An evaluation of environmental quality: opportunity costs of channelization and land use change in the floodplain of the Obion-Forked Deer River Basin in Tennessee

George Francis Smith
To the Graduate Council:

I am submitting herewith a dissertation written by George Francis Smith entitled "An evaluation of environmental quality: opportunity costs of channelization and land use change in the floodplain of the Obion-Forked Deer River Basin in Tennessee." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Merton B. Badenhop, Major Professor

We have read this dissertation and recommend its acceptance:

J.A. Martin, H.E. Jensen, D.W. Brown

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
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[Signatures]

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research
AN EVALUATION OF ENVIRONMENTAL QUALITY: OPPORTUNITY COSTS
OF CHANNELIZATION AND LAND USE CHANGE IN THE FLOODPLAIN
OF THE OBION-FORKED DEER RIVER BASIN IN TENNESSEE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee

George Francis Smith
June 1974
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The author's greatest debts are unquestionably to his wife, Ruth, and his son, Jorgito. Without their support, encouragement, and cheerful sacrifice graduate study would have been impossible. Un millón de gracias mis queridos.
This study analyzed two incompatible uses of the land and related water resources of the floodplain of the Obion-Forked Deer Rivers in western Tennessee. The related problems of flooding and a high groundwater table limit crop yields to levels below the potential productivity of the floodplain soils and prevent the dedication of other floodplain lands to agriculture. Stream channelization has been proposed as a solution to these problems. The flood protection and land drainage which channelization offers are desirable for agricultural purposes and represent an enhancement of the quality of the natural environment to rural landowners and related interests. However, the existing wetlands-forest environment and associated fish and wildlife habitat are desirable for the purposes of sportsmen and other environmentalists. The transformation and loss of this environment through channelization and following land use changes represent a decrease in environmental quality to these interests. Either resource allocation would thus enhance the welfare of one set of interests at the expense of other interests.

The analysis was based on the proposition that resources should be allocated to the use which makes the greatest contribution to the welfare of society as a whole. Monetary values were used as a proxy for welfare with the assumption that a gain or loss to any individual is a corresponding social gain or loss.

The value of the transformed environment or net development value was computed as the change in net agricultural returns attributable to channelization and following land use changes less the costs of channelization. The value of the current environment or preservation value was
computed as the net values of forest products, fish, and wildlife which would be lost through development. Preservation value estimates were incomplete because of the current inability to predict the effects of channelization and land use change on potentially important parameters.

A project life of 50 years was assumed. Estimates were made for three levels of land use change at 8, 9, and 10 percent discount rates. Development values were estimated for five assumed crop price sets. While preservation values were estimated for six different sets of values, comparisons were made at the largest value set to reflect the loss of options which development entails.

The results indicated that the current environment should be maintained if crop prices were expected to approximate the three lower sets used in the analysis. The optimum resource use would be a matter of judgment if crop prices were expected to approximate the two highest sets because of the incompleteness of the preservation value estimates. Agricultural development would be the optimal alternative only if these unquantified, and perhaps unquantifiable, parameters were not judged to at least equal the differences between the net development and preservation values.

The divergences between the social and the private costs and returns associated with channelization indicated that land use controls would be required to assure socially optimal resource allocation. The analysis also suggested that arguments other than a significant benefit stream would be required to justify public financing of the project.

This analytical approach can identify the optimal resource allocation in a specified set of alternatives but provides no information to evaluate the possible existence of a superior, unspecified alternative.
The important question of the optimal social organization for efficient and equitable decision making is also unanswered by this approach to the problem.
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CHAPTER I

INTRODUCTION

The quality of the environment has emerged as a growing public concern during the post World War II period. One manifestation of this issue is the debate over the use of the land and related water resources of the floodplain of the Obion-Forked Deer Rivers in western Tennessee. The floodplain soils are potentially among the most productive in the State; however, persistent problems of flooding and poor drainage have limited crop yields and have prevented the use of land for agriculture. Rural landowners want flood protection and land drainage for crop production while sportsmen and wildlife interests want to maintain the fish and wildlife habitat provided by the existing wetlands-forest environment.

In an effort to resolve this conflict, the Tennessee Department of Conservation requested the U.S. Department of Agriculture (USDA) to conduct a survey of the Obion-Forked Deer Basin (1) to provide data on the land and water resources of the Basin, (2) to assess the needs and potentials of the Area, and (3) to evaluate alternative proposals for the use and development of the resources in the Basin.1 A primary concern of the survey was the floodplain where most of the controversy over resource use exists. This study was concerned with the evaluation of these incompatible floodplain resource allocations.

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1Participating in the survey were the U.S. Soil Conservation Service, the U.S. Forest Service, the Economic Research Service of the USDA, and several State and other Federal agencies. The Soil Conservation Service was responsible for overall leadership.
I. Description of the Problem Area

The Basin

The Obion-Forked Deer watershed is bounded by the Tennessee River divide on the east, the Mississippi Rover on the west, the Hatchie River divide on the south, and the Kentucky border on the north. The total drainage area is 3,185,000 acres contained in 14 Tennessee counties (Figure 1).

The South Fork of the Forked Deer River originates in the Tennessee River divide in McNairy County. It flows northwest through Madison County to a point a few miles north of Dyersburg where it is joined by the North Fork of the Forked Deer. This confluence forms the Forked Deer River some 20 miles above its mouth. The Obion River is formed by the junction of its North and South Forks in Obion County. The Obion flows southwest from this point to its confluence with the Mississippi River at Mile 821.4. The Forked Deer River joins the Obion River three miles upstream from its mouth. The system contains approximately 470 miles of stream channels (14, p. 32).

Annual rainfall varies from 32 to 73 inches with an average of 50 inches. Monthly precipitation varies from 3.0 to 5.6 inches. The growing season is approximately seven months long (5, p. 1).

---

2Hydrologically, the Obion-Forked Deer Basin includes small portions of Fulton County and Graves County, Kentucky. However, the Tennessee-Kentucky border is generally defined as the northern limit of the watershed.

3Thomsen (41) presents a wealth of socioeconomic information on the area.
Figure 1. Obion-Forked Deer River Basin.
The Floodplain

The Obion-Forked Deer floodplain is generally rather narrow, averaging less than two miles in width in the central portions of the floodplain (Figure 2). The floodplain encompasses approximately 759,000 acres or approximately 24 percent of the total Basin. Prior to drainage, the floodplain consisted of an almost continuous expanse of forest and swamp, dotted with ox-bow lakes and sloughs and interwoven by meandering river channels.

Most of the river channels were dredged in the early part of this century. The channel enlargement reduced flooding, opening substantial portions of the floodplain for cultivation. Concurrently, technological advances embodied in farm machinery made more intensive cultivation of the uplands possible. Soil erosion in the uplands increased, accelerating siltation of the channels. The dredged channels have not been maintained and consequently flooding has increased. Historically, major overflows on the main channels have occurred during the winter months. Flooding occurs most frequently in the upper portions of the main streams and tributaries following heavy rains. These isolated, relatively small floods occur throughout any given year. An average of 63 percent of the floodplain experiences at least one overflow annually.

Erosion and siltation are associated with other floodplain problems. The level of the groundwater table has shown a general increase as stream channels have lost capacity through sedimentation. The impact is obvious in low areas where the groundwater table has risen sufficiently to swamp the land; a more subtle, widespread effect is the hinderance of plant growth because of a reduction in soil aeration. Not all silt is deposited in the stream channels; sediment left by receding floodwaters
Figure 2. Flood Plain or the Obion-Forked Deer Rivers.
has decreased the productive capacity of many acres of floodplain land. In addition, sediment deposits have formed natural levees along stream courses which cause ponding by impeding the flow of floodwater back into the channel.

**Floodplain Land Resources**

As a part of its survey, the USDA has divided the soils of the Basin into seven soil productivity groups. A soil productivity group (SPG) is defined as two or more land capability units which are similar in yield characteristics, fertilizer response, and management requirements. All of the floodplain soils fall into three groups: SPG-5 (high inherent productivity), SPG-6 (moderate inherent productivity), and SPG-7 (low inherent productivity).^4

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^4The U.S. Department of Agriculture (49, p. 6) describes these three groups as follows:

**Soil Productivity Group No. 5**—are deep, well-drained to moderately well-drained bottom land soils. Most of this group has a brown, very friable silt loam surface and the subsoil is the same texture except some have gray mottles. They have good tilth, moderate to high natural fertility, and high moisture supplying capacity. These soils are capable of high yields of all common crops and timber. Representative soils are Collins, Dekover, Adler, Morganfield, and Vicksburg.

**Soil Productivity Group No. 6**—are deep, somewhat poorly-drained bottom land soils. The surface layer is brown but gets grayer with depth and is mottled. Most of the group has a high water table which is near the surface in winter and spring and lowers in the summer. These soils drain readily where outlets are available. With drainage, yields are higher and more consistent but are 10-15 percent less than crops on SPG-5. These soils are medium in natural fertility and respond highly to fertilizer. Representative soils are Waverly, Iberia, Mhoon, and Hatchie.

**Soil Productivity Group No. 7**—are nearly level, poorly drained soils. The surface soil is light gray to dark grayish brown or brown friable silt or sandy loam to over 36 inches. The subsoil is a mottled gray to brown friable silt loam. Surface drainage is low and soils are difficult to drain because outlets are few. Yields of common crops such as soybeans and corn are usually 35-45 percent less than yields on SPG-5. Representative soils are low Waverly, Beechy, and Swamp.
The USDA mapped floodplain land use from the air in 1971 by updating 1964 aerial photographs. The floodplain is predominantly rural; 19,200 acres are dedicated to urban uses, roads, railroads and the like while approximately 740,000 acres, or 97 percent of the floodplain, is cropland, pasture, forest, and marshland. More than half of the floodplain was cropland and nearly a third was forest in 1971. Soybeans were by far the leading crop, occupying 45 percent of the total floodplain and 76 percent of the cropland. Floodplain land use by soil productivity group is shown in Table 1.

II. Purpose and Objectives of the Study

The Environmental Policy Act of 1969 requires that the evaluation of proposed publicly financed projects include an assessment of the impact of the project on the environment. This legislation demands attention in fulfilling the objectives of the USDA survey of the watershed. The purpose of this study was to determine procedures for use in estimating the environmental effects of alternative water and related land resource management plans in the Obion-Forked Deer floodplain.

Two related lines of justification for the study existed. First, the study represented a potential contribution to the formulation of methodology for evaluating the environmental effects of human actions. Second, the information provided by the study could be useful in determining appropriate resource management policies for the Obion-Forked Deer floodplain.

Specific objectives were (1) to develop a method of assessing the impact of public projects on environmental parameters, and (2) to evaluate a project proposed to enhance the land resources of the Obion-Forked
### Table 1. Land Use by Soil Productivity Group, Obion-Forked Deer Floodplain, 1971

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<tr>
<th>Land Use</th>
<th>Soil Productivity Group 5</th>
<th>Soil Productivity Group 6</th>
<th>Soil Productivity Group 7</th>
<th>Total Acres</th>
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<tr>
<td>Soybeans</td>
<td>197,910</td>
<td>90,944</td>
<td>53,952</td>
<td>342,806</td>
</tr>
<tr>
<td>Corn</td>
<td>14,165</td>
<td>2,645</td>
<td>1,899</td>
<td>18,709</td>
</tr>
<tr>
<td>Cotton</td>
<td>11,413</td>
<td>1,813</td>
<td>960</td>
<td>14,186</td>
</tr>
<tr>
<td>Pasture</td>
<td>45,184</td>
<td>7,126</td>
<td>4,971</td>
<td>57,281</td>
</tr>
<tr>
<td>Miscellaneous cropland</td>
<td>11,306</td>
<td>3,158</td>
<td>3,499</td>
<td>17,963</td>
</tr>
<tr>
<td><strong>Total cropland</strong></td>
<td><strong>279,978</strong></td>
<td><strong>105,686</strong></td>
<td><strong>65,281</strong></td>
<td><strong>450,945</strong></td>
</tr>
<tr>
<td>Forest</td>
<td>34,965</td>
<td>74,496</td>
<td>121,792</td>
<td>231,253</td>
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<tr>
<td>Swamp</td>
<td>1,835</td>
<td>9,238</td>
<td>32,405</td>
<td>43,478</td>
</tr>
<tr>
<td>Wildlife areas</td>
<td>491</td>
<td>4,011</td>
<td>9,856</td>
<td>14,358</td>
</tr>
<tr>
<td>Urban</td>
<td>4,437</td>
<td>2,261</td>
<td>491</td>
<td>7,189</td>
</tr>
<tr>
<td>Other</td>
<td>4,714</td>
<td>4,737</td>
<td>2,624</td>
<td>12,071</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>326,420</strong></td>
<td><strong>200,429</strong></td>
<td><strong>232,499</strong></td>
<td><strong>759,298</strong></td>
</tr>
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- Includes rice, milo, small grains, truck crops, and idle cropland.
- Includes roads, railroads, ponds, ditches, and levees.

Deer floodplain. The second objective provides an empirical test of the method developed as well as an assessment of the specific project.

III. Description of the Project

A river channelization plan proposed by the U.S. Army Corps of Engineers was evaluated. Channelization involves straightening, deepening, and enlarging stream courses through dredging and excavation. The frequency, extent, and duration of flooding are reduced because of increased channel capacity. Channelization also enhances the potential productivity of some land by lowering the groundwater table.

Two types of negative environmental effects are associated with channelization. The first is pollution from such sources as silt released during construction and from agricultural chemicals associated with intensified land use following construction. The second is the transformation and loss of an environment because of channelization and the resulting land use changes. Opponents of channelization almost universally base their opposition upon this second effect.

5Pragmatism dictated this choice. No other complete project proposal existed at the time of this study.

6A relatively large body of economic thought concerning pollution problems exists. For a review of current literature in this area, see Mishan (32). In contrast, the second type of environmental effect has received little attention. Fisher, Krutilla, and Cicchetti (17, p. 605), for example, state:

Where reference is made to the despoliation of natural environments, note is made only in passing of "extra-economic" considerations. Similarly in texts on land economics no mention is made of the economic issues involved in the allocation of wildlands and scenic resources, nor do the costs of land development include the opportunity returns foregone as a result of destroying natural areas.

