we referred to a 1950 document issued by an interagency committee on water resources. (See app. II, No. 10.) All policy statements taken from this source (as well as those taken from expired Corps engineering manuals and circulars) were discussed with Corps officials and verified as describing actual Corps policy. Throughout the report this document is (in the text) referred to as "Proposed Practices." We also examined eight recent feasibility studies for proposed water projects, most of them concerned with flood control, to determine the Corps' practice for dealing with uncertainty in its benefit-cost analyses. (See app. II, Nos. 14, 16-22.)

As agreed with the Committee, we limited the scope of our review to examining the use of probability analysis in calculating benefits from water resources projects and to recommending methods by which this analysis could be improved. At the Committee's request, we did not obtain written agency comments on our report. We did, however, receive informal comments, which have been incorporated in the report where appropriate. These comments were not subjected to internal review within the Corps or the Army; consequently, they should not be interpreted as the official position of either organization.

CHAPTER 2

RELATIVE FREQUENCY APPROACH TO UNCERTAINTY

COMPUTING BENEFITS

Principles

The relative frequency interpretation, the classical interpretation of probability, is well suited for making inferences about games of chance--the original application of probability theory. 1/ In these instances, uncertainty can involve the outcome of a coin toss, the spin of a roulette wheel, or the value of a hand of cards. All of these games have a common characteristic--the play of the game is repeatable under the same circumstances. The probability of a given outcome is seen as the relative frequency of its occurrence when the event is repeated many times. The expected value of a series of independent outcomes is the average value of these outcomes when each is weighted by its probability (observed relative frequency) of occurring.

The way this type of uncertainty should be dealt with in the Corps' benefit-cost analysis can be demonstrated by an example relating to flood control. 2/ The benefits from flood control include the prevented damages to property on the flood plain. The damages are determined by the value of the property and the extent of flooding. Although the extent of flooding (and, hence, damages) cannot be known with certainty for any future time period, the expected amount of flooding can be predicted from past experience.

Suppose that for a certain river the damages caused by its annual peak flood were recorded over a 100-year period. Suppose further that in 5 of those 100 years, flooding caused between $21,000 and $23,000 in damages. Taking the midpoint of this range, we could say that there is a 5-percent probability that in any 1 year flooding will cause $22,000 in damages. This probability is simply the relative frequency with which floods of this size occurred during the period of observation. 3/

The expected value of completely eliminating floods on this river (the benefits of flood control) is computed by first calculating the annual damages expected with no flood control. This is done by multiplying each level of damages by its probability of occurrence and summing the resulting products. Suppose past observation had yielded the following data.

Table 1

Hypothetical Flood Damages and Probabilities of Occurrence

Range of flood damage	Midrange	Probability of flood causing damage in specified range
(000 omitted)		
33-45	39	0.01
29-33	31	.02
25-29	27	.03
23-25	24	.04
21-23	22	.05
19-21	20	.06
15-19	17	.07
13-15	14	.09
11-13	12	.12
9-11	10	.14
0-9	4.5	.17
0	0	.20

The expected annual amount of flood damages would then be:

$$(.20 \times 0) + (.17 \times 4.5) + \ldots + (.01 \times 39) = \$11,135$$

With complete flood control, the probability of any level of damages occurring would be 0.0, and expected annual damages would then be:

$$(0.0 \times 0) + (0.0 \times 4.5) + \ldots + (0.0 \times 39) = \$0$$

The benefits of complete flood control are then the difference between these two expected values ($11,135 - $0). Thus, an average of $11,135 in damages would be prevented by completely controlling floods on this river. Of course, in some years the damages would have been greater, and in other years they would have been less. Nonetheless, given the relative frequency of various levels of damages observed in the past, complete flood control would yield average annual benefits of $11,135.

The expected annual benefits from partially controlling floods on this river can be calculated similarly. With partial flood control, the probability of each flood stage occurring would be reduced, but not to zero. If we constructed a project that reduced the probability of each level of damages occurring by 90 percent, our expected annual damages would also decrease by 90 percent, to $1,113--leaving $10,022 in expected damages averted as the annual benefits from this project. 4/

Corps of Engineers policy

A general policy that all Federal agencies could follow in evaluating flood control benefits was expressed in "Proposed Practices." The section of this document related to the relative frequency view of probability reads:

> "The amount of flood damage to be expected in a given area varies with the magnitude of the floods expected. Although the date of occurrence of a flood of any given magnitude cannot be predicted, the probability of occurrence of a flood of any given magnitude in a specified period of time such as 50 or 100 years or in a particular season of the year can be estimated when adequate stream flow data are available. Accordingly, the average annual damage to be expected from all floods that may occur in the period of analysis of a project can best be computed on the basis of the expectancy in any one year of the various amounts of flood damage that would result from floods of all magnitudes up to those approaching the maximum probable flood. The difference in expected damages with and without flood control is the benefit attributable to the project." 5/

This prescription parallels the methodology outlined above, and expresses the appropriate way in which uncertainty of a relative frequency nature should be dealt with in benefit-cost analysis. The Corps in fact uses this approach in dealing with the uncertainty surrounding benefits to be derived from its flood control projects.

Corps of Engineers practice

The Corps' approach to estimating flood control benefits is exemplified by a recent study of a proposed project:

> "Benefits of the recommended plan would be the reduction in future flood damages throughout the Skagit River flood plain, downstream from the mouth of the Baker River. Future average

annual flood damages prevented represent the difference in average annual flood damage that would be expected without the project change and residual average annual damages which would exist with the change." 6/

This methodology parallels that expressed in the above policy prescription.