7During a recent series of Congressional hearings on stream channelization (47) the pollution issue was rarely raised by opponents of the practice. For a summary of the major arguments against channelization presented in these hearings, see Harnik (21).
This proposal involves channelization along the main courses and tributaries of the Obion and Forked Deer Rivers for an aggregate length of approximately 160 miles. The project would benefit approximately 140,000 acres of cropland and permit the clearing of approximately 18,000 acres of woodland for agricultural purposes (43, p. 11). The project is opposed by sportsmen and other environmentalists who believe that the loss of the current wetlands ecosystem represents an environmental cost which exceeds the benefits of the project.
I. The Concept of Environmental Quality

Vlasin (51, p. 236) has defined man's environment as an interrelated system of physical (both natural and man-made), economic, social, cultural, and aesthetic situations. The concept of the environment as a totality is undoubtedly correct but presents a system too large for easy comprehension and manipulation. To alleviate this problem the total environment may be conceptually divided into a natural subsystem and a social subsystem (9). The natural environment, the traditional domain of the natural sciences, encompasses the relations between plant life, animal life (including man), and the physical world. The social environment is the traditional domain of the social sciences, encompassing the relations between individuals and their wants, social institutions, and the limitations imposed by the physical world. The term "environment" has often been used in a social context. However, it appears fair to say that in today's usage "environment" refers to the natural environment.

For this study "environment" was understood to mean the natural environment, defined as a single complex organism involving the physical world and interdependent plant and animal communities which produces a

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1These divisions may also be defined as a subsystem encompassing a multitude of species and a subsystem which contains only a single species, man himself.
number of products of interest to man. The products of the environment include commodities, such as timber; services, such as the biological degradation of wastes; and attributes, such as the scenic properties of a landscape. This concept of environment suggests that the question of environmental quality may be addressed by examining the quality of the products of the natural environment.

**Quality**

Lancaster (27) has proposed that the quality of a product is determined by its embodied characteristics. These characteristics range from objective attributes, such as size and shape, to subjective attributes, such as aesthetic appeal. In general, a product will possess more than one characteristic and a particular characteristic can be found in more than one product. Additionally, products consumed in combination will, in general, embody characteristics different from those embodied in the same products when consumed by themselves.

The subjectivity of some product characteristics implies that quality also depends upon the individual consuming or using the product.

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2This definition was suggested by McComb (31). McComb argues that the often bewildering complexity of the natural environment is greatly simplified when man is used as the point of reference.

3Quality is an important concept in monopolistic competition. In this area of economic theory, goods which are close substitutes are differentiated by real differences (chemical composition, horsepower, and so forth) or spurious differences created by advertising and sales promotion. While this second element undoubtedly enters into the issue of environmental quality, the goal of this study was to focus upon actual differences.

4An example may aid in clarifying these ideas. The characteristics of table salt include taste, color, grain size, and shape. The size and shape of a salt grain are characteristics which are also found in granulated sugar. When salt is added to food, the resulting taste characteristic is different from salt and the unsalted food.
Abbott (1) has proposed that the basic human motivation is the desire for satisfying experiences and that products represent a means to satisfaction. Quality then is a measure of how well a product satisfies an individual's basic desires. This is essentially a personal judgment, as Abbott (1, p. 41) states:

What is considered satisfying is a matter for individual decision; it varies according to one's tastes, standards, beliefs, and objectives—and these vary greatly, depending on individual personality and cultural environment.

In addition, each individual has a number of desires which interact to modify one another. The relative priority of these desires change in response to changing situations (1, pp. 42-43).

Quality, in sum, may be defined as an evaluation of the characteristics embodied in a product. The evaluation depends to some extent upon the characteristics of products used or consumed with the product in question. Judgment on the quality of a product may vary between people because of individual differences. An individual's evaluation of a product may change over time because of changed circumstances and/or personal changes. Consequently, an absolute, definitive judgment on the quality of a product would appear difficult, if not impossible.

Environmental Quality

Combining these concepts, "environmental quality" may be defined as an individual judgment on the suitability of an environmental product or set of products for a specific purpose. The quality of the environment is impaired by activities which reduce the value of environmental

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5North (34) has defined environmental quality in similar terms. North mentions physical, chemical, biological, economic, social, and aesthetic parameters as the characteristics influencing an individual's judgment.
products for a subsequent user. However, all human activity occurs within the environment and unavoidably alters it. Among others, Green (20, p. 185) has concluded that it is meaningless to speak of preserving the quality of the environment; the real question is the degree of environmental change which will be acceptable.

II. A Theoretical Framework

An environmental change may affect many individuals, each with a unique set of desires. Presumably, few changes will be acceptable to all affected parties. Welfare economics provides a theoretical framework for analyzing issues of this type. In theory, a given change would be desirable if those who lose from it cannot bribe those who gain into not accepting the change and/or if those who gain can compensate the losers; that is, if net gains accrue to the group.

Following Schaller (36, p. 16), social welfare is defined as a positive function of economic and noneconomic well-being. Economic well-being may be measured in terms of income, employment, or gross national product. Noneconomic well-being is assumed to be a positive function of the quality of the environment.

A proposed cause for man's unavoidable impact on the environment is the pervasive nature of externalities (3). Briefly, the law of the conservation of energy, the first law of thermodynamics, states that the energy in the universe is constant. In production, inputs are changed in form, but the total mass and energy remain unchanged. Accordingly, any production process results in both usable outputs and residuals.

Empirically, the predicted benefits would determine the appropriate economic parameters.
The law also implies that final consumption is impossible; consumers extract services from commodities and are left with residuals. The residuals from production and consumption accumulate, impairing the quality of the environment.

Man can also intentionally alter the environment within limits established by physical processes and levels of technology. Intentional alteration, such as the extraction of environmental products or the enhancement of environmental characteristics for certain purposes, is often undertaken for economic gain. Presumably, these alterations will also impair the quality of the environment for other socially desirable purposes.

The impact of most human activity from the social viewpoint would appear to fall somewhere between the extremes of highly positive and overwhelmingly negative environmental change. In the general case, then, both the benefits of production and consumption and the unimpaired environment contribute to the welfare of society. The problem therefore is to choose among desirable alternatives.

Figure 3 illustrates the tradeoffs implicit in this discussion. Point T represents the maximum noneconomic well-being possible within the limitations of the physical world. Point T' represents the maximum economic well-being attainable given the level of technology, resource availability, and socially acceptable hazards to human health and safety. Man cannot exist without some environmental impact. The environment has an assimilative capacity corresponding to the perpendicular portion of the curve. As economic well-being increases beyond this point, the accompanying environmental impacts exceed this finite capacity and
Figure 3. The trade off curve.
environmental quality begins to decrease. The actual shape of the curve is, of course, open to conjecture. Man's social environment is perhaps the primary determinant of the shape of the curve.

It should be noted that the origin in Figure 3 is not a zero point. A level of economic well-being sufficient for human subsistence exists at point T. Similarly, non-economic well-being is positive at point T' because of the constraint of socially acceptable health hazards.

Ciriacy-Wantrup (10) has questioned the applicability of welfare economics to environmental issues. His basic criticism appears to be that welfare economics uses an increase in real national income as the primary policy criterion while income measures do not come to grips with the total problem. The use of income as the primary criterion for policy decisions implies that an increase in income (economic well-being) increases the total well-being of society. This is represented by curve A in Figure 4. The hypothesized social welfare function and the noneconomic costs of increases in national income suggest that curve B is a more nearly correct representation. The downward turn occurs at the point where gains in total well-being from increasing income are outweighed by the losses from decreasing noneconomic well-being. The location of this inflection point is determined by the values of society; its location may change over time in response to the changing social environment.

Groups within a society may differ on the location of the point of inflection at a given point in time. A level of economic well-being

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7Population growth also plays a role in environmental degradation. However, Ayers and Kneese (4) found a much stronger relationship between per capita income and pollution that between population growth and environmental abuse.
Figure 4. Economic and total well-being curves.
beyond subsistence provides time and resources which can be devoted to matters other than survival. Such affluence in America has been partially credited with widening public interest in the natural environment which before World War II was "the distinctive mark of the upper class nature enthusiast" (22, p. 25). The suggestion that some level of affluence is a precondition for concern about environmental quality has an opposite side—the relatively unaffluent prefer economic growth unimpeded by environmental concerns as, historically, their best chance of increased real income is through growth, not income redistribution.®

Analytical Approaches

One empirical approach within this framework is to focus on non-economic well-being, measuring the impact of alternative management policies on the environment and then evaluating the effects on the well-being of society. A review of selected literature dealing with this alternative is presented in Appendix A.

A second approach is to consider both economic and noneconomic well-being with the aim of maximizing social welfare. Possible maximization procedures include indifference curve analysis, constrained maximization, and opportunity cost analysis. ⁹

Indifference curve analysis. The proposed welfare function and the interrelations between economic and noneconomic well-being suggest that various combinations of these parameters can result in the same

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⁸Reports from the recent United Nations Conference in Stockholm suggest that the effect of differing economic status on environmental valuation may be observed among societies as well as among groups within a society. See, for example, Doty (15).

⁹For a discussion of maximization, see Samuelson (35).
level of welfare. Identifying these combinations would establish a set of welfare indifference curves. In addition, the analysis would require the construction of a production possibility curve similar to curve TT' of Figure 3 reflecting the maximum combinations of economic and noneconomic well-being attainable with a given base of resources and technology. The point of tangency between this curve and the highest indifference curve would determine the optimal combination of economic and non-economic well-being. The required resource allocation could then be derived from the data used to construct the production possibility curve.

The empirical value of this procedure is limited by the problem of establishing social indifference curves and by the current lack of data needed to construct a production possibility curve.

**Constrained maximization.** Constrained maximization is a second possible approach to maximizing social welfare. The problem may, for example, be stated as maximizing economic well-being with the constraint that noneconomic well-being at least equal a given level. Legal standards, such as those established for automobile emissions or water quality, in effect create this type of problem for solution by the economy. Agreement on constraints, such as maintaining pollution below toxic levels, is possible. Within such extremes, however, opinion varies from the need for a stationary economy as a supposed means to minimize environmental deterioration to the need for continued growth with minimum constraints. The problems involved in reaching agreement on the level of the constraint in areas where human health or safety is not a key issue appear to limit this approach. A second limitation is that continuous functions are required for the solution of a constrained maximization
problem. The method is thus not suitable for the assessment of alternatives involving essentially indivisible actions.

Opportunity cost analysis. This approach involves successive approximation of a maximum. It is based on the premise that if alternative X is chosen over alternative Y, the gains from X exceed the gains from Y and, therefore, a movement towards a maximum has occurred. The assumption is, of course, that the choice follows rational evaluation of the gains and losses associated with each alternative. Empirically, monetary values may be used as a proxy for welfare with the implied assumption that the marginal utility of money is constant and identical for all members of society.

Opportunity cost analysis is recognized as a potentially valuable tool in resource management decisions.\textsuperscript{10} The analysis may be in terms of the opportunity cost of foregoing a project and the accompanying environmental effects. This approach is found in Krutilla's (26) analysis of the Hell's Canyon Dam proposal. Alternatively, the analysis may involve using opportunity costs to estimate the benefits of a project designed to enhance environmental quality such as that reported in a study of water quality in the Delaware Estuary (13).

Two weaknesses of opportunity cost analysis should be noted. First, several local optimum points may exist. Choice among a set of alternatives may then move society towards a local optimum rather than the global welfare optimum. The procedure offers no information to evaluate this possibility.

\textsuperscript{10}See, for example, Schmid (37). Coase (12, p. 43) argues that opportunity cost analysis is a desirable approach to any policy question involving "alternative social arrangements."
Second, the gains and losses involved in an alternative rarely correspond; those who gain do not automatically bear the associated losses and those who lose do not automatically receive compensating benefits. It is generally assumed that a dollar gain or loss by an individual is a gain or loss to society, implying a constant, identical marginal utility for money. Social actions such as the progressive income tax imply an inverse relation between income levels and the marginal utility of money. The validity of decisions involving this assumption may be questioned.\textsuperscript{11}

The Procedure Used in the Study

Opportunity cost analysis was the maximization procedure used in this study. It was recognized that successive approximation is essentially a second best approach as it may lead to a "betterization" of social welfare rather than a maximization. The decision was, in part, pragmatic. Input-output coefficients (where output is a commodity plus environmental impact) are needed to construct a production possibility curve for indifference curve analysis. Similar data are required to specify a problem for constrained optimization. Opportunity cost analysis does not require this type of data, which are not available in many instances.

The nature of the problem was a second decision factor. The primary issue is the change and loss of a river-swamp environment through channelization. The opportunity cost approach is amenable to the analysis of mutually exclusive alternatives. Additionally, potentially

\textsuperscript{11}Mohring (33) argues that assuming a constant and equal marginal utility of money is inferior to identifying the distribution of gains and losses and weighing them by individual utility levels. However, such comparisons would require cardinal measures of utility which are not reliable.
important parameters, such as the psychological satisfaction derived from the knowledge that a natural state is being maintained, are difficult to measure, if measurable at all. The value of the current environment becomes a matter of judgment if adequate estimates cannot be calculated. The estimated cost of foregoing a project provides a minimum value for use in this judgment.

III. The Opportunity Cost of Alternative Land Uses

Channelization and the following land use changes would fundamentally alter the Obion-Forked Deer floodplain environment. The basic justification for channelization is flood control and land drainage with benefits accruing to the agricultural sector. The loss of the current environment is the basis of opposition to the project. This study focused upon the value of the rural floodplain land as a measure of the quality of these two distinctly different environments.

Private Land Values

Consider, first, the value of land to the individual farmer. Assuming that the rural landowner is an economic being, he will rationally select the land use which has the greatest expected present value when faced with a finite number of feasible, mutually exclusive alternatives. The private value of land may then be defined as the present value of the expected returns from the land in its best use.

A change in the probability of flooding can alter the best use of the land and thus change its value. Figure 5 illustrates the relation

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12 Brown (7), Goldstein (18), and Krutilla (26) were instrumental in the formulation of the following models.
between the probability of flooding and the expected present value of alternative land uses.\(^\text{13}\) Two land uses are assumed, a soybean alternative and a forest alternative.\(^\text{14}\) The expected returns from forestry are relatively unaffected by flooding while the expected returns from soybean cultivation are much more dependent on the probability of flooding. If the probability of flooding is less than \(P_0\), soybean production is the better land use. If the flood probability exceeds \(P_0\), the forest alternative is the better land use.

Assume that the current flood probability on a given parcel of land is \(P_1\). The better use of the land is for forest with an expected value of \(V_1\). Assume that channelization would reduce the probability of floods on this land from \(P_1\) to \(P_2\). Soybean production would then be the better land use, yielding an expected return of \(V_2\). The gross value of channelization to the landowner is the change in expected returns because of flood control, \(V_2 - V_1\). Let the cost of channelization to the landowner have a present value of \(C\). The private net value of channelization then equals the gross value less the individual cost, \((V_2 - V_1) - C\). The landowner would rationally support channelization if \(V_2 - C\) exceeds \(V_1\); that is, if his expected net returns after channelization exceed his expected returns before channelization.

These private land values may be expressed in functional terms.

\(^{13}\)This example relies heavily upon Brown (7).

\(^{14}\)The soybean alternative was used to make the example concrete. This alternative would be labeled crop production in a more realistic example. When flood probabilities are slightly to the left of \(P_0\), a relatively low value, flood tolerant crop, such as pasture, may yield the highest returns. As the probability of flooding decreases, the expected returns from higher value, more flood susceptible crops, such as soybeans, may be greater and land use would change accordingly.
Figure 5. The effects of flooding on the private value of land.
These private land values may be expressed in functional terms. In the general case, the present value of an acre of land to the landowner after channelization ($V_2$) is the discounted net return from agricultural production.\textsuperscript{15} It may be expressed as:

$$V_2 = \sum_{t=1}^{n} \frac{P_{it} Q_{it} - C_{it}}{(1+r)^t}$$  \hspace{1cm} (1)

where:

- $P_{it}$ = the price per unit of crop i in year t
- $Q_{it}$ = the yield per acre of crop i in year t
- $C_{it}$ = the cost of producing $Q_{it}$
- $r$ = the interest rate
- $t$ = the planning horizon

In the general case, the present value of an acre of land to the landowner before channelization ($V_1$) is the discounted net return from timber or other harvestable forest products. It may be expressed as:

$$V_1 = \sum_{t=1}^{n} \frac{P'_t F_t - C'_t}{(1+r)^t}$$  \hspace{1cm} (2)

where:

- $P'_t$ = the price per unit of forest products in year t
- $F_t$ = the quantity of forest products harvested in year t
- $C'_t$ = the cost of producing $F_t$

and all other parameters are as previously defined.

\textsuperscript{15} It was assumed throughout the analysis that all parameters are constant over time. This assumption eliminates uncertainty of the future; present values are thus known, not expected.
Assume that the individual landowner can undertake the channelization at the previously defined total cost, $C$. His decision criterion may be expressed as the inequality

$$V_2 - C \geq V_1$$  \hspace{1cm} (3)

The property owner's decision is determined by the direction of this inequality. In the case of an equality, his action is a matter of indifference.

**Social Land Values**

Equations (1) and (2) express the social value of an acre of land provided that no external effects are associated with the two alternative land uses. The private decision criterion expressed in (3) would also be the social decision criterion assuming that alternative social land uses are the same as alternative private land uses.

Externalities do exist, however. The unchannelized stream and adjacent lands which are uncultivated because of flood hazards form a complex environment. Numberous individuals and groups derive benefits from the products of this ecosystem but the landowner is generally unable to capture the value of these benefits through the market. These products are significant in social land allocation decisions for many are

\[\text{16}\] The previously discussed assumption that an individual's gain or loss is a corresponding social gain or loss is maintained.

\[\text{17}\] An externality exists when individual action benefits others but the individual receives no payment in return; or conversely, when individual action is detrimental to others without commensurate cost to the individual. Market resource allocation thus would not be socially optimal because the market system provides no price for these services and disservices.
not produced in the distinctly different environment created by channel modification and the following land use changes.

**External Effects.**

Channel modification has a major impact on aquatic life. Fish, for example, would be eliminated as excavation destroys food sources, shelter, and spawning areas. Also, the destruction of streamside vegetation during construction eliminates shade; the temperature of the water may increase beyond the limits which temperature-sensitive species can tolerate. Such damage to aquatic habitat can render the stream essentially lifeless. Some degree of recovery is possible but, apparently, the impact is essentially permanent.

Clearing the land for agricultural use has a major impact on terrestrial wildlife. For example, the loss of suitable food sources, cover, and breeding areas inevitably lead to the loss of the species in question. If development occurs in an area which is part of a waterfowl migration route, a shift in the flyway may result. The net social impact of such a shift may not be negative; the value of increased waterfowl numbers in areas positively affected by the change could outweigh the losses experienced in other areas. The loss of feeding and resting areas may also result in a decreased waterfowl population with a negative impact throughout the flyway.

Fish and wildlife do not enter conventional marketing channels since they are fugitive resources owned by the public rather than by the individual whose resources are an input in their production. Ownership

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18 Parts of the following discussion draw heavily upon Goldstein (18) and the House hearings on stream channelization (47).

19 See, for example, the statement submitted by Reed in the House hearings on stream channelization (47, pp. 1088-1105).
of game species passes to an individual upon harvest under specified regulations but the numbers which may be harvested are limited. The possibility exists that the landowner may be able to capture part of the value of the fish and wildlife produced as a result of his wetlands holdings by leasing land use rights to sportsmen. The rental price for such rights would not, however, reflect the value of the habitat to society. Goldstein (18, pp. 7-8) points out that no individual would rationally pay a sum sufficient to induce a landowner to preserve his wetlands; the probability of an individual harvesting the resulting fish and wildlife approaches zero because of their fugitive nature. Action by sportsmen as a group is an imperfect solution because an individual could share in the benefits of such collective efforts without contributing to the group. Rental values may also be constrained by competition from free or nominal fee access to public lands. Similar access to private lands may be available as a result of public or private actions.20

The crops which replace the original vegetation may provide habitat for wildlife. In general, the species would differ from those normally present before the pattern of land use was changed. However, the upland or "farm" species normally associated with the habitat provided by land used for agricultural purposes often utilize wetland to meet seasonal requirements. The loss of wetlands may then be detrimental to these species as well as to the wildlife which is essentially dependent on the wetlands environment (40, pp. 40-43).

20Any net returns from land rental would be a factor in the private value of land before channelization. This potential income stream was assumed to be zero in expression (2).
Wetlands also provide services beyond their downstream boundaries. The meandering stream course and the associated floodplain area serve as a reservoir for the temporary storage of flood waters, thus decreasing downstream flood peaks. This water storage capacity contributes to a more even annual stream flow since water is released during periods of reduced flow. Enlarging the stream channel increases the velocity of stream flow. The accelerated water velocity reduces storage and thus the stream flow usually becomes more cyclic. It is also possible that flood waters will accumulate and produce higher downstream flood crests than those experienced before channel modification.

Many plant species are dependent upon rather precise soil-water relationships. Higher water levels during peak flow periods and a more cyclic stream flow can inflict damage on native plant communities. Plants which produce timber and other marketable products may be affected adversely in addition to the potential negative impact on wildlife habitat and aesthetics. The changed water relations may also damage agricultural crops.

Wetlands also contribute to downstream water quality. Sediments in the slowly flowing water are deposited and trapped by plant root systems. Thus, human wastes and other pollutants are often held for biological degradation by the appropriate micro-organisms. Nonbiodegradable pollutants may be trapped by their chemical affinity for silt and/or organic matter. Increasing the flow velocity through channelization often denies micro-organisms sufficient time for water treatment. Suspended materials are transported over greater distances as flow velocity increases; the sediment load will tend to flow through channelized portions of a stream and collect in areas of reduced flow. The
sediment load may also increase as the destruction of aquatic and stream-side vegetation frees silt immobilized by the plant roots.

These downstream benefits may be external to the wetlands property owner because of imperfections in ownership. The extent of the externality would be a function of the degree of ownership separation; that is, while the landowner cannot capture the value of the downstream services of his holdings through market transactions, he may internalize at least part of the value through the ownership of downstream resources receiving these benefits. An externality will exist, however, unless there is perfect correlation between the ownership of the two sets of resources.21

The unmodified stream can impose diseconomies in the form of flood damages to structures and other man-made improvements. The magnitude of flood damage is, in part, a function of the pattern of flood plain settlement. In a predominantly rural area, the settlement pattern would presumably be such that most of this damage is caused by infrequent, large-scale flooding. Sufficient channel enlargement to contain large floods is technically difficult and quite costly; the typical rural channelization project is designed to control the relatively small, frequent inundations characteristic of wetlands and as such has only a minor impact on large-scale flooding. The implication is that the costs of flood damage will be approximately equal in both environments. If that is the case, then this diseconomy would not be relevant to the channelization decision.

21 The private land values expressed in equations (1) and (2) represent a general case and assume total divorce of ownership from the services and disservices of wetlands.
Wetlands can also impose diseconomies on adjacent land dedicated to agricultural use. For instance, the relatively high groundwater table associated with wetlands may reduce crop yields. The farm machinery used on these lands may become mired, producing time losses and possible damage to equipment. Cultivation in irregular patterns may be necessary to avoid such hazards and this would require more time and increase production costs. Finally, the wildlife which exists because of the presence of wetlands may feed on the crops in adjacent areas, reducing agricultural incomes through their depredations. If such costs are not restricted to the property of the owner of the wetlands a negative externality will exist for these costs cannot be transferred to the wetlands owner through the conventional market system. Thus, land allocation decisions based on the market would tend to provide excessive wetlands from the social point of view.

Floodplain water relations are a significant factor in the composition of wetlands plant communities. While flood protection provided by a modified channel may not be sufficient for the cultivation of land bordering the stream, the lowered water levels will have an impact on native plant communities. The aesthetic pleasure and wildlife habitat provided by wetlands vegetation are external to the market. Although the possibility for improvement exists, empirical studies indicate that the impact is usually negative. Profit maximizing landowners would tend to leave these negative effects out of their calculations and thus provide more channelization than desirable. Plants which produce marketable products may be among the affected species. The higher ground-
water tables and frequent inundations associated with wetlands tend to foster the growth and development of valuable hardwoods found in some bottomland plant communities. An externality because of ownership patterns may exist. Landowners, whose holdings include such hardwood stands, receive the benefits while the costs are borne by the owners of the marginal agricultural land.

Finally, natural reversion to the prechannelized environment is a lengthy process. The new environment may be essentially permanent, particularly if the new channels are maintained. It would also appear technically difficult, if not impossible, to recreate the original environment. Irreversible environmental change would impose these effects on future generations as well as on the present generation.

Externalities and Land Values. Social land values differ from private land values by the value of the externalities associated with the particular land allocation. A social land value model may then be constructed by introducing the values external to the landowner into expressions (1) and (2).

The discounted social value of an acre of land dedicated to agriculture may be expressed as:

\[ DV = \sum_{t=1}^{n} \frac{P_{it} Q_{it} - C_{it} + G_{it}}{(1+r)^t} \]  

These hardwoods include gum and cypress. The forest curve in Figure 5 would be convex from above to depict this special case.

Folkers (47, p. 2142) estimates that the effects of channel modification will persist for 300 to 1000 years without project maintenance. Wharton (47, p. 2198) provides a more conservative estimate of 100 years.
where:

\[ G_{it} = \text{the value of wildlife produced in year } t \text{ as a result of the habitat provided by crop } i \]

and all other parameters are as previously defined. The expression implies that no externalities are associated with the use of the land for agricultural purposes other than the provision of wildlife habitat, an external economy.\(^{25}\) It is assumed in this analysis that additional external economies arising from the use of the land for agriculture are negligible from the social point of view and that diseconomies which may arise are within socially acceptable limits. The development value, DV, will be underestimated if the first part of this assumption is invalid. Conversely, DV will be overestimated if socially significant diseconomies are associated with the use of the land for agriculture.\(^{26}\)

The discounted social value of wetlands preservation may be expressed as:

\[
PV = \sum_{t=1}^{n} \frac{F_t + F'_t + R_t + D_t - C_{ft} - C_{pt}}{(1+r)^t}
\]  

\(^{25}\)This externality may be negative; as previously noted, wetlands loss may have an adverse effect on upland wildlife.

\(^{26}\)Goldstein (18, p. 14) states that it seems likely that "there are not external economies associated with agricultural production or consumption." Pollutants from such sources as chemicals used in production, animal by-products, and the residuals of consumption are likely sources of diseconomies. However, data are lacking, as Langham (28, p. 1) notes "often we do not know how to measure the real effects of pollution on parties involved in and influenced by pollution . . . we have done very little to systematically record observations on pollution processes."
where:

\[ F_t = \text{the per acre value of forest products in year } t \]
\[ F'_t = \text{the value of forest products produced on other land in year } t \text{ dependent upon the water relations of the wetlands environment} \]
\[ R_t = \text{the per acre value of the fish and wildlife dependent upon wetlands habitat in year } t \]
\[ D_t = \text{the value of the downstream benefits created by the existence of an acre of wetlands in year } t \]
\[ C_{ft} = \text{the costs imposed on adjacent land by the presence of an acre of wetlands in year } t \text{ which would be avoided if the channel were modified} \]
\[ C_{pt} = \text{the per acre costs associated with the production of these wetlands products} \]

and all other parameters are as previously defined.

The preservation value, PV, is an estimate of the social cost of land use change following channelization. A different set of externalities may be associated with an alternative development measure, such as the construction of a dam. An expression of the value of preservation would correspondingly change. Also, PV is not an estimate of the total value of the wetlands to society. The social value of wetlands would include the total value of flood damage. The relevant decision parameter for inclusion into expression (5) is the change in flood damage produced by a particular modification of the stream channel. These two values do not necessarily coincide.

The divergence between private and social land values will tend to produce socially nonoptimum amounts of channelization. Brown
(7, p. 17), in his analysis of rural stream modification, notes that almost all of the identified externalities are economies associated with wetlands. Presuming this to be true, decisions based on land values derived from the market will tend to result in excessive channel modification.

Defining CD as the present value of the cost of development, the social decision criterion may be expressed as:

\[ DV - CD > PV \]  \hspace{1cm} (6)

The left hand expression is an estimate of the net value of development and represents the benefits which would be foregone if the wetlands were maintained. The right hand expression is an estimate of the net value of the wetlands which would be foregone if the area were dedicated to agriculture.