Another recent study for a proposed project presents tables of relative frequencies for various observed flood levels and the Corps' estimates of corresponding damages. One table relates to natural conditions and another expresses the expected conditions with flood control. 7/ These data are used to calculate expected annual damages with and without a flood control project, which further substantiates our opinion that the Corps' methodology, insofar as it deals with relative frequencies and the estimation of expected values, is correct.

Recommended changes in the Corps' analysis

No changes are needed in either the Corps' policy or analytical practice concerning events that are repeatable and that have predictable future outcomes. Further, there is no reason to change the presentation of either the underlying data or the results of this analysis. This is not to say, however, that the benefits estimates are necessarily correct or that the times when benefits will be realized can be predicted.

INCREMENTAL ANALYSIS AND INTANGIBLE BENEFITS

A flood control project of a certain scale reduces to zero the probability of damages from streamflows below some magnitude. It also reduces the likelihood of damages from larger streamflows, but these probabilities remain positive. As the scale of a project increases by increments, the threshold of zero probability rises to higher streamflow levels, and the likelihood of damages from the greater streamflows that remain only partially controlled diminishes. After some point, however, additional increments will yield progressively smaller expected benefits. This is true because the likelihood of a very large streamflow is typically small; thus, the expected damages associated with it, even with no flood control, are also small. Eliminating the possibility of $1 million in damages, that have only a 0.05-percent chance of occurring, yields an expected annual benefit of $500.

With measurable benefits, it is appropriate to limit the scale of a project to the level at which the incremental benefit equals the corresponding incremental cost. Increasing the scale beyond this point would yield an incremental benefit smaller than its associated cost, which is a waste of resources. As stated in "Proposed Practices":

> "* * * the optimum scale of development is that at which the net benefits are at a maximum. Net benefits are maximized if the scale of development is extended to the point where the benefits added by the last increment of scale or scope are equal to the costs of adding that increment." 8/

The Corps of Engineers has adopted the maximization of net benefits as its general policy guide for determining the scope of flood control projects. A recent Corps policy circular advises that the planner "determine the level of protection afforded by maximizing tangible net economic benefits." 9/ That the Corps puts this policy into practice is confirmed by recent studies for proposed flood control projects. 10/

> "Maximization of net benefits. The proposed plan was formulated to yield the maximum excess benefits over cost. After establishing that the three-element plan was economically superior, preliminary cost estimates and benefits for similar three-element plans of varying scope were evaluated to determine the extent of improvements which would yield the maximum excess of benefits." 11/

Determining the scope of a project using this maximization criterion is possible only when all benefits and costs can be expressed in dollar values. With many projects this is not the case. There can be intangible benefits from flood control, such as reduced risk to human life, as well as intangible costs, such as a decrease in the beauty of a river and its surroundings. Although benefits and costs do not enter into the maximization calculus, they can nonetheless influence decisions about the scope of a flood control project. This is exemplified by the economic criteria used in a recent Corps study for a proposed flood control project.

> "Scope of the development is such to provide the maximum net benefits, however, intangible considerations, such as risk to lives and

property, could result in a project size which is greater than that which would produce maximum net benefits." 12/

It is appropriate that intangible considerations affect the scale of a flood control project. However, the Corps' analysis of these intangibles could be improved, along with its presentation of their importance to congressional decisionmakers. The analysis could be improved by increased quantification of intangible elements that lend themselves to numerical measurement. The Corps has apparently already begun doing this, 13/ and further efforts would be desirable. In addition, probabilities attached to intangible elements should be specified as accurately as possible.

As with other benefits, the expected number of lives that will be saved each year by successive increases in the scope of a flood control project will likely diminish. Some people may be uncomfortable with this calculated view of human life. Corps officials have, in fact, suggested that the number of lives expected to be saved by successive increments should not be considered in deciding a project's scope, because it is not possible to place a value on human life. However, we believe that such information gives decisionmakers a more concrete idea of the benefits (and costs) involved in changing the scope of a project than do general statements of concern for public health and safety.

When the Corps believes that the scale of a project should be other than that which maximizes net tangible benefits, it should present the following for various possible scales of the project, including both the "maximum net benefits" and "recommended" scales:

--The expected benefit-cost ratio.

--The level of tangible net benefits.

--The intangible benefits and costs that are quantifiable.

--The intangible benefits and costs that are not quantifiable.

This information could be more readily evaluated if it were presented in a concise, tabular form as part of the benefit-cost analysis for a proposed project. Further, the estimates for the "maximum net benefits" and "recommended" scales might be highlighted in such a way as to aid the decisionmaker in selecting one or the other.

CHAPTER 3

SUBJECTIVE APPROACH TO UNCERTAINTY

The subjective interpretation of uncertainty is well expressed by an originator of this area of probability analysis, who states that, in the subjective view:

> "* * * probability measures the confidence that a particular individual has in the truth of a particular proposition.* * * [This view postulates] that the individual concerned is in someways 'reasonable,' but [it does] not deny the possibility that two reasonable individuals faced with the same evidence may have different degrees of confidence in the truth of the same proposition." 14/

A subjective statement involves events that have uncertain outcomes and that are not repeatable (the 1978 World Series, for example), and is interpreted as a measure of degree of belief; a quantified judgment of a particular individual.

The distinction between the subjective and relative frequency views of uncertainty is exemplified by the different interpretation given to a projection of future population growth in an area, as opposed to a projection of future rainfall. In the case of rainfall, the average annual amount can be calculated from past observations. Athough this may be an overestimate one year and an underestimate another, on the average it will be correct. This is not necessarily true for a population projection, however. A prediction of future population growth in an area can be based on past trends, but such growth is not a repeatable event. Thus, there is no assurance that a population projection will be correct on average.

The uncertainty inherent in this type of prediction can be dealt with in a number of ways in benefits-cost analysis. Each of our suggested approaches will be discussed separately, along with a review of the Corps of Engineers' policy and practice regarding each approach.