Assume a wetlands area amenable to agricultural use following channelization of an adjacent watercourse. The theoretical framework has led to the proposition that agriculture would be the optimal land use if the discounted stream of social benefits from agriculture (DV) less the cost of channelization (CD) exceeded the discounted value of the foregone stream of social benefits from the wetlands (PV). If the opposite inequality holds, the area should remain as wetlands; channel modification would enhance the quality of the environment for agricultural purposes at the expense of an incompatible set of purposes which make a relatively greater contribution to the total well-being of society. 27

27 In the case of an inequality, society would be indifferent. The land use change would have no net impact on social welfare.
CHAPTER III

THE ESTIMATION PROCEDURE

Analyzing the Corps of Engineers proposed channelization project involved estimating the parameters DV, CD, and PV. The analysis required determination of the rates of discount and the planning horizon for the computation of the present values of these parameters. It was necessary to modify the structure of equations (4) and (5) because of the nature of the watershed, data availability, and the magnitude of the project. Equations for estimating the cost of the project were also determined.

I. Present Value Computations

Discount Rates

Discounting was required to compare values estimated at different points in time in the analysis. The present value of a given future sum has an inverse relation with the discount rate; that is, lowering the rate of discount increases the present value of a fixed amount accruing in the future and increasing the discount rate lowers the present value of a future sum. If perfect markets existed and if there were no risk and uncertainty, a single private interest rate would exist. Optimality would require that the public sector use this rate. If the public discount rate exceeded the private interest rate, resources would be diverted into private investments with relatively lower returns than foregone public investments. If the public discount rate were lower than the private interest rate, the result would be an overinvestment in public projects because of the diversion of resources from investments with higher returns in the private sector of the economy. In the real world,
however, markets are not perfect, capital does not flow freely, and risk and uncertainty exist. As a result, social rate of discount cannot be determined by simple reference to private capital markets and the optimal rate is a frequently debated question.¹

Among recent estimates of the social rate of discount, Eckstein (46, pp. 56-57) has estimated the opportunity cost of public funds raised through taxation and arrived at a rate of approximately 9 percent.² Harbinger (46, p. 63) arrived at a similar discount rate through the estimation of the opportunity cost of borrowing by the public sector. Seagraves (38) has estimated social rates of discount between 8 and 13.2 percent through imposing various levels of adjustment on the returns from class A corporate bonds. Based upon these studies, a discount rate of 9 percent and alternative rates of 8 percent and 10 percent were used in the analysis.³

The Planning Horizon

While the physical effects of channel modification may persist for 100 years or more, the relevant time horizon for this analysis was the economic life of the project. The effective economic life was estimated by determining the point in time where the discounted value of one dollar was essentially equal to zero; a present value of $0.01 was

¹Aspects of this debate are found in two sets of hearings before the Joint Economic Committee (45 and 46).

²Eckstein's methodology is presented in Chapter 4 of Multiple Purpose River Development: Studies in Applied Economic Analysis (24, pp. 82-134)

³In addition, evidence presented during Congressional hearings was strongly in favor of a social rate of discount in the range of 7 percent to 10 percent (46, pp. 141-145).
considered to be an equality (17, P. 613). One dollar has a present value of $0.01 at approximately 53 years with a 9 percent rate of discount. A 50 year planning horizon was, however, used for convenience in computation.\(^4\) A 50 year span has the additional advantage of corresponding with the mandatory planning horizon of the USDA survey of the Obion-Forked Deer Basin.

Nineteen seventy-one was selected as the base year for the planning horizon, and all values were calculated in terms of 1971 dollars.

**Discounting Procedure**

The magnitude of the proposed channelization project complicated the calculation of present values. The proposal involves modifying the main channels and major tributaries of the Obion and Forked Deer Rivers for an aggregate length of approximately 160 miles and would require an estimated 11 years to complete (43, p. 3). Some land would presumably be enhanced by the work completed in each year and, therefore, portions of the total benefit and cost streams would begin to accrue throughout the construction time span.

Data on the cost of project design and construction presented in Appendix Table B-6 were used as proxy variables for annual work completion. It was assumed that the proportion of the total construction cost budgeted for a given year was identical to the proportion of the total project completed during that year. These data are illustrated in Figure 6; the solid line represents the assumed annual project completion as

\[ 0.01 = \frac{1}{(1+r)^t} \]

where \( r \) is the discount rate and \( t \) is the time in years. When the discount rate is 8 percent, $1.00 approximately 59 years in the future has a present value of $0.01. At 10 percent, the time span is approximately 48 years.
a cumulative percentage of the total project. An equality between the assumed proportion of the project completed in a year and the proportion of all benefit and cost streams was also assumed. Thus, the solid line in Figure 6 also represents the percentage of any annuity coinciding in time with construction, such as annual land costs, which begins to accrue in a given year.

It appears unlikely that land which is enhanced by construction in a given year would be cleared and planted in that year. Thus, a one-year lag between construction and the start of the agricultural income stream from the land was assumed. This is represented by the dotted line in Figure 6. By assumption, this line also represents the start of the stream of foregone benefits from the land as wetlands.

The base year for the analysis, 1971, is represented by year zero in Figure 6; the benefit and cost streams associated with the project thus begin to accrue in the future. The present value of an annuity beginning at some point in the future is computed by, first, calculating the present value of the annuity in the year in which it begins and, second, discounting this value to the present time as a lump sum. This calculation may be made by computing the present value of a one dollar annuity beginning in the year in question and then multiplying the annual value of the annuity by this discount factor. This procedure was used in the analysis.

The initiation of portions of an annuity over the 10 years allowed for construction results in 10 distinct value streams. The calculation of the present value of a benefit or cost stream associated

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5Planning and design work alone are scheduled for year zero.
Figure 6. The time span of construction and associated values.
with the project involved four steps: (1) estimating the annual value of the total annuity, (2) estimating the portion of this total annuity beginning in each year by multiplying by the assumed annual percentages of project completion, (3) multiplying each of the 10 resulting values by the present value of a one dollar annuity beginning in the appropriate year, and (4) summing the resulting present values.

II. The Value of Channelization (DV)

The value of the upland wildlife habitat provided by land used for agricultural purposes, parameter $G_t$ of equation (4), was omitted from the model used for estimation. This parameter was omitted because the impact of wetlands conversion on upland wildlife has not been specifically studied and available information is inconclusive (47, p. 1496). This impact may depend on the type of crop grown and the intensity of cultivation rather than the loss of wetlands (47, p. 1284). Lacking conclusive data on this impact, $G_t$ was set equal to zero through the assumption that upland wildlife in the Obion-Forked Deer watershed would be neither benefited nor harmed by the conversion of wetlands to agricultural use.  

Another structural change of equation (4) was the redefinition of the yield and the production cost parameters. In addition to reducing the probability of flooding so that wetlands may be used for agriculture, altering the Obion-Forked Deer stream channels will also enhance the

---

6A potential bias is introduced into the analysis by this assumption since wetlands conversion may have an impact on upland wildlife. It is not possible to predict the nature of this bias because of the inconclusiveness of available evidence.
productivity of some land already in cultivation. This enhancement will occur because such land produces below its potential because of a combination of flooding and a high groundwater table. In recognition of these benefits to land already in cultivation, the parameters were defined as the change in yield and the associated change in production costs following channel modification. In the case of converted wetlands, the changes in yield and in production costs would equal the total value of the parameter.

Finally, an estimate of the distribution pattern of land among the various crops was needed in order to estimate the value of the benefit stream. For this purpose a crop distribution pattern for each soil productivity group (SPG) was estimated. This was necessary because the crop distribution will vary among the three soil groups in response to differences in the agronomic characteristics of each SPG. The crop distribution parameter was defined as:

$$A_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}}$$

where:

- $A_{ij}$ = the expected proportion of SPG-$j$ land dedicated to crop $i$
- $C_{ij}$ = the number of acres of SPG-$j$ dedicated to crop $i$
- $n$ = the number of crops found in SPG-$j$

Incorporating these changes, the present value of a representative acre of SPG-$j$ land benefited by channelization in year $y$ was estimated with the following equation:

$$DV_{jy} = \sum_{i=1}^{n} \left( A_{ij} (P_i dQ_{ij} - dC_{ij}) \right) D_y$$
where:

\[ dQ_{ij} = \text{the change in yield per acre of crop } i \text{ in SPG-}j \]
\[ (dQ_{ij} = Q_{ij} \text{ if the land were not cultivated before channel modification}) \]

\[ dC_{ij} = \text{the change in production costs } (dC_{ij} = C_{ij} \text{ if the land were not cultivated before channel modification}) \]

\[ D_y = \text{the present value of a one dollar annuity beginning in year } y \]

and all other parameters are as previously defined.

The number of acres of SPG-\( j \) land converted from wetlands to agricultural use in year \( y \) was defined as:

\[ N_{jy} = (TW_j) (B_{y-1}) \]

(9)

where:

\[ TW_j = \text{the estimated total acreage of wetlands on SPG-}j \text{ soil converted to agricultural use as a result of the project} \]

\[ B_y = \text{the percentage of the total construction completed in year } y \]

\[ y = 2, 3, \ldots, 11 \]

The assumed one year lag between construction of a portion of the project and the start of the agricultural income stream is created by the values of \( y \) expressed in this equation.

The number of cultivated acres of SPG-\( j \) land enhanced in year \( y \) was defined as:

\[ M_{jy} = (TA_j) (B_{y-1}) \]

(10)
where:

\[ TA_j = \text{the estimated total acres of SPG-}j \text{ soil cultivated prior to channelization benefited by the project} \]

\[ y = 2, 3, \ldots, 11 \]

In the analysis \( DV_{jy} \) was estimated for all \( j \) and all \( y \). These representative acre values were then increased by the corresponding estimated number of converted wetland acres \( (N_{jy}) \) and the enhanced cultivated acres \( (M_{jy}) \). The summed products are an estimate of the discounted value of the land use benefits arising in each year of the time span of construction. The total present value of the land use benefits from the project \( (DV) \) was then estimated by summing over years and summing over soil groups. These calculations may be expressed as:

\[
DV = \sum_{j=5}^{7} \sum_{y=2}^{11} (DV_{jy} N_{jy}) + (DV_{jy} M_{jy}) \quad (11)
\]

with all terms as previously defined.

III. The Costs of Channelization (CD)

The channelization project involves three types of costs: the cost of design and construction, the cost of the required land, and the cost of channel maintenance. The total cost of development, \( CD \), was calculated by estimating the present value of each type of cost and then summing the three values.

The present value of the cost of design and construction, \( CC \), was computed by summing the discounted annual costs. Mathematically this is stated as:
$CC = \sum_{y=0}^{10} \frac{AC_y}{(1+r)^y}$

(12)

where:

$AC_y = \text{the cost incurred in year } y$

and all other terms have been previously defined.

The cost of land is the second type of cost associated with the project. Land is required: (1) to enlarge and straighten the channels, (2) to deposit the dredged spoil, and (3) to provide access to the channels during construction and maintenance work. It was assumed that the land requirements coincided through time with construction. The present value of the cost of the land, $CL$, was calculated as:

$CL = \sum_{y=1}^{10} (RL) (TL) (B_y) (D_y)$

(13)

where:

$RL = \text{the annual rental value of one acre of land}$

$TL = \text{the total acres of land required}$

$y = 1, 2, \ldots, 10$

and all other parameters have been previously defined.

The cost of maintenance is the third type of cost associated with the project. The project design provides for periodic removal of silt, drift, and snags, and also the control of vegetation with herbicides (43, p. 10). A one year lag between construction of the channel and the start of the maintenance cost stream was assumed. The present value of the cost of maintenance, $CM$, was calculated as:

$CM = \sum_{y=2}^{11} (AM) (B_{y-1}) (D_y)$

(14)
where:

\[ \text{AM} = \text{the total annual maintenance cost} \]
\[ y = 2, 3, \ldots, 11 \]

and all other parameters are as previously defined.

Finally, the present value of the total cost of development may be expressed as:

\[ \text{CD} = \text{CC} + \text{CL} + \text{CM} \quad (15) \]

all parameters having been previously defined.

IV. The Value of Preservation (PV)

The parameter \( D_t \) of equation (5) was omitted from the model used for estimation. It was assumed that wetlands in the Obion-Forked Deer watershed generate no downstream benefits and that channelization will have no adverse effects downstream from the junction with the Mississippi River. This assumption is not unrealistic. Wetlands in the watershed make a negligible contribution to downstream flow levels and to water quality because of the relative size and content of the Mississippi River. Increases in the discharge of water and suspended materials following channelization would be minor in relation to the capacity of the Mississippi.\(^7\) It should be noted, however, that the possibility of downstream benefits from the retention of these wetlands does exist.\(^8\)

\(^7\)These conclusions were drawn from conversations with the Watershed Planning Group, Soil Conservation Service, Nashville, Tennessee.

\(^8\)This omission may bias the analysis by understating the opportunity cost of channelization. The possible bias would be significant only if the estimated net value of development exceeded the estimated value of preservation by a marginal amount since it appears that the value of any downstream benefits would be small.
The variable $C_f^t$ of equation (5) was also omitted from the estimation of the opportunity cost of channelization. The costs imposed on adjacent agricultural lands is one dimension of $C_f^t$. Reductions in crop yields, one element in this cost, were included in the development value estimates as representing a cost of maintaining wetlands. Other elements of this cost are wildlife inflicted crop damage and the costs associated with wet areas of fields. Available evidence suggests that these costs, in general, are not statistically different from zero; however, these results are not regarded as conclusive. Lacking conclusive data, it was assumed that wetlands do not impose costs on adjacent agricultural lands.

The second dimension of $C_f^t$ is flood damage to structures, roads, and similar assets. Omission of $C_f^t$ then also implies that the channelization project will not reduce such flood damage in the watershed. The primary justification for modifying the Obion-Forked Deer River channels is the benefits of increased land use. The prevention of other types of flood damage is a secondary benefit (43, p.11). However, the prediction of these secondary benefits conflicts with evidence that flood damages have increased following channel modification (47, p. 1286). No means was found to resolve this apparent conflict. Thus, it was assumed that non-crop flood damage would neither increase nor decrease following channelization.

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9Goldstein (18, p. 27 and pp. 33-35). Note also his references to attempted evaluations.

10A possible explanation of increased flood damage is the commitment of assets beyond the bounds of flood protection.

11The assumption that wetlands do not impose costs on adjacent agricultural lands may bias the analysis towards the retention of excessive wetlands acreages. The nature of the possible bias introduced into the analysis by the assumption that channelization will have no net impact on total non-crop flood damages is open to question.
The value of fish and wildlife lost through wetlands conversion, parameter $R_c$ of equation (5), was divided into several parameters for estimation. In addition to resident fish and wildlife, the Obion-Forked Deer wetlands provide feeding areas, resting areas, and breeding sites for migratory waterfowl. Two dimensions are suggested: (1) the value of fish and wildlife within the watershed and (2) the value of migratory waterfowl beyond the boundaries of the watershed.