MEASURES OF DISPERSION

Principles

While for many uncertain factors "no appropriate basis is available for prediction," 15/ such is not the case for others. For example, to estimate the expected benefits of a flood control project, one might have to estimate future development on the flood plain, since this would determine the extent of future damages prevented by flood control. 16/ One method of deriving such a projection would be to ask various qualified individuals to make their own projections, and then derive a projection from these. Suppose 10 individuals were sampled and they made the following projections of annual population growth (column A).

Table 2

Hypothetical Population Growth Rates

Individual	Projected growth rate A	Projected growth rate B
1	2%	7.5%
2	5	7.4
3	10	7.5
4	8	7.2
5	3	7.3
6	17	7.6
7	4	7.4
8	9	7.7
9	5	7.1
10	11	7.3

The average of these growth rates, 7.4 percent, could be used as an estimate of expected future population growth.

However, it is important to consider the confidence that can be attached to this estimate. If, instead of the projections listed in column A, suppose that the individuals polled had responded with those in column B. The average of these growth rates is also 7.4 percent. The projection of population growth would be the same in either instance, but one would have more confidence in an estimate derived from column B responses than one derived from column A because there is greater consensus among the experts in the former case. This consensus can be measured by the dispersion of the individual estimates around their average value. 17/ The greater the dispersion relative to the expected (average) value, the less confidence the decisionmaker could have in this expectation. The degree of dispersion can be used as a gauge for caution in interpreting a project's benefit-cost analysis.

Corps of Engineers policy

Corps policy statements do not discuss calculating measures of dispersion when the expected value of a variable is derived from a sample of estimates. 18/

Corps of Engineers practice

A recent Corps pollution control study 19/ involved an analysis similar to the hypothetical example presented above. Instead of soliciting a range of population growth estimates, the Corps obtained a sample of studies estimating the costs of salt pollution to water users in an area. Estimates from area studies were combined to obtain an "average user cost factor," measuring the benefits to users of having the Corps control the pollution. For an acre-foot of water, the cost estimates for municipal and industrial users ranged from $4.27 to $18.42 per unit of pollution, with an average of $9.89, which was used in the benefit estimates. 20/ No summary measure of dispersion was presented, in keeping with the fact that the Corps policy guidelines do not mention calculating such measures.

Recommended changes in the Corps' analysis

When the Corps bases an estimate for some cost or benefit factor on a sample of possible values, it should report not only the average of these values, but also some measure of dispersion around this average. It should also develop criteria relating this measure of dispersion to the average and indicating the amount of confidence that can be placed on the average. 21/ This information should be presented as part of a project's benefit-cost analysis, and should be highlighted whenever the measure of dispersion indicates the need for caution in evaluating estimated benefits and costs.

ASSIGNMENT OF PROBABILITIES

Principles

One method for indicating the degree of uncertainty associated with components of a benefit-cost analysis is to quantify that uncertainty in a probability estimate. When dealing with events that are not repeatable, this quantification amounts to a subjective probability statement. While assigning probabilities to individual components (such as a population projection) can be informative, this approach is more useful to the decisionmaker when probability statements are attached to the summary estimates of benefits and costs themselves and to the corresponding benefit-cost ratio and net benefits estimates.

It is often more useful to establish a confidence interval for some statistic rather than simply assigning it a subjective probability. For example, to say that there is a 50-percent chance that a project's realized benefit-cost ratio will be 2.0 is of limited value, since such a statement does not indicate the likelihood of alternative possibilities. It would be more informative to say that there is a 90-percent chance that the project's realized benefit-cost ratio will fall between 1.5 and 2.5. 22/

Corps officials point out that such a confidence interval would have to be based on judgment, rather than a statistical estimate of probabilities. This is to be expected since the uncertainty associated with many elements of a benefit-cost analysis is of a subjective, rather than relative frequency, nature. Of course, this observation is equally applicable to the Corps' present designation of uncertainty levels for these elements, as described below.

Corps of Engineers policy

The Corps' policy concerning the assignment of probabilities in a benefit-cost study is summarized in the following statement.

> "Probabilities of Occurrence. Although often difficult to quantify, some indication of probability should be associated with each variable, hypothesis and assumption found to be significant to the study results. Whereas study results may be highly sensitive to a given assumption, if the planner has a high level of confidence (high probability) in its occurrence, its use in plan formulation and evaluation would be justified * * *. In extreme cases where the probability of occurrence or validity may be critical * * * the methods by which these probabilities were derived should be well documented. 23/

This policy statement has two shortcomings. First, it does not call for assigning probabilities to benefits and costs themselves, but appears to limit such assignments to the underlying factors. (In practice, however, the Corps' analysis does go beyond this limitation.) Second, it makes no mention of confidence intervals, but simply suggests attaching single probability estimates whenever quantification of uncertainty is possible. 24/

Corps of Engineers practice

The quantification of uncertainty in the Corps' benefit-cost analysis is exemplified by a recent study of a proposed flood control project. 25/ In that study the Corps quantified uncertainty regarding the project's tangible benefits and costs, as well as its effects on a number of intangible factors, in the following way.

UNCERTAINTY

a Level of uncertainty associated with the impact is greater than 50 percent because of data limitations or inadequacy of theoretical framework or methodology.

b Level of uncertainty is between 10 and 50 percent.

c Level of uncertainty is less than 10 percent. 26/

While we appreciate this effort at quantification, we do not feel that the information is presented in a manner useful to a decisionmaker. For example, by attaching uncertainty level b (10 to 50 percent) to a portion of its estimated annual benefits, 27/ the Corps is essentially saying that the probability of its benefits estimate being realized is between 50 and 90 percent. It is not clear how this should be interpreted, because we are not told what other possibilities exist or how likely they are. Does the statement mean that there is a "fairly good" chance that the estimated benefits will be realized? If so, then a verbal statement would have sufficed, since the numerical version adds nothing to our understanding of the risks involved. In addition, the Corps did not assign any probability statement to the estimated benefit-cost ratio presented in the body of the report (the discussion of uncertainty appears in an appendix). 28/

Recommended changes in the Corps' analysis

Our survey of eight recent Corps studies did not reveal any more extensive attempts to quantify uncertainty than the one just described. Based on these findings, we suggest the following changes. First, the Corps should establish, as a matter of policy as well as practice, that any quantification of uncertainty be applied to its estimates of a project's net benefits and benefit-cost ratio. Second, the Corps should establish the policy and practice of using confidence intervals to bracket the expected values of those variables that it views with uncertainty. Third, the quantified effects of uncertainty on a project's benefit-cost analysis should be included in the main presentation of that analysis.

SENSITIVITY ANALYSIS

Principles

The principle underlying sensitivity analysis is straightforward. If uncertainty exists about the future value of some component of an analysis, but a range of values can be established within which it might vary then this range can be used to calculate how the final estimates of the analysis will vary with variations of the uncertain component.

For example, the benefits of a flood control project might depend on future population growth on the flood plain. The expected rate of population growth may be somewhat uncertain, however, and, consequently, it would be desirable to see how benefits would change if the estimate were wrong. This can be accomplished by substituting alternative rates of population growth into the benefits calculation, deriving a different estimate of benefits for each rate of growth. Such a procedure reveals how crucial uncertainty about the population projection is in evaluating the proposed project. If, for all reasonable rates of population growth, benefits were sufficient to justify the project, there would be less cause for concern than if a small decrease in the growth rate caused benefits to fall short of expected costs.

Corps of Engineers policy

The Corps' stated policy regarding sensitivity analysis mirrors our suggested approach.

> "Sensitivity Analysis. Sensitivity analysis is a necessary feature of any good, multivariable analysis. The planner cannot be satisfied with the definition of a plan for resource (e.g., land, water, recreation, etc.) allocation that is optimal for a specific set of conditions if the plan is particularly sensitive to changes in the model. Water and land resource allocation models require

> the planner to predict both the rate of changes in the assumed values of the model parameters and the range of conditions over which any particular plan is recommendable; these data are obtained by sensitivity analysis. In cases where a solution is found to be particularly sensitive to a given variable or parameter, such information must be made explicit in the plan formulation and evaluation report." 29/

We agree completely with this position.

Corps of Engineers practice

An example of the Corps' use of sensitivity analysis is contained in a recent study for a proposed water pollution (by salt) control project. The problem and the Corps' approach are described below:

> "As previously stated, the recommended project would control an average of 1,360 tons of total dissolved solids each day. However, the salt load downstream from the project would probably not be immediately reduced by this same amount because of residual salt in the streambed of the Brazos River and three main stem lakes. Thus, the quality improvement * * * would not be fully realized until this residual salt can be flushed into the Gulf of Mexico. * * * Information on which to base a reasonable time-lag period is not available; * * * however, it can be shown * * * what the estimated benefits and benefit-cost ratio would be assuming various time-lag periods." 30/

Accompanying these statements are a diagram and a table showing how the benefit-cost ratio and net benefits vary with (presumably) reasonable variations in the time-lag between construction of the project and flushing of the river (ranging from 0 to 50 years). This analysis is completely consistent with the Corps' policy.

There is, nonetheless, one shortcoming in this particular application of sensitivity analysis. The analysis shows that, if the time lag were zero, the benefit-cost ratio would be 2.1 and that, for longer time lags, the ratio would be lower. However, the benefit-cost ratio attributed to the Corps' recommended plan is 2.2, which can only occur if the time lag is negative--an impossibility. It would be more reasonable for the Corps to assume a time lag within the range it uses for its sensitivity analysis, with zero being a minimum. Also, the Corps' presentation of its benefit-cost analysis does not explicitly state the time lag assumed in calculating the net benefits and benefit-cost ratio of its recommended plan. The decisionmaker could more readily interpret the analysis and evaluate the proposal if this information were clearly stated.

Recommended changes in the Corps' analysis

We do not disagree with either the Corps' policy or, for the most part, its practice regarding sensitivity analysis. However, we feel that, when this analysis identifies a variable which could significantly affect a project's net benefits, the Corps should clearly state the value assumed for it in calculating expected benefits and costs. In addition, the Corps ought to use sensitivity analysis more than it has in recent studies.

Corps officials cite two problems. First, the quantity of sensitivity analysis provided to decisionmakers could easily become unwieldy, since numerous uncertain factors are usually involved in any benefit-cost analysis. Second, benefit-cost ratios less than unity would often result from reasonable variations in many of these factors, even when the expected ratio exceeds unity. This raises the question of what project authorization decision rule is appropriate. The first problem will have to be resolved by Corps analysts, while the second must be left to the Congress.

The Corps is required to make recommendations on projects, not simply provide information. It bases its recommendations on a project's most likely benefit-cost ratio, and recommends authorization when this ratio exceeds unity. Such a decision rule need not be abandoned when sensitivity analysis shows that the ratio could reasonably fall below unity. This information merely gives congressional decisionmakers a basis for either accepting or rejecting the Corps' recommendation.

ADJUSTMENT OF EXPECTED BENEFITS AND COSTS

Principles

When the future values of either costs or benefits are uncertain, they can be adjusted to reflect the extant degree of uncertainty. Benefits could be decreased and costs increased in order to reduce the likelihood of an undesirable project being approved.

Corps officials contend that there is no inherent value in being conservative when dealing with uncertainty. Not approving a project that would have been desirable is as objectionable as approving an undesirable one. Consequently, the analyst should not necessarily adjust benefits down or costs up to account for uncertainty.