Five parameters were identified for valuation of the fish and wildlife within the watershed: sport fishing, big game, small game including furbearers, waterfowl, and general recreation. The valuation procedure involved (1) estimating the maximum sustained productivity of the fish and wildlife in the Obion-Forked Deer floodplain in terms of recreation activity days, (2) estimating the losses due to channelization, and (3) attributing values to the estimated number of foregone recreation days.

Estimates of the impact of channelization and land use changes in the Obion-Forked Deer floodplain beyond the boundaries of the watershed were not obtained in the analysis. Research on the quantitative and qualitative impacts of habitat loss on migratory waterfowl is in the incipient stages and models of the dynamics of waterfowl populations have not yet been developed. The complexity of prediction is increased by

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12The aquatic resources of the watershed support a small commercial fishing industry in addition to sport fishing, however, virtually no data are available. Data from other areas show that it is questionable if the benefits of a fresh water commercial fishery are greater than the correctly calculated costs (12, p. 12). It was assumed that the total costs of the commercial fishery in the Obion-Forked Deer equal the total revenues.

13Reed (47, pp. 393-413). The possibility of differential impact among species, thus altering the composition or "quality" of the water-
the possibility of the interaction of the wetlands conversion and habitat losses occurring throughout the Mississippi Flyway. The magnitude of the impact of the loss of wetlands habitat in the Obion-Forked Deer would be partly determined by habitat losses in other areas during the planning horizon if the effects do interact.

The relevant social opportunity costs identified for this analysis were the losses incurred beyond the boundaries of the watershed as a result of channelization and following land use adjustments within the watershed. A movement to comparable breeding sites and overflight by migrating waterfowl is a possibility; in this case society would incur no such losses. A shift within the migration route with no change in the size and composition is a second possibility. The negative impact in adversely affected regions would be compensated to some extent by the positive impact in other regions; a net gain to society as a whole would be theoretically possible. A final possibility is a decline in the waterfowl population with an accompanying loss to society. In the absence of adequate information to eliminate any of these possible outcomes, this dimension was omitted from the analysis, potentially increasing the incompleteness of the estimation.

A representative wetlands acre was constructed with the assumption that the value of wetlands does not vary among soil groups. The opportunity cost of converting this representative acre to agricultural use in year $y$ was defined as:

$$PV_y = (F_1 + F_2 + R_1 + R_2 + R_3 + R_4 + R_5 - C_p) (D_y) \quad (16)$$

The waterfowl population is mentioned by Goldsberry and Stotts (47, pp. 1496-1497).
where:

\[ F_1 = \text{the annual value per acre of harvestable forest products} \]

\[ F_2 = \text{the annual value of the change in productivty of the remaining wetlands forest per acre of converted wetlands} \]

\[ R_1 = \text{the annual value of lost sport fishing per acre of converted wetlands} \]

\[ R_2 = \text{the annual per acre value of small game hunting including furbearers} \]

\[ R_3 = \text{the annual per acre value of big game hunting} \]

\[ R_4 = \text{the annual per acre value of waterfowl hunting} \]

\[ R_5 = \text{the annual per acre value of general recreation} \]

and all other parameters are as previously defined.

The number of wetlands acres converted to agricultural use in year \( y \) was derived from equation (9) by summing over soil groups. The calculation was:

\[ N_y = \sum_{j=5}^{7} N_{jy} \quad (17) \]

In the analysis \( PV_y \) was estimated for all \( y \). These representative acre values were then increased by the corresponding estimates of the number of converted wetlands acres \( (N_y) \). The product is an estimate of the discounted value of the wetlands benefits lost in each year of the construction time span. The total present value of the social land use benefits from foregoing the project \( (PV) \) was then estimated by summing over the years of the time span. These calculations may be expressed as:

\[ PV = \sum_{y=2}^{11} PV_y N_y \quad (18) \]
with all terms as previously defined.

Equation (16) is an incomplete expression of the social opportunity cost of wetlands conversion. For example, a number of people derive satisfaction from the knowledge that a natural state is being preserved even though they have no direct contact with the area. The observable actions of individuals and groups reveal that this vicarious consumption has a value, however the methodology for measurement and valuation has not yet been developed.\(^{14}\) The incompleteness of the preservation value will not affect the results of the analysis if the estimated opportunity cost of development exceeds the estimated net value of development (\(DV - CD\)). A more complete estimate would only increase the magnitude of the difference and strengthen the economic justification for wetlands preservation. If, on the other hand, the estimated net value of development exceeds the estimated value of preservation the analysis would be inconclusive; the magnitude of the unmeasured, and perhaps unmeasurable, development opportunity costs could be sufficient to justify preservation. The land allocation decision would be a matter of judgment in this case. The difference between the net value of development and the value of preservation would provide a threshold value for the decision. Foregoing the project would be economically justified if it were judged that the unmeasured preservation value at the minimum equaled this difference.

\(^{14}\) While assumed to be nonexistent in this study, it should be noted that vicarious consumption may also be associated with the development alternative. Given the world food situation, individuals may derive satisfaction from the knowledge that land is being developed for agriculture even though they do not personally benefit from the enhanced productivity.
CHAPTER IV

ESTIMATION OF THE MODEL

I. The Cases Analyzed

The development value, cost of development, and preservation value were estimated for three assumed levels of wetlands conversion. Each represented an increase in wetlands conversion relative to the prior case.

Case I

Estimates were calculated for the land expected to be benefited by the project. The project is expected to enhance the productivity of 140,140 acres of cropland and allow the conversion of 17,690 acres of forested wetlands, including 2,740 acres of woodlands above the limits of overflow, to agricultural use (43, p. 11). The areas involved were estimated to be 86,554 acres of SPG-5 cropland, 53,586 acres of SPG-6 cropland, and 17,690 acres of woodlands on SPG-5 soils.\(^{1}\)

Case II

It was assumed that all privately owned wetlands forest of SPG-5

\(^{1}\)The total acreage, 157,830 acres of enhanced land, was taken from the project design memorandum (43, p. 11). No means were found to identify this data with the three soil groups and interpolation was required. It was assumed that unfavorable water relations were the reason for uncultivated SPG-5 land. On the basis of the water relations associated with each SPG, it was assumed that benefits would accrue to all SPG-5 cropland estimated to have unfavorable water relations. The difference between this estimated area and the predicted 140,140 acres of cropland to be benefited by the project was assumed to be SPG-6 cropland.
and SPG-6 soils would be converted to agricultural use.\(^2\) Five distinct categories of land are involved: (1) the SPG-5 land in cultivation prior to channelization and enhanced by the project, (2) the SPG-6 land in cultivation prior to channelization and enhanced by the project, (3) the converted SPG-5 wetlands protected by the project, (4) the converted SPG-5 wetlands not protected by the project, and (5) the converted SPG-6 wetlands. The areas in the first three categories are identical to the Case I estimated acreages. The areas in the last two categories were estimated as 20,015 acres of SPG-5 forested wetlands and 74,496 acres of SPG-6 forested wetlands. The land in the last three categories, the total converted acreage, has a total area of 112,201 acres.

Case III

It was assumed that 70 percent of all privately owned forested wetlands in the floodplain would be converted to agricultural use following the channelization project.\(^3\) The assumption was also made that the land conversion would proceed in a rational manner; that is, all forested wetlands on SPG-5 soils and SPG-6 soils would be converted to agriculture before the conversion of wetlands on SPG-7 soils because of their relatively low productivity. The area involved was estimated to include all SPG-5 and SPG-6 wetlands and 52,416 acres of SPG-7 forested wetlands. This case thus included the five categories of land identified

\(^2\)This level of wetlands conversion was suggested by data from the USDA survey of the Obion-Forked Deer Basin. Preliminary results suggest that the cultivation of SPG-5 and SPG-6 land will, on the average, generate positive returns under flooded conditions (49, pp. 26-28).

\(^3\)This level of wetlands conversion reflects the predictions of opponents of the project. These predictions are apparently based on the responses of landowners in the Obion-Forked Deer to past channel modification (47, p. 323).
in Case II plus a sixth category, the converted SPG-7 wetlands. The total wetlands conversion in this case was 164,617 acres.

II. The Present Value of Development

Representative Acre Values

The discounted representative acre values expressed in equation (8) were the central element in the estimation of the present value of development. Calculation of the present value of the benefit stream from a representative acre of SPG-j land beginning in year \( y \) of the planning period required estimates of the crop distribution, the prices of the output, the changes in crop yields attributable to the project, and the associated changes in production costs.

**Crop Distribution (\( A_{4j} \)).** The channelization project is expected to enhance the productivity of land in cultivation prior to channel modification and also result in the clearing of forested land for agricultural use. A representative crop distribution was calculated for each SPG using the procedure expressed in equation (7) for each of these two pre-project land uses. Crop distribution weights for land in cultivation prior to the project were calculated from the land use data in Table 1 (p. 8) with the assumption that the distribution of land among the various crops would not change after channel modification. Weights for land cleared following the project were calculated from the data on the 1971 distribution of crops on land cleared between 1964 and 1971 presented in Table B-1 of Appendix B. It was assumed that land converted to agricultural use following channel modification would be allocated among the various crops in the same proportions as the land cleared during this period. The two sets of representative acre crop distribu-
tion weights calculated for each SPG are presented in Table B-2 of Appendix B.

**Output Prices (P_j).** Five sets of crop prices were used in the analysis. The price sets were constructed by: (1) establishing an assumed price range for soybeans, corn, cotton, and pasture, (2) identifying five points within the range for each crop—the high, average, and low price and the midpoints between the average price and the high and low prices, and (3) grouping the corresponding points of each price range. The five resulting sets of output prices are presented in Table B-3 of Appendix B. 4

Prices for the miscellaneous cropland category, which included rice, milo, small grains, truck crops, and idle cropland, were not estimated. Data on yields and production costs for the crops in this category were incomplete. Miscellaneous cropland was arbitrarily assigned a net return 25 percent less than the average net returns per acre from soybeans, corn, cotton, and pasture for each price set. Any inaccuracy introduced into the analysis by this procedure was believed to be minor for the crops in this category would appear to represent a relatively minor portion of the total agricultural income stream.

**Yield (Q_{i,j}).** Yields per acre were estimated for each SPG under both flooded and flood-free conditions. The soybean, corn, and cotton yields were derived from working papers of the USDA survey of the Basin (56, pp. 8-9). The pasture yields were derived from data developed at the University of Tennessee (2, p. 38). These yield data are presented in Table B-4 of Appendix B.

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4The two sets of representative acre weights were derived from 1971 cropping patterns and, therefore, depend upon a particular set of
The changes in yield on land cultivated prior to channelization and enhanced by the project were assumed to equal the differences between the estimated flooded and flood-free yields. The yields on land not cultivated prior to channelization and enhanced by the project were assumed to equal the estimated flood-free yields. The yields on land not cultivated prior to channelization and not enhanced by the project were assumed to equal the estimated yields under flooded conditions.

Production Costs ($C_{ij}$). The per acre costs of production were derived from budgets developed at the University of Tennessee as a part of Regional Project S-67 (23). These budgets were developed for a region of Tennessee which includes a significant portion of the Obion-Forked Deer Basin and were assumed to be representative of the flood-plain. The estimates included the cost of fixed and variable inputs, a $1.60 per hour labor cost, a return to management of 5 percent of the estimated total revenue per acre, a $9.81 per acre general overhead cost, and an average land cost of $25.37 per acre. The estimates were computed for a 180 acre farm, the average farm size in the 14 county area which contains the watershed (41, p. 34). Production costs were estimated for each SPG under both flooded and flood-free conditions. These cost data are presented in Table B-5 of Appendix B.

The changes in production costs for land cultivated prior to channelization and enhanced by the project were assumed to equal the differences between the estimated costs under flooded and flood-free conditions. The production costs for land not cultivated prior to input and output prices. The representative crop distribution may not correspond to the profit maximizing distribution for the five output price sets used in estimating the model. The analysis is open to criticism on this point.
channelization and enhanced by the project were assumed to equal the estimated costs of production without flooding. The production costs for land not cultivated prior to channelization and not enhanced by the project were assumed to equal the estimated costs of production under flooded conditions.⁵

Case I

The value of development has been defined as the discounted stream of net agricultural income attributable to the channelization project and land use changes. In Case I it was assumed that no unprotected wetlands would be developed. The value of development was thus computed as the present value of (1) the net revenue stream from the forested wetlands expected to be protected by the project and converted to agricultural use and (2) the change in the net revenue stream from land expected to be benefited by the project which was cultivated prior to channelization. The areas involved were estimated to be 17,690 acres of forested wetlands, 86,554 acres of SPG-5 cropland, and 53,586 acres of SPG-6 cropland.

The procedure defined by equation (8) was used to estimate the present value of a representative acre of land in each category. These present values were calculated at an 8, 9, and 10 percent rate of discount for each set of output prices. The acreages of each category of land which begin to generate benefits in year y as a result of channel modification in year y-1 were estimated with equations (9) and (10).

⁵The per acre costs of land clearing were assumed to equal the value of the resulting timber throughout the analysis. The stumpage value of the timber on an average acre was estimated to be approximately $200.00 (1971 dollars).
The discounted representative acre values were increased by the estimated acreage of SPG-5 cropland, SPG-6 cropland, or SPG-5 wetlands forest benefited in the corresponding year and summed. The totals were grouped by price level and discount rate and summed to provide an estimate of the present value of development. These calculations are expressed in equation (11). The resulting estimates of the present value of development from the cropland and wetlands expected to be benefited by the project are presented in Table 2.

Case II

The Case II development value included the stream of benefits from the three sources identified in Case I, the net benefits from the conversion of the remaining privately owned wetlands forest on SPG-5 soils to agriculture, and the net benefits from the conversion of all privately owned SPG-6 wetlands forest to agriculture. The areas in the last two categories were estimated as 20,015 acres and 74,496 acres, respectively. The productivity of these areas was assumed to be unaffected by the project.