There is nothing basically wrong (or, for that matter, right) with this view. How much, if any, adjustment should be made for uncertainty depends simply upon the decision-maker's attitude toward risk taking, with more conservative adjustments to costs and benefits being made as this attitude becomes more negative.

Corps of Engineers policy

The Corps' policy regarding adjustments for uncertainty is expressed in the following general policy guideline.

> "Methods of allowing for uncertainties or unpredictable risks include the use of estimates of benefits that are reasonably conservative; * * * or including a contingency reserve in project costs to cover unforeseeable developments." 31/

The uncertainties accounted for in the "contingencies" adjustment relate specifically to the design and construction of a project; they do not include adjustments for uncertainties about benefits.

As far as such benefits adjustments are concerned, the Corps' policy is to base its estimates of future benefits on what it considers the most likely future conditions for a flood plain, chosen from a set of possible conditions.

> "* * * [A] number of reasonably probable alternative future conditions should be projected * * * and presented to the public. * * * The one which best reflects the public's desires and aspirations, consistent with * * * economic * * * environmental, social and political systems (is) the most probable future.

"Most Probable Future is the * * * basis for defining the 'without condition' and the planning objectives.* * *

"The primary use of the without condition is in evaluating plan impacts.

"Other determinants of the without condition include * * * economic, environmental, social, and political projections and constraints using the existing conditions as a base." 32/

These statements do not indicate that the estimated benefits derived from these expected conditions should be made conservatively to account for uncertainty, but this appears to be the Corps' approach.

Corps of Engineers practice

Recent Corps studies suggest that, insofar as the "contingencies" adjustment is concerned, the Corps' practice is consistent with the above general policy guidelines. 33/ The Corps also appears to follow its stated policy of basing estimates of flood control benefits on the most likely future conditions for a flood plain. 34/ In addition, in a few instances the Corps deliberately made conservative benefits estimates, in one case specifically citing uncertainty of future conditions as its reason for caution. 35/ This also accords with the policy guideline.

Recommended changes in
the Corps' analysis

When there is uncertainty about the future benefits or costs of a project, the Corps should adjust its estimates to reflect this uncertainty. Although the Corps appears to follow this practice, it does not, in the case of benefits, present its analysis in a way that shows the amount of adjustment made due to uncertainty. Instead of calculating separate conservative and expected estimates, the Corps seems to combine its knowledge of past trends, its view of likely future conditions, and its uncertainty into one conservative estimate. The Corps would do better to indicate the degree of uncertainty surrounding a project's benefits by estimating them both with and without adjustments for this uncertainty.

The amount by which expected benefits or costs are adjusted for uncertainty should be clearly stated in a project's benefit-cost analysis. The differences between both net benefits and the benefit-cost ratio with and without the uncertainty adjustment should be presented. Finally, the sources of uncertainty should be specified and described, and the extent of uncertainty quantified whenever possible. 36/

TREATMENT OF "OPTION VALUE"

Adjustments of expected benefits or costs for uncertainty become particularly important when the construction of a project irreversibly eliminates activities or local ecological conditions that could yield future benefits to some people. An example of such a situation is a proposed flood control project that would create a reservior innundating "several miles of high quality trout stream and about 3000 acres of forest and upland wildlife habitat." 37/ In such cases, when the future value of an activity that would be precluded by a project is uncertain, there exists an "option value" to maintaining the present environment.

This option value, which is in addition to the present evaluation of the expected future benefits derivable from the environment, results from the possibility that our uncertain future valuation of these benefits may exceed their present expected value. As two authors have recently argued:

> "* * * environmental modifications having irreversible consequences may require a premium, over and above all costs, in order to be efficient. The premium is the value of retaining an option to consume the amenity services of an unspoiled environment under conditions of uncertainty as to future demands for the services." 38/

Further, caution should be increased if the future will yield additional information concerning the value of the present "unspoiled environment." It may pay to wait for more information if this can reduce the chances of committing an irreversible error.

Although Federal policy on water projects recognizes the importance of possible irreversible consequences, 39/ we have found no Corps policy statements suggesting that, in the face of uncertainty, a local environment may have an option value in addition to the expected value of its benefits. Likewise, we have not found any policy statements indicating that a project's cost estimate should be increased to reflect this option value when the project would detrimentally and irreversibly alter the local environment.

We suggest that the Corps explicitly recognize option values by increasing its cost estimates when a project would irreversibly eliminate activities or local ecological conditions whose future values are uncertain. This adjustment should reflect the value of maintaining an option, such value being additional to the expected value of the amenities that would be eliminated.

Corps officials have two comments on option value. First, they correctly point out that the option lost by building a water project would not necessarily be an "unspoiled environment," but rather could be any possible alternative use of a site. Determining the appropriate alternative could make calculating option value more difficult. Second, they prefer to omit option value from benefit-cost calculations because, for this reason and others, it would be difficult to measure reliably. We recognize that calculating option value may be difficult, but we nonetheless maintain that it should be considered in a project's benefit-cost analysis, even if it receives only a heuristic treatment.

MINIMIZING UNCERTAINTY

Uncertainty, either of a relative frequency or subjective nature, surrounds many factors in a project's benefit-cost analysis (for example, future weather conditions, population and economic development, and water quality needs). In evaluating a contemplated project, the Corps must integrate all of these factors into a summary measure of expected benefits and costs. The uncertainty inherent in this measure should be minimized (subject to the constraint imposed by limited analytical resources), and as we have suggested above, the extent of uncertainty that remains should be made known to decisionmakers.

Minimizing uncertainty requires that the Corps concentrate its information-gathering and analysis efforts on factors which have values that are relatively more uncertain, which are of greater quantitative importance in determining benefits and costs, and for which the uncertainty is reducible by increased analytical effort.