The discounted returns from the first three sources were identical to the Case I estimates. The discounted returns from a representative acre of land in the last two categories were calculated with the procedure defined in equation (8) using the appropriate parameters for SPG-5 and SPG-6 wetlands under flooded conditions. Discounted development values were then computed with the procedure defined in equations (9) through (11). The resulting estimates of the present value of the development alternative with all privately owned SPG-5 and SPG-6 wetlands converted to agriculture are presented in Table 3.
Table 2. The Estimated Present Values of Development, Obion-Forked Deer Floodplain: Case I

<table>
<thead>
<tr>
<th>Price Set</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Low</td>
<td>$18,755,146</td>
</tr>
<tr>
<td>Low Median</td>
<td>$27,238,654</td>
</tr>
<tr>
<td>Average</td>
<td>$35,836,466</td>
</tr>
<tr>
<td>High Median</td>
<td>$44,406,345</td>
</tr>
<tr>
<td>High</td>
<td>$52,990,725</td>
</tr>
</tbody>
</table>

^Case I assumed that no unprotected wetlands would be developed for agricultural purposes.

^The output prices within each set are presented in Table B-3 of Appendix B.
Table 3. The Estimated Present Values of Development, Obion-Forked Deer Floodplain: Case II

<table>
<thead>
<tr>
<th>Price Set</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Low</td>
<td>-671,473</td>
</tr>
<tr>
<td>Low Median</td>
<td>16,129,447</td>
</tr>
<tr>
<td>Average</td>
<td>33,032,838</td>
</tr>
<tr>
<td>High Median</td>
<td>49,904,428</td>
</tr>
<tr>
<td>High</td>
<td>66,788,764</td>
</tr>
</tbody>
</table>

*aCase II assumed that all privately owned wetlands forest on SPG-5 and SPG-6 soils would be developed for agricultural purposes.

*bThe output prices within each set are presented in Table B-3 of Appendix B.
Case III

In Case III it was assumed that 70 percent of all privately owned wetlands forest in the floodplain would be used for agriculture. The area involved was estimated to include all SPG-5 and SPG-6 wetlands and 52,416 acres of SPG-7 wetlands forest. The development value in this case thus included the five categories of development benefits identified in the second case and the value of the converted SPG-7 wetlands.

The discounted returns from a representative acre of converted SPG-7 wetlands were calculated by substituting the appropriate parameters into equation (8). These estimates were combined with the values for the enhanced SPG-5 and SPG-6 cropland, the enhanced SPG-5 wetlands, and the unprotected SPG-5 and SPG-6 wetlands and discounted development values were computed with the procedure defined in equations (9) through (11). The present values of development estimated for this case are presented in Table 4.

III. The Cost of Development

The present value of the cost of the channelization project was computed by summing the discounted estimates of the three types of costs involved in the project. This procedure is expressed in equations (12) through (15) in Chapter III.

The Cost of Construction

The estimation of the cost of modifying the Obion-Forked Deer stream channels was based upon estimated annual design and construction costs (43, p. 10). The original values were converted to 1971 dollars with a composite construction cost index (44, p. 677). The resulting annual values, which are given in Table B-6 of Appendix B, were
Table 4. The Estimated Present Values of Development, Obion-Forked Deer Floodplain: Case III^a

<table>
<thead>
<tr>
<th>Price Set^b</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Dollars</td>
</tr>
<tr>
<td>Low</td>
<td>-15,630,771</td>
</tr>
<tr>
<td>Low Median</td>
<td>4,420,573</td>
</tr>
<tr>
<td>Average</td>
<td>24,548,516</td>
</tr>
<tr>
<td>High Median</td>
<td>44,648,383</td>
</tr>
<tr>
<td>High</td>
<td>64,753,584</td>
</tr>
</tbody>
</table>

^aCase III assumed that 70 percent of all privately owned wetlands forest would be developed for agricultural purposes.

^bThe output prices within each set are presented in Table B-3 of Appendix B.
discounted at the three alternative discount rates and summed following the procedure expressed in equation (12).

**The Cost of Land**

The project will require unencumbered rights of way to 9,280 acres of land with an estimated annual value of $9.51 per acre (43, p. 8). The portion of this acreage required for annual construction was assumed to equal the portion of the total construction undertaken in a year. The cost data used as a proxy variable for annual construction in the analysis are presented in Table B-6 of Appendix B. Following the procedure expressed in equation (13), the product of the estimated total annual land value and the annual proportions of total construction was discounted at the three alternative discount rates and summed.

Not all of the required land will be used in enlarging the channels; some portion will continue to produce wetlands products after construction. Also, the original channels bypassed in straightening stream courses represent a potential increase in land area. It was not possible to estimate the land area lost in channel modification. It was judged preferable to underestimate rather than overestimate the value of preservation and none of this area was subtracted in estimating the losses associated with the project.

**The Cost of Maintenance**

Maintenance of the project channels will cost an estimated $122,000 annually (43, p. 10). This value was converted to 1971 dollars.

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6 It was assumed that the total area would be required through the life of the project; available project data were not specific on this point. The annual land value was derived from project design data (43, Appendix I) and data developed at the University of Tennessee (23).
with the composite construction cost index used to inflate the cost of construction (44, p. 677). It was assumed that this estimated cost, $197,640, would begin to accrue in proportions equal to annual construction with a one year lag. Following the procedure expressed in equation (14), the portions of this cost stream beginning in years 2 through 11 were estimated with the proxy values for the annual proportion of total construction given in Table B-6 of Appendix B, discounted, and summed.

The Cost of the Project

The estimated construction costs, land costs, and maintenance costs discounted at the three rates used in the analysis are presented in Table 5. The present values of the cost of development, the sums of these values, are likewise presented in Table 5.

IV. The Present Value of Preservation

The discounted representative acre values expressed in equation (16) were the central element in the estimation of the present value of preservation. The calculations required estimates of the value of forests and the impact of channelization on forest productivity, parameters $F_1$ and $F_2$, the value of fish and wildlife, parameters $R_1$ through $R_5$, and the associated costs, parameter $C_p$.

Representative Acre Values

The five $R$ parameters were estimated in a similar manner using the concept of the maximum sustained yield of a renewable resource. Data from the Tennessee Fish and Game Commission were used to estimate the sustained productivity of the fish and wildlife in the Obion-Forked Deer
Table 5. The Estimated Present Values of the Cost of Construction, the Cost of Land, the Cost of Maintenance, and the Total Cost of Development, Obion–Forked Deer Floodplain

<table>
<thead>
<tr>
<th>Item</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Dollars</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>9,411,050</td>
</tr>
<tr>
<td>Land Cost</td>
<td>673,390</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>1,342,733</td>
</tr>
<tr>
<td>Total Development Cost</td>
<td>11,477,174</td>
</tr>
</tbody>
</table>

floodplain and to convert these estimates into recreation activity days. Sport fishing, small game hunting, and general recreation were assumed to be non-specialized recreation while waterfowl and big game hunting were judged to be activities involving relatively limited opportunities and were valued as specialized recreation. The values proposed by the Water Resources Council (WRC) per day of specialized and non-specialized recreation were used in activity valuation (50, p. III-17). Specialized recreation was also valued at the higher levels recommended by the University Council on Water Resources (UCOWR) (8, p. 15).

It was assumed that the costs of producing the fish and wildlife of the floodplain equaled zero. The production costs would appear to be limited to the costs incurred by State and Federal agencies in the management of these renewable resources. It is difficult to assign these costs to a set of species in a specific area; agency budgets would presumably not decline if these species were reduced in numbers. The parameter $C_p$ was then estimated for the costs of forestry production alone.

The Cleared Forest ($F_1$). The value of a representative acre of forest to society was defined as the net annual return from the maximum sustained forest production. The average annual net increment in the growth of the Obion-Forked Deer floodplain forest is estimated to be approximately 58 cubic feet per acre (49, p. 11). The estimated range in stumpage value of this net growth was $13.44 to $16.80 per acre in 1971 dollars. Calculations were made with these two values and their simple average, $15.12$.

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7These data are usefully summarized by Barstow (5).

8This price range was derived from data on bottomland forests from the USDA survey of the Basin (49, p. 27) and from the Tennessee Game and
The stumpage value represents total returns less the costs of harvest. Net returns were computed by subtracting the estimated annual cost of the land ($9.51 per acre), the annual costs of general overhead estimated in developing the crop budgets ($9.81 per acre), and 5 percent of the stumpage value as a return to management. The results were the negative returns of $6.55, $4.96, and $3.36 per acre for the low, average, and high stumpage values, respectively.9

The Remaining Forest (F9). The reduction in frequency and duration of overflows following channel modification decreases the growth of bottomland forests through the reduction in soil moisture. A 50 percent decline in productivity has been estimated for forests on the Obion-Forked Deer floodplain soil groups (5, p. 14 and p. 25). The net value of this decrease in productivity, approximately 29 cubic feet per year, was estimated to be $6.39, $7.19 and $7.98 per acre at the low, average, and high stumpage values, respectively.

This average per acre change in value was assumed to be representative of the impact of channelization on the private forest holdings remaining in each case plus the 11,500 acres of forest in State and Federal lands. This total value was divided among the reclaimed acres.

Fish Commission (5, p. 26). Stumpage values were converted to 1971 dollars with the wholesale price index for lumber and wood products (48, p. 552).

9These losses may be the result of the use of averages. For example, the overhead per acre was calculated by the division of the estimated total overhead for the average farm by the size of the average farm. The portion of the general overhead in reality chargeable to forest holding may be less than this average value. In addition, the annual overhead of nonfarm forest owners may be less than the values used in the analysis.
in each case in creating the representative acre.\textsuperscript{10}

\textbf{Sport Fishing (R₁).} The aquatic resources in the Obion-Forked Deer channels to be modified in the project can support an estimated 969,200 sport fishing activity days annually (5, p. 13). A 90 percent loss following channelization was assumed on the basis of a study of 23 channelized streams in North Carolina (47, p. 39). The estimated annual loss of 872,280 activity days were valued at the low, average, and high levels recommended by the WRC for non-specialized recreation: $0.75, $1.50, and $2.25 per activity day (50, p. III-17). Representative acre values were derived by dividing the total estimated values among the estimated number of reclaimed acres in each case.

\textbf{Small Game (R₂).} Parameter R₂ was defined to encompass small game including squirrel, raccoon, and rabbit and furbearers including mink, beaver, and muskrat. Tennessee Game and Fish Commission data on populations, sustainable harvests, and potential harvest per trip were used to estimate an annual 0.36 small game hunting activity days per acre (5, p. 9 and p. 19). It was necessary to eliminate the furbearer dimension of this parameter because of the lack of data on populations and harvests. The estimated annual activity day fraction was valued at the low, average, and high values recommended by the WRC for non-specialized recreation and used as the opportunity cost of converting

\textsuperscript{10}The present values calculated with this method and present values calculated with the alternative method of dividing the total annual value among the years of the construction time span and discounting are identical. The method used allowed calculation on a representative acre basis and added symmetry to the computation of development and preservation values.
an acre of wetlands to agricultural use.\textsuperscript{11} 

**Big Game (R\textsubscript{3}).** Big game species, deer and turkey, were estimated to have the potential of annually supporting 0.12 hunting activity days per acre on a sustained basis from Game and Fish Commission data (5, p. 13). Representative acre values were computed by valuing this activity at the low, average, and high benefit levels proposed by the WRC for specialized recreation: $2.50, $4.75, and $7.00 per activity day. Valuation was also made at the levels recommended by the UCOWR: $15.00, $17.50, and $20.00 per specialized recreation activity day.

**Waterfowl (R\textsubscript{4}).** Calculations with Game and Fish Commission data produced an estimate of 0.49 waterfowl hunting trips annually per acre on a sustained bases (5, pp. 26-27). The assumption of unaltered productivity of unreclaimed areas was maintained in creating representative wetlands acres. The estimated annual recreation per acre was valued at the six levels utilized in valuing big game hunting.

**General Recreation (R\textsubscript{5}).** This parameter was defined to include wildlife related activities such as bird watching, wildlife photography, and nature hikes. A ratio of 2.27 general wildlife related activity days per hunting activity day in Tennessee has been estimated (5, p. 8).\textsuperscript{12} Representative acre values were computed by summing the estimated annual days of hunting activity per acre, increasing the sum

\textsuperscript{11}The implied assumption is that the productivity of the remaining habitat will be unchanged. The opportunity costs may be underestimated by this procedure (55, pp. 29-35).

\textsuperscript{12}Other general recreation activities, such as pleasure boating and camping, were not included in deriving this ratio. A relationship between such omitted activities and wildlife could presumably exist; a conservative bias may, therefore, have been introduced into the preservation value estimation.
by the factor 2.27, and valuing the resulting estimate with the non-specialized recreation day values used in the analysis.

Case I

The value of preservation has been defined as the discounted stream of benefits foregone as a result of channel modification and land use change. The quantifiable benefits foregone in Case I were the benefits from the 17,690 acres of forested land assumed to be converted to agricultural use, the change in the sustained yield of the remaining forest on public and private lands, and the decline in fish population.

Discounted opportunity costs of channelization and land conversion were calculated for a representative acre with the procedure defined in equation (16). All parameters were assigned the estimated average values for benefited wetlands within the boundaries of overflow. Parameter \( R_4 \) was set equal to zero in calculating the representative acre values for benefited woodlands beyond the limits of overflow under the assumption that clearing this land would have no impact on waterfowl.

The opportunity costs were calculated at two low, average, and high levels which differed by the valuation of a specialized recreation activity day. The six value sets are presented in Table B-7 of Appendix B. The present value of preservation was estimated with the procedure defined by equation (18). The resulting estimates of the opportunity costs of channelization and land use change for Case I are presented in Table 6.

Case II

The preservation value for Case II included the stream of foregone benefits from the 112,201 acres of converted land, the change in the
Table 6. The Estimated Present Values of Preservation, Obion-Forked Deer Floodplain: Case I\textsuperscript{a}

<table>
<thead>
<tr>
<th>Valuation\textsuperscript{b}</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Low (WRC)</td>
<td>14,445,290</td>
</tr>
<tr>
<td>Average (WRC)</td>
<td>20,915,042</td>
</tr>
<tr>
<td>High (WRC)</td>
<td>27,369,940</td>
</tr>
<tr>
<td>Low (UCOWR)</td>
<td>15,287,247</td>
</tr>
<tr>
<td>Average (UCOWR)</td>
<td>21,773,828</td>
</tr>
<tr>
<td>High (UCOWR)</td>
<td>28,245,575</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Case I assumed that no unprotected wetlands would be developed for agricultural purposes.

\textsuperscript{b}The values within each set are presented in Table B-7 of Appendix B.
sustained yield of the remaining forest, and the decline in fish population. Discounted representative acre values were computed using equation (16) and the present values of preservation were computed with the procedure defined in equations (17) and (18). The opportunity costs of channel modification and land use change estimated for Case II are presented in Table 7.