It is not possible to determine whether or not the Corps has, in the sense of these criteria, effectively allocated its analytical resources. The studies reviewed reveal neither the relative amounts of effort devoted to analyzing the various factors involved in the benefit-cost analyses nor the relative degrees of uncertainty associated with these factors. Consequently, our purpose here is merely to make some observations for the Corps' consideration rather than to suggest particular actions.

These observations are contained in a study that investigates the relative importance of various factors in determining the performance of a particular water resources system. 40/ The techniques used included sensitivity analysis and computer simulation. Four factors were considered in the study. The first factor included hydrologic variables relating to rainfall and waterflow. The second was estuarial behavior, reflecting "the way in which the various factors affecting dissolved oxygen in the estuary are interrelated." 41/ Third, an economic variable encompassed "assumptions about economic growth characteristics of water utilization and waste generation in municipalities * * *; technologic change in production process; and * * * demands for various products for consumption." 42/ Finally, a variable represented the level of water quality to be achieved.

The study found that the relative importance of the variables, measured by the effect that variations in a factor had on total system performance, was:

1. Economic development projection.

2. Water quality objective.

3. Dissolved oxygen modeling.

4. Hydrology.

In relation to the criteria listed above, these results suggest that the uncertainty surrounding economic variables may impart more uncertainty to final benefit-cost estimates than does the uncertainty associated with hydrologic phenomena. A better allocation of limited planning resources for a particular project might devote more time to economic projections and less time to detailed hydrologic specification. As the Corps has pointed out, however, any reduction in the hydrologic analysis used to estimate the expected benefits of a water project is limited by the fact that the same analysis is used to design the project. Corps officials have said that the minimum amount of hydrologic analysis required for the latter purpose will typically exceed the optimum amount needed for the former. In addition, they noted that some past studies have encountered problems due to insufficient hydrologic analysis.

A similar argument can be made for costs and benefits in general. This is partly because most costs are incurred immediately, while most benefits are deferred, and deferred effects involve more uncertainty than do immediate effects. 43/ In addition, "whereas real benefits depend primarily upon variables of an evolutionary and hence, relatively unpredictable nature, real costs depend upon the semi-static principles of engineering theory." 44/

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

In this report, we examine the various ways in which uncertainty affects the evaluation of Corps of Engineers water projects. Uncertainty is viewed from two perspectives: relative frequency, in which probability estimates are based on observations of repetitive events, and subjective, in which probability estimates are seen as statements of belief concerning nonrepetitive events. We have reviewed the Corps' policy and practice in dealing with uncertainty in its benefit-cost analysis, and have made comparisons with the policy and practice that we feel are needed, suggesting changes in the Corps' approach when we found a difference. Accordingly, we recommend the following to the Secretary of the Army.

Regarding uncertainty of a relative frequency nature (flood activity, for example), we see no difference between the Corps' approach and what we would recommend for estimating tangible benefits and costs. However, when the recommended scale of a project is influenced by intangible benefits (the protection of human life, for example), we recommend that, for all possible scales considered, the Corps

--calculate the expected benefit-cost ratio,

--calculate the level of net benefits,

--calculate intangible benefits and costs that are quantifiable, and

--delineate unquantifiable benefits and costs.

Further, the quantified information should be presented in concise, tabular form in a study's benefit-cost analysis, and the information relating to the project scale that maximizes net benefits and the scale that the Corps recommends should be highlighted.

Regarding the analysis of subjective uncertainty (for example, that which surrounds a population projection), we recognize a number of approaches that the Corps could use. Some are already embraced by the Corps' policy or practice, although not necessarily to the extent or in the manner that we believe is appropriate. Specifically, we recommend that:

--When a projection is based on the expected value of a variable derived from a sample, the degree of sample dispersion around this expected value be reported. Also, the degree of dispersion should be related to the expected value by criteria that indicate the confidence warranted by the estimate.

--When the Corps assigns probabilities to benefits or costs, it assign corresponding probabilities to estimates of net benefits and benefit-cost ratios appearing in the main section of its benefit-cost analysis. The Corps should also use confidence intervals for bracketing the expected values of variables viewed with uncertainty.

--When the Corps uses sensitivity analysis, it state the value of the analyzed variable that it uses in calculating expected benefits and costs. It should also show where this value falls in the range of possible values considered. Sensitivity analysis should be more extensively used than it is now.

--The Corps modify its practice of adjusting benefit or cost estimates to account for uncertainty associated with expected benefits. The amount of adjustment and its effect on the expected net benefits and benefit-cost ratio should be reported. The sources of uncertainty should be cited and the extent of uncertainty described and quantified whenever possible.

--The Corps explicitly recognize option values by increasing cost estimates when a potentially desirable activity or local ecological condition would be irreversibly eliminated by a proposed project.

--The Corps devote its limited resources to analyzing variables which involve the greatest amount of uncertainty, which significantly affect the benefit-cost analysis, and for which the uncertainty is reducible by increased analytical effort. This approach could entail a greater concentration on economic projections, as well as on the estimation of benefits rather than costs.

FOOTNOTES

1/Robert L. Winkler and William L. Hays, Statistics: Probability, Inference and Decision, 2nd ed., 1975, pp. 64-65.

2/Adapted from L. Douglas James and Robert R. Lee, Economics of Water Resources Planning, McGraw Hill, pp. 255-256. For other examples, see James and Lee, ibid., pp. 182-231, 256-261, 276-314, or for a larger and more varied sample, "Proceedings of the International Symposium on Uncertainties in Hydrologic and Water Resource Systems," 1972.

3/For a more complete description of the methodology used in this calculation, see James and Lee, op. cit., pp. 231-235.

4/For a more complete explanation, see Otto Eckstein, Water Resource Development, 1961, pp. 117-127.

5/Subcommittee on Evaluation Standards, Report to the Inter-Agency Committee on Water Resources, Proposed Practices for Economic Analysis of River Basin Projects, Washington, D.C., May 1950, p. 39.

6/U.S. Army, Corps of Engineers, Upper Baker Project, Skagit River Basin, Washington, H. Doc. No. 95-149, May 9, 1977, pp. 56-57.

7/U.S. Army, Corps of Engineers, Flathead and Clark Fork River Basins (Flathead River Near Kalispell), Montana, H. Doc. No. 94-635, September 28, 1976, pp. 209-210 and 232-233.

8/Subcommittee on Evaluation Standards, op. cit., pp. 12-14.

9/U.S. Army, Corps of Engineers, Flood Damage Reduction Policy: Level of Protection, EC 1105-2-47, December 12, 1975, p. 2.

10/U.S. Army, Corps of Engineers, Red River and Tributaries, Downstream. From Denison Dam-West Agurs Levee, Louisiana; Days Creek and Tributaries, Arkansas and Texas; and McKinney Bayou, Arkansas and Texas, H. Doc. No. 94-647, September 29, 1976, p. 206. U.S. Army, Corps of Engineers, H. Doc. No. 95-149, op. cit., p. 35. U.S. Army, Corps of Engineers, Lock Haven, Clinton County, Pa., H. Doc. No. 94-577, August 5, 1976, pp. 69, 107-112.

11/U.S. Army, Corps of Engineers, H. Doc. No. 94-647, *op. cit.*, p. 206.

12/U.S. [illegible], Corps of Engineers, H. Doc. No. 95-149, *op. cit.*, p. 35.

13/U.S. Army, Corps of Engineers, *Park River, Subbasin, North Dakota*, H. Doc. No. 94-645, Sept. 29, 1976, p. 66.

14/L. J. Savage, *Foundations of Statistics*, New York: John Wiley & Sons, Inc., 1954, p. 3.

15/Subcommittee on Evaluation Standards, *op. cit.*, p. 23.

16/This "economic development" factor is, in fact, taken into account in the Corps' benefit-cost analyses. See, for example, U.S. Army, Corps of Engineers, H. Doc. No. 95-149, p. 57; H. Doc. No. 94-635, pp. 50, 220.

17/The measurement of dispersion, known as the variance, is calculated by squaring each individual estimate's deviation from the average value, summing these squares, and dividing by the number of estimates. The squareroot of the variance, the standard deviation, is also commonly used.

18/See, for example, U.S. Army, Corps of Engineers, *Digest of Water Resources Policies*, EP 1165-2-1, January 1975.

19/U.S. Army, Corps of Engineers, *Natural Salt Pollution Control Study, Brazos River Basin, Texas*, H. Doc. No. 95-101, March 16, 1977, particularly p. 221.

20/The Corps also calculated benefits using the lowest of the user cost estimates obtained in order to test the sensitivity of the benefit-cost ratio to these estimates. See *ibid.*, pp. 223-224.

21/For example, confidence could be low, medium, or high, depending upon whether the standard deviation of sample values was, respectively, twice, equal to, or half the mean.

22/For a related methodology, see Altouney.

23/U.S. Army, Corps of Engineers, *Evaluation of Beneficial Contributions to National Economic Development for Flood Plain Management Plans*, ER 1105-2-351, June 13, 1975, p. 6-2.

24/See also Federal Register, Vol. 40, No. 217, November 10, 1975, p. 52537.

25/See U.S. Army, Corps of Engineers, H. Doc. No. 95-149, op. cit., p. 130.

26/Ibid.

27/Ibid., p. 149.

28/Ibid., p. 57.

29/U.S. Army, Corps of Engineers, ER 1105-2-351, op. cit., p. 6-1.

30/U.S. Army, Corps of Engineers, H. Doc. No. 95-101, op. cit., pp. 142-143.

31/Subcommittee on Evaluation Standards, op. cit., p. 23.

32/U.S. Army, Corps of Engineers, DAEN-CWP-P, binders on: Principles and Standards, April 1976; and Planning, November 10, 1975, sections 5-c, d.

33/See, for example, U.S. Army, Corps of Engineers, H. Doc. Nos.: 94-647, p. 173; 94-645, p. 70; 95-101, p. 140; 94-577, p. 66; op. cit.; and 94-465, Saw Mill River at Elmsford and Greenburgh, N.Y., Greenburgh, N.Y., April 26, 1976, p. 57.

34/See, for example, U.S. Army, Corps of Engineers, H. Doc. Nos.: 94-645, p. 45; and 94-635, p. 195, op. cit.

35/U.S. Army, Corps of Engineers, H. Doc. Nos.: 94-639, p. 100; 94-635, p. 211, and particularly 94-577, p. 106, op. cit.

36/An alternative approach that might be considered is including a risk factor in a project's discount rate. See Orris C. Herfindahl and Allen V. Kneese, Economic Theory of Natural Resources, 1974, p. 216.

37/The White House, Statement on Water Projects, April 18, 1977, p. 3.

38/John V. Krutilla and Anthony C. Fisher, The Economics of Natural Environments, 1971, p. 268.

39/See *Federal Register*, Vol. 40, No. 217, November 10, 1975, pp. 52524 and 52538.

40/I. C. James II, B. T. Bower, and N. C. Matalas, "Relative Importance of Variables in Water Resources Planning," *Water Resources Research*, Vol. 5, No. 6, December 1969.

41/*Ibid.*, p. 1167.

42/*Ibid.*

43/Robert H. Haveman, *Water Resource Investment and the Public Interest*, 1965, p. 160.

44/*Ibid.*, p. 161.