Case III

The Case III preservation value included the stream of foregone benefits from the 164,617 acres of converted land assumed in this case, the change in the sustained yield of the remaining forest, and the decline in fish population. The present values of preservation were computed with the procedure stated in equations (18) through (20). The opportunity costs of channelization and land use change estimated for Case III are presented in Table 8.
Table 7. The Estimated Present Values of Preservation, Obion-Forked Deer Floodplain: Case II\(^a\)

<table>
<thead>
<tr>
<th>Valuation(^b)</th>
<th>Discount Rate</th>
<th>Discount Rate</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
<td>9%</td>
<td>10%</td>
</tr>
<tr>
<td>Low (WRC)</td>
<td>8,146,959</td>
<td>6,880,691</td>
<td>5,884,351</td>
</tr>
<tr>
<td>Average (WRC)</td>
<td>17,359,952</td>
<td>14,683,019</td>
<td>12,538,782</td>
</tr>
<tr>
<td>High (WRC)</td>
<td>26,571,470</td>
<td>22,474,059</td>
<td>19,192,098</td>
</tr>
<tr>
<td>Low (UCOWR)</td>
<td>14,125,460</td>
<td>11,947,303</td>
<td>10,202,544</td>
</tr>
<tr>
<td>Average (UCOWR)</td>
<td>23,458,024</td>
<td>19,840,760</td>
<td>16,943,328</td>
</tr>
<tr>
<td>High (UCOWR)</td>
<td>32,789,103</td>
<td>27,732,937</td>
<td>23,683,006</td>
</tr>
</tbody>
</table>

\(^a\)Case II assumed that all privately owned wetlands forest on SPG-5 and SPG-6 soils would be developed for agricultural purposes.

\(^b\)The values within each set are presented in Table B-7 of Appendix B.
Table 8. The Estimated Present Values of Preservation, Obion-Forked Deer Floodplain: Case III\(^a\)

<table>
<thead>
<tr>
<th>Valuation</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Dollars</td>
</tr>
<tr>
<td>Low (WRC)</td>
<td>4,653,891</td>
</tr>
<tr>
<td>Average (WRC)</td>
<td>15,388,291</td>
</tr>
<tr>
<td>High (WRC)</td>
<td>26,128,637</td>
</tr>
<tr>
<td>Low (UCOWR)</td>
<td>13,481,129</td>
</tr>
<tr>
<td>Average (UCOWR)</td>
<td>24,392,075</td>
</tr>
<tr>
<td>High (UCOWR)</td>
<td>35,308,952</td>
</tr>
</tbody>
</table>

\(^a\)Case III assumed that 70 percent of all privately owned wetlands forest would be developed for agricultural purposes.

\(^b\)The values within each set are presented in Table B-7 of Appendix B.
CHAPTER V

DISCUSSION OF THE RESULTS

I. Estimated Development Values

The development values estimated for each case increased with output price level as was expected. In comparing the estimated values among the three cases it was found that the Case II estimates exceeded the Case I estimates at the high median and high output price levels. It was also found that the Case III estimates were less than the Case II estimates at all output price levels.

Assume that the channelization project is undertaken and that society's goal is to maximize the net returns from this investment. The relationships among the cases imply that a policy prohibiting the conversion of SPG-7 forested wetlands to agricultural use would be in the interest of society. Further, a policy prohibiting the development of unprotected SPG-5 and SPG-6 forested wetlands would contribute to this goal if output price levels were expected to approximate the low, low median, or average price sets over the planning horizon.¹

These policy implications follow logically from the analysis but present an apparent paradox. The differences among the three cases were the assumed acreages of forested wetlands developed for agricultural purposes while receiving no flood protection from the channelization

¹Subtraction of the costs of development would reduce the development value estimates by constant amounts and would not change these implications.
The development values for these cases were estimated with a static model based upon the net agricultural returns from a representative acre of each soil group. The relationships among these cases then reflect the estimated annual net revenues under flooded conditions presented in Table 9. These estimates imply that the conversion of SPG-5 and SPG-6 wetlands to agricultural use is economically rational only with optimistic crop price expectations and that the conversion of SPG-7 wetlands is economically irrational under all output price sets considered.

The paradox arises from a comparison of these estimates with the acreages of wetlands converted to agriculture from 1964 to 1971 in Table B-1 of Appendix B. The observed conversion of SPG-5 and SPG-6 wetlands may be explained by optimistic crop price expectations; however, the conversion of the 10,837 acres of SPG-7 wetlands cannot be explained on this basis unless prices greater than those used in the study are hypothesized. A second possible explanation for this apparent paradox is that annual flood probabilities are based upon long run calculations. Observed flooding below these computed averages may create expectations which induce landowners to convert wetlands to agricultural use for short run gains.

A second paradox was apparent in the study results. The discounted development values attributable to channel modification, Case I, exceeded the discounted development costs at all output price levels. Why then have the owners of the land which would be enhanced by channel modification not undertaken the channelization themselves? One possible explanation is that annual flood probabilities are based upon long run calculations. Observed flooding below these computed averages may create expectations which induce landowners to convert wetlands to agricultural use for short run gains.

2Case I assumed no unprotected wetlands would be developed, Case II assumed the development of all unprotected SPG-5 and SPG-6 wetlands, and Case III assumed the development of slightly less than half of the SPG-7 wetlands in addition to the unprotected SPG-5 and SPG-6 wetlands.
Table 9. Estimated Annual Net Agricultural Returns from a Representative Acre Under Flooded Conditions by Soil Productivity Group, Obion-Forked Deer Floodplain

<table>
<thead>
<tr>
<th>Output</th>
<th>SPG-5</th>
<th>SPG-6</th>
<th>SPG-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Set a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>-24.70</td>
<td>-30.37</td>
<td>-40.50</td>
</tr>
<tr>
<td>Low Median</td>
<td>-10.69</td>
<td>-18.29</td>
<td>-31.70</td>
</tr>
<tr>
<td>Average</td>
<td>3.31</td>
<td>-6.23</td>
<td>-22.97</td>
</tr>
<tr>
<td>High Median</td>
<td>17.32</td>
<td>5.82</td>
<td>-14.23</td>
</tr>
<tr>
<td>High</td>
<td>31.28</td>
<td>17.88</td>
<td>-5.51</td>
</tr>
</tbody>
</table>

\(^a\)The prices within each set are presented in Table B-3 of Appendix B.
explanation is that this analysis considered only one use of the limited capital available to the landowner while a number of alternative investment opportunities presumably exist. Channelization would be deferred until all investments which promise greater returns have been undertaken. A second possible explanation involves the difficulties of group action. The cost of transactions among participants and various games of strategy are widely recognized impediments to large group action. In addition, channel modification is somewhat unique in that the benefits cannot be restricted solely to participating landowners. This characteristic provides an incentive to remain outside the group and share in the benefits without sharing the costs. Finally, the Obion-Forked Deer channelization project was authorized in 1948 (43, p. 1). The expectation of public funding would presumably tend to dissuade landowners from undertaking the project at their own expense. Such deferment may not be permanent; continued failure to fund the authorization might induce property owners to incur the project cost themselves rather than continue to bear the costs implicit in foregoing the benefits of the project.

Assume that the best social use of the area is as forested wetlands. Alternative uses for private capital and the expectation of public funding would appear to produce only a short run postponement. The other hindrances might presumably be surmounted. These considerations suggest that public action would be required to prevent private channelization and thus assure optimality.

The economic feasibility of channelization by a group of

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3The problem of the free rider, for example, may be solved by transforming the group into a legal entity with the power of taxation. Brown (7, pp. 21-30) discusses this solution as well as other aspects of channel modification through group action.
landowners also raises the question of the appropriateness of public involvement. Public investment is frequently justified with the previously discussed assumption that a gain or loss to an individual is a corresponding gain or loss to society. It is presupposed, of course, that no alternative investments with greater returns are available. A large net return from channel modification would, however, appear to be an argument for the project and not an argument for public financing.

Assume that no externalities are associated with channelization and the following land use changes. Public financing could be justified if the landowners would not undertake the project at their own expense. Public funds might best be used, however, to remove the impediments to channelization by the owners of enhanceable property. Assume this alternative is chosen and, as a result, the landowners undertake the project. The public sector would in effect gain the difference between the cost of channelization thus avoided and the cost incurred in fostering this private effort for other investments. The alternative chosen would appear to depend upon the probabilities of successfully aiding private action and the positive magnitude of the implicit gain in the public account.

Alternatively, the returns from channelization may exceed the costs by an amount great enough to induce the landowners to undertake the project, overcoming any obstacles on their own. In this case, public involvement would be justified if the public sector were more efficient than the private sector and, therefore, could complete the project at a lower cost. Society would in effect gain the difference in the cost of

4For example, public assistance in the formation of a private channelization corporation could remove the barriers to private action.
the project as a public undertaking as opposed to a private undertaking since the channels will be modified irregardless of the source of funds. This difference would represent the relevant decision parameter; public financing would be economically justified if no alternative public investment would yield returns greater than the difference in costs.

Finally, public funding of the channelization project could be justified as a means of providing public assistance to a segment of society. If society decides that the owners of enhanceable property are deserving of public assistance, the decision to publicly finance channel modification is a question of whether there are more appropriate or more efficient methods of providing aid to this group (7, pp. 28-30).

Relaxing the assumption of the absence of externalities would not appear to strengthen the argument for public financing of the project. External economies provide a rational for public investment; however, the externalities identified in this study were diseconomies associated with channelization and resulting wetlands loss. The theoretically correct role for the public sector is then to represent the segments of society whose interests would be adversely affected by the project. While the limited incidence of benefits may be an argument for local financing, the wider incidence of external diseconomies is an argument for social control over the decision irregardless of the source of funds.6

5In the prior case, the value of any such difference in efficiency would reduce the gains from fostering private action.

6The potential impact on migratory waterfowl gives an international dimension to these externalities. The correct jurisdiction for the decision may be multi-national rather than national.
II. Estimated Preservation Values

The preservation values estimated for each case increased with the valuation level as was expected. However, the relationships between cases did not coincide with a priori expectations at the four lowest valuation levels.

Increasing the amount of converted wetlands would be expected to increase the associated opportunity cost. However, the opposite relation was found between the three cases at the four lowest valuation levels. These results may be rationalized by the forestry values used in the analysis. The procedure used to compute the value of a representative acre of forested wetlands, parameter F₁, produced negative values. Thus, clearing additional forest reduces the computed foregone benefits.

The relations between cases at the Average (UCOWR) and High (UCOWR) valuation levels do coincide with a priori expectations. These results may be rationalized by the magnitudes of the values attributed to a specialized recreation activity day at these levels of valuation.

The UCOWR values for a specialized recreation activity day, $15.00, $17.50, and $20.00, are significantly larger than the WRC values, $2.50, $4.75, and $7.00. Use of the UCOWR values rather than the WRC values did not create as large a divergence between the preservation value estimates as might be expected from a comparison of their relative magnitudes. These results may be rationalized by the number of specialized recreation activity days estimated for the floodplain. The choice of recreation values may have been of greater significance if greater numbers of specialized recreation activity days were involved.
III. The Comparison of Estimated Development and Preservation Values

The decision criterion expressed in equation (6) stated that channelization and the following land use changes are economically justified if the discounted value of the resulting net income stream exceeds the discounted value of the foregone net benefits from the wetlands environment. The decision criteria also stated that maintenance of the wetlands environment is economically justified if the opposite relationship exists. In addition to being economically sound, the selection of the alternative with the greatest opportunity cost is desirable as it will tend to move society to a higher welfare position.

Development values were estimated at five crop price levels and preservation values were estimated at six levels of valuation in the study. While all possible comparisons might be enlightening, it has been argued that, when dealing with an irreversible alternative, adjustments should be made to reflect the loss of options involved in a decision (17, p. 609). The technical and biological considerations discussed in prior chapters suggest that wetlands conversion through channelization is essentially irreversible. A current land allocation decision could presumably prove incorrect in the future because of unforeseen events. An error because of the possible overvaluation of the preserved environment would not eliminate the option of channelization at some future time. Development through channelization would, however, apparently eliminate the option of the wetlands alternative if future events indicate that wetlands represent the optimal land use. A single set of comparisons, employing the preservation values estimated
at the highest valuation level, was therefore made.\(^7\)

The results of these comparisons are present in Table 10. The discounted value of preservation estimated at the high (UCOWR) valuation level was found to exceed the discounted net value of development estimated at the low, low median, and average crop price sets in the three cases examined. This set of preservation values was also found to exceed the net value of development estimated at the high median crop price set for Case III.\(^8\)

In terms of the decision criteria, if agricultural output prices over the 50 year planning horizon are expected to approximate these price levels, the area should remain as forested wetlands. It should be noted that these results were obtained with an incomplete estimate of the value of preservation. A more complete estimate would probably increase the magnitude of the difference between the values estimated for these two alternatives as omitted parameters would appear to be wetlands.

\(^7\)The concept of irreversibility is also a justification for the method of quantifying wetlands benefits employed in the study. Krutilla (25, p. 785) has noted that irreversible environmental decisions are similar in concept to a dynamic linear programming problem which requires that current actions be compatible with the attainment of a desired future state even though they may not coincide with the actions which are optimal under current conditions. He also notes that, while the optimal amount of natural environments is unquantifiable with the current state of knowledge, it is probably increasing over time (25, pp. 785-786). The measurement of sustained productivity implies that the renewable resource in question has a value independent of current utilization which should be included in decisions on irreversible environmental transformations. The computations were based upon estimated sustained productivity under current conditions rather than potential productivity under intensive management to avoid possible unrealistic overinflation of the value of renewable wetlands resources.

\(^8\)Comparison at the high (WRC) valuation level changes the direction of the inequality only for the Case III development values estimated at high median crop prices.
Table 10. Discounted Net Values of Development (DV-CD) Estimated for 3 Cases and 5 Output Price Sets, Obion-Forked Deer Floodplain

<table>
<thead>
<tr>
<th>Case and Price Set&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Discount Rate</th>
<th>8%</th>
<th>9%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Discount Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>7,277,972</td>
<td>5,163,156</td>
<td>3,529,060</td>
<td></td>
</tr>
<tr>
<td>Low Median</td>
<td>15,761,479</td>
<td>12,338,494</td>
<td>9,656,561</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>24,359,291</td>
<td>19,610,502</td>
<td>15,866,649</td>
<td></td>
</tr>
<tr>
<td>High Median</td>
<td>32,929,171&lt;sup&gt;b&lt;/sup&gt;</td>
<td>26,858,890&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22,056,542&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>41,513,550&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34,119,545&lt;sup&gt;b&lt;/sup&gt;</td>
<td>28,256,932&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Case II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>-12,148,648</td>
<td>-11,267,930</td>
<td>-10,502,581</td>
<td></td>
</tr>
<tr>
<td>Low Median</td>
<td>4,652,272</td>
<td>2,942,350</td>
<td>1,632,549</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>21,555,664</td>
<td>17,239,209</td>
<td>13,841,651</td>
<td></td>
</tr>
<tr>
<td>High Median</td>
<td>38,427,253&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31,509,153&lt;sup&gt;b&lt;/sup&gt;</td>
<td>26,027,705&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>55,311,589&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45,789,887&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38,223,056&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Case III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>-27,107,946</td>
<td>-23,920,477</td>
<td>-21,307,471</td>
<td></td>
</tr>
<tr>
<td>Low Median</td>
<td>-7,056,601</td>
<td>-6,960,989</td>
<td>-6,824,604</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>13,071,341</td>
<td>10,063,195</td>
<td>7,713,562</td>
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<tr>
<td>High Median</td>
<td>33,171,208</td>
<td>27,063,598</td>
<td>22,231,331</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>53,276,409&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44,068,532&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36,753,081&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>The 3 cases are described in Chapter IV. The output prices within each set are presented in Table B-3 of Appendix B.

<sup>b</sup>The value exceeds the present value of preservation estimated at the high (UCOWR) valuation level for the identical case and rate of discount. The values within each level are presented in Table B-7 of Appendix B.
benefits lost through channelization and land use change.

The incompleteness of the estimated value of preservation is important for those cases and price sets where the net value of development exceeds the value of preservation. If crop prices are expected to approximate the high median-high range, the land allocation decision becomes a question of judgment. The difference between the discounted value of preservation provides a threshold for the decision. If the unquantified, and perhaps unquantifiable, parameters are judged to have a potential social value at least equal to this difference the area should be maintained as wetlands. Development for agricultural purposes is justified if the opposite judgment is made. These positive differences or threshold values are presented in Table 11.

The value of the wetlands flora and fauna, for example, was not completely quantified in the study. The procedure employed captured a portion of this value, however, the natural biota also represents a reservoir of genetic material and a source of plant materials for medicinal or industrial purposes. These potential uses have economic value but are not readily quantifiable.

A related, unquantified parameter is the value of wetlands as a subject of scientific study, an "open air" laboratory for the training of students and for basic biological research. Krutilla (25, p. 780) has argued that, in addition to adding to the state of knowledge, the proven "serendipity value" of basic research provides a significant reason for preservation.9 Two additional parameters in this category which have been previously discussed are the value of furbearers and the

9 The possible existence of archeological sites in the floodplain is another element of this parameter.
Table 11. Threshold Values: The Positive Differences Between the Net Present Value of Development and the Present Value of Preservation at the High (UCOWR) Valuation Level ((DV-CD)-PV)

<table>
<thead>
<tr>
<th>Case and Output Price Set&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Case I</td>
<td></td>
</tr>
<tr>
<td>High Median</td>
<td>4,683,596</td>
</tr>
<tr>
<td>High</td>
<td>13,267,975</td>
</tr>
<tr>
<td>Case II</td>
<td></td>
</tr>
<tr>
<td>High Median</td>
<td>5,638,150</td>
</tr>
<tr>
<td>High</td>
<td>22,522,486</td>
</tr>
<tr>
<td>Case III</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>17,967,456</td>
</tr>
</tbody>
</table>

<sup>a</sup>The 3 cases are described in Chapter IV. The output prices within each set are presented in Table B-3 of Appendix B.
role of the area in the Mississippi Flyway. As a final example, the value of vicarious consumption was not included in the estimation. The aspect of psychological satisfaction has been previously discussed. The desire to preserve an area which an individual in all probability will never see may also be explained by a "bequest motivation," maintaining the area for possible visitation or use by one's heirs (25, p. 781).  

The differences estimated for Case II would appear to be the relevant threshold values for the land use decision. The net development benefits estimated for Case II exceeded the Case I estimates at the high median and high crop price levels. Thus, if the streams were channelized, society would not receive the maximum possible net benefits if land conversion were limited to lands enhanced by the project. Similarly, maximum obtainable social benefits would not be realized if the conversion of SPG-7 land assumed in Case III were undertaken.  

Assume that crop prices are expected to approximate the high median—high range and that an acceptable mechanism for social decision exists. In this situation, the estimated differences between the discounted net development value and preservation value for Case II are approximately $4 million at the high median price set and approximately $18 million at the high price set with the 9 percent discount rate.  

Also assume a social consensus that the unquantified wetlands benefits have a present value to society of $4 million but do not have a present

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10 Additional omitted parameters may, of course, by hypothesized. The contribution of biological diversity to ecological stability is one parameter suggested by the material reviewed in Appendix A.  

11 A 50 year annuity of approximately $156,000 has a present value of one million dollars at the 9 percent discount rate. A 50 year annuity of approximately $133,000 and $182,000 is required per million dollars in present value at 8 and 10 percent, respectively.
value of $18 million. It may be possible to establish a definite point between these two values where a marginal change in the threshold value will alter the optimal land use. It would appear likely, however, that a diversity of opinion would exist. The outcome would then be a range in values within which the correct land allocation decision is uncertain. A possible decision guideline in this case would be the concept of maintaining the maximum number of options open when dealing with irreversible environmental transformations. This concept would suggest preservation of the wetlands until the uncertainty is resolved.

IV. The Value of Flooded Wetlands

The results of the study raised the question of the optimal social use of flooded wetlands in the Obion-Forked Deer floodplain without channel modification. The data presented in Table 9 (p. 78) indicate that the dedication of SPG-5 wetlands to agriculture will yield positive returns at the average, high median, and high price sets and the dedication of SPG-6 wetlands to agriculture will yield positive returns at the high median and high price sets. Assume that crop prices are expected to fall within these ranges. A landowner would rationally convert his SPG-5 and/or SPG-6 wetlands holdings to agricultural use since his opportunity cost would be small.12

Maintaining the assumption of static conditions, the optimal social land use was evaluated by comparing the magnitude of the estimated annual net agricultural returns with the net annual value of forested

12In the simplest case the private opportunity cost is the foregone return from forestry.
wetlands estimated at the high (UCOWR) valuation level, $14.60. This value exceeded the net agricultural returns from a representative acre of SPG-5 land under flooded conditions estimated at the average crop price set and the returns from a representative acre of SPG-6 land under flooded conditions at the high median price set. These results imply that maintaining the wetlands on these soils is the optimum social policy given these crop prices. Land use controls would appear necessary since the market would provide incentive for wetlands conversion.

The estimated net annual value of forested wetlands was exceeded by the net agricultural returns from a representative acre of SPG-5 land at the high median and high crop price sets and the net returns from a representative acre of SPG-6 land at the high crop price set. The incompleteness of the wetlands valuation again makes the optimal land use a question of judgment. The differences between the estimates were $2.72 and $16.68 for a representative acre of SPG-5 land at the high median and high crop price set and $3.28 for a representative acre of SPG-6 land at the high price set. Optimality would require the prevention of agricultural use of these two soil groups if the value of the unestimated wetlands parameters were judged to equal or exceed these differences.

13The calculation was $F_1 + R_2 + R_3 + R_4 + R_5 - C_P$. 
CHAPTER VI

SUMMARY AND SUGGESTIONS FOR FUTURE RESEARCH

I. Summary

Growing public concern about the effect of environmental modification on the quality of the natural environment demands attention in resource allocation decisions. The phrase "the quality of the natural environment" implies a judgment about the suitability of a natural resource or bundle of resources for a specific purpose. Therefore, a given modification may lower the quality of the environment for some purposes while enhancing it for other purposes. An inherent potential for conflict among opposing interests in these resource allocation decisions thus exists.

This situation is reflected in the debate over the use of the land and related water resources of the floodplain of the Obion-Forked Deer Basin in West Tennessee. The related problems of flooding and a high groundwater table limit crop yields to levels below the potential productivity of the floodplain soils and prevent the use of land for agriculture. Stream channelization has been proposed as a solution to these problems by the U.S. Army Corps of Engineers. The flood protection and land drainage which channelization offers are desirable for agricultural purposes. However, the existing forested wetlands environment is desirable for the purposes of sportsmen and other wildlife interests. The objectives of this study were then (1) to develop a method to evaluate the effects of environmental modifications and (2) to evaluate these two incompatible resource uses.
The conceptual model used in the study was based on the proposition that resources should be allocated to maximize social welfare. Monetary values were used as a proxy for welfare with the assumption that a gain or loss to any individual is a corresponding gain or loss to society. Three maximization techniques were considered: (1) indifference curve analysis, (2) constrained maximization, and (3) opportunity cost analysis. The opportunity cost technique appeared best suited for the analysis of incompatible alternatives and was therefore used.

The externalities associated with channelization and the alternative land uses were studied. No significant externalities associated with agricultural use were identified. The net benefits of allocating floodplain land to the agricultural sector through stream channelization were, therefore, estimated as the market value of the increment in agricultural products less production costs and the costs of channel modification.

Five alternative price sets were used in the computations. The relevant opportunity cost was defined as the net benefits which would be foregone if the streams were channelized and land used for agriculture. In the simplest case, all foregone benefits, except the returns from cleared forest, would be external to the market. Benefits were estimated in terms of maximum sustained yields. The sustained yields of fish and wildlife resources were converted into recreation day estimates for valuation. Six alternative valuation levels were used in these computations. These estimates were incomplete because of data limitations and imprecise knowledge about potentially important parameters.

The decision criteria was stated as an inequality. If the estimated net benefit stream from retaining the wetlands exceeds the estimated
net benefit stream from conversion to agricultural use through channelization, the wetlands should be preserved. The incompleteness of the preservation value estimate will not affect the decision. If this relationship is reversed, the land allocation decision becomes a matter of judgment. The area should be preserved as wetlands if the unquantified wetlands parameters are judged to have a social value at least equal to the difference between the estimated value of development and value of preservation.

Three alternative levels of agricultural land use were analyzed: Case I assumed only land enhanced by channelization would be converted to agricultural use, Case II assumed all land classified as highly productive and moderately productive would be converted to agricultural use, and Case III assumed that 70 percent of all privately owned forested wetlands would be converted to agricultural use. Computations were made for a 50 year planning horizon with static conditions assumed. The present values of the estimated benefit streams were calculated at 8, 9, and 10 percent discount rates and the magnitudes of the resulting discounted values were compared. The largest set of preservation value estimates was used in these comparisons to reflect the irreversibility of channelization and land use conversion and the consequent loss of options entailed in the decision.

The discounted value of preservation estimated at the highest valuation level exceeded the discounted value of development estimated at the low, low median, and average crop price sets in each case evaluated. The optimal social land use would be as forested wetlands if agricultural crop prices were expected to approximate these levels over the planning horizon.
The opposite relationship was found in Case I and Case II when the net development value was estimated at the high median and high crop price sets and in Case III at the high crop price set. The optimal social land use would be a question of judgment if agricultural crop prices were expected to approximate these levels. The difference between the estimated development and preservation values represent a threshold; preservation would be economically justified only if the unmeasured parameters were judged to have a social value at least equal to the estimated difference.

The divergence between the private and social opportunity costs of converting wetlands to agricultural use and the positive net returns from wetlands conversion led to the conclusion that land use controls would be required to assure optimal social land use. This conclusion was reached in considering the alternative uses for the wetlands without channel modification as well as in considering land use following the channelization project.

It was also concluded that a decision to modify the stream channels in the Obion-Forked Deer watershed does not imply that the public sector should finance the project. No significant external economies associated with channelization and agricultural land use were identified. Consequently, there appears to be no divergence between the economic incentives facing the public sector and the benefited private sector. Public financing would be indicated if the resulting net benefits were greater than the net benefits generated by private financing.\(^1\)

The difference between these two benefit streams would represent

\(^1\)Computation of net benefits would include any costs incurred by the public sector in stimulating private action.
the net gain attributable to public intervention and would appear to be the relevant parameter in the decision to commit limited public resources to this use.

Alternatively, channelization by the public sector could be justified as a means of enhancing the incomes of a group which society judges to deserve assistance. While the owners of floodplain property may merit assistance, it is not clear that channelization is the most equitable nor the most efficient method of providing public support.

II. Suggestions for Future Research

Debate surrounding environmental modifications usually involves the twin issues of the magnitude and the importance of the modifications to society. The approach taken in this study was to evaluate importance of environmental modifications by imputing monetary values to the predicted magnitudes of environmental alteration. The study, however, suffered from the lack of information on the impacts of channelization and land use change and on the valuation of natural resources.

Parameters, such as the impact of habitat loss on the Mississippi Flyway and vicarious consumption, were omitted because of a lack of data. The parameters omitted in the analysis are viable subjects for future research; their inclusion would obviously improve this type of analysis. In addition, the opportunity cost estimates used in the study implicitly assumed that the productivity of unmodified lands would not change. While this assumption is questionable, the topic has not been the subject of specific study. Better data on the effects of wetlands modification on the remaining wetlands would also improve analyses of this type.

The valuation of natural resources is also an obvious subject for
future research. The differences between the WRC and UCOWR valuations of a specialized recreation activity day, for example, suggest a need for investigation in the area of the value of recreation. There is also a need for research into the value of preserved natural environments as objects of scientific study and areas for the training of future scientists.

In valuing the alterations of the floodplain environment, a constant, identical utility of money was assumed. Evidence such as the progressive income tax suggests that this assumption may not reflect the beliefs of society. Research on the distribution of gains and losses among income groups could provide needed information relevant to public decisions.

This study was basically a static analysis of the value of a limited range of products resulting from either maintaining the wetlands or developing the floodplain for agricultural purposes. All risk and uncertainty were eliminated by assumption.

The real world is characterized by stochastic production processes and uncertainty over the future values of alternative product sets. The future value of the floodplain in either alternative use is interrelated with conditions and activities beyond the boundaries of the watershed. Developing a model which would be more representative of real world conditions requires prediction of the impact of technology and future market conditions on net agricultural returns. Predicting changes in the value of wetlands over time requires analysis of the demand for this type of environment, predictions of future wetlands supply, and analysis of natural production processes. These data needs