United States Senate

COMMITTEE ON THE BUDGET
WASHINGTON, D.C. 20510

August 5, 1977

The Honorable Elmer B. Staats
Comptroller General
General Accounting Office
411 G. Street N.W.
Washington, D.C. 20548

Dear Elmer:

We are requesting that a study of certain aspects of water resources programs be conducted by your office for the Senate Budget Committee. This study will center on those aspects of water resources programs that affect the authorization of individual projects. Results of the study should be presented to the Committee in a series of separate reports.

Water is a limited resource. Where it is scarce, development of any kind is limited drastically. Careful allocation and wise, conservative use of our remaining water resources are becoming more and more critical as our population expands and our supplies of fresh water are depleted.

Moreover, our water reousrces programs bear closer scrutiny from an economic standpoint. The Administration recently has raised questions concerning the documention of need, the accuracy of benefit-cost ratio analyses, and the enormous cost overruns that have occurred in some water projects. Congress and the Administration agree on the need for a water resources program which promotes prudent fiscal policy and careful resource planning.

To enable Congress to set national spending priorities and accordingly to direct and control water resources programs, all pertinent information pertaining to water projects authorizations must be accurately presented to the committees involved. To provide a complete picture, alternatives to projects and their associated costs must be delineated. Also, Congress sorely needs better information on costs at the time of project authorization and during construction for predictive purposes. Committees should be notified as estimated costs change during construction, so that projects can be reevaluated on a regular basis.

We wish to see the GAO study directed to four main areas elaborated upon here:

1. <u>Benefit-cost ratio analysis</u>

(a) A procedure should be outlined whereby the benefits and costs of alternatives to individual projects are identified for authorizing committees. These data would make possible rigorous comparisons with the standard benefit-cost ratio analyses on water projects and provide for well-informed decisions as to the need for particular projects.

(b) The general methodology of benefit-cost ratio analysis as carried out by the Corps of Engineers and the Bureau of Reclamation should be investigated. Particular emphasis should be directed to identification of questionable benefits such as area redevelopment, enhancement of project values, recreation values, and fish and wildlife enhancement. These types of benefits deserve special consideration, for by pushing benefit-cost ratios above unity, they can make projects appear economically sound. As examples, projects in varying stages of completion should be examined to find if the validity of benefits claimed at project authorization can be reaffirmed during and after construction.

(c) The use of probability analysis in the calculation of benefits for water resources projects should be reviewed. For example, for a flood control project, is the probability of the flood occurring during the life of the project used to calculate benefits or is the flood assumed to be a certainty? Similarly, are probabilities assigned to such variables as local population growth projections? Data on the effects of probability analysis on benefit-cost ratios and determination of the most realistic method of calculating the value of benefits should result.

2. Cost projections

(a) The accuracy of the estimated costs in authorization bills for water resources projects should be evaluated. Alternative methods of cost estimation should be suggested that would permit increased accuracy at the time of project authorization. We recognize that GAO has investigated cost indexing during project construction by the Bureau of Reclamation. Similar analyses should be done for the Corps of Engineers. Suggested means of monitoring intra-agency cost estimation and cost indexing should be made.

(b) Alternative procedures for funding projects leading to closer regulation by authorizing committees should be determined. The effectiveness of cost ceilings on Bureau of Reclamation projects should be evaluated, and recommendations concerning similar treatment of Corps of Engineers projects should be made. The impact of requiring re-authorization of Corps projects when the estimated cost is exceeded should be included. Regulation of spendout rates by authorizing projects in steps (as in the Phase I stage of Corps projects) should be studied.

(c) A determination of the total number of authorized projects and the estimated remaining cost of these should be made. The proportion of these for which funds have not been appropriated, current methods of project deauthorization, and new suggestions for deauthorization should be determined.

3. Efficiency of project construction. The GAO should investigate the rates at which projects should be constructed such that the resources of a particular agency are best utilized and the real costs are kept at a minimum.

4. Individual project authorization. The study should include an analysis of general options for continuing authorizations of individual water resources projects. It may be that benefits to the nation can be maximized through authorization of general water resources development plans rather than through individual project authorizations. Alternative plans should be identified and their merits reviewed.

All sections of this study should be completed and transmitted to the Budget Committee by October 1, 1978. We have chosen this rather lengthy time frame for two reasons. First, a very detailed, in-depth analysis of the more complicated parts of this study should be possible in this time period. Second, it will allow the GAO to incorporate the recommendations and revisions resulting from President Carter's review of national water resources policy (to be completed November 1) in the study, and to evaluate these formally. We believe, however, that some parts of the study could be completed well before the final deadline. Therefore, we are requesting that your staff meet with Brenda Tremper of the Senate Budget Committee staff to schedule completion of draft and final versions of a series of separate reports on these issues.

With best wishes, we are

Sincerely,

Henry Bellmon

Edmund S. Muskie

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14. U.S. Army, Corps of Engineers, Flathead and Clark Fork River Basins (Flathead River Near Kalispell), Montana, H. Doc. No. 94-635, September 28, 1976.

15. U.S. Army, Corps of Engineers, Flood Damage Reduction Policy: Level of Protection, EC 1105-2-47, December 12, 1975.

16. U.S. Army, Corps of Engineers, Grand Isle and Vicinity, Louisiana, H. Doc. No. 94-639, September 29, 1976.

17. U.S. Army, Corps of Engineers, Lock Haven, Clinton County, Pa., H. Doc. No. 94-577, August 5, 1976.

18. U.S. Army, Corps of Engineers, Natural Salt Pollution Control Study, Brazos River Basin, Texas, H. Doc. No. 95-101, March 16, 1977.

19. U.S. Army, Corps of Engineers, Park River Subbasin, North Dakota, H. Doc. No. 94-165, September 29, 1976.

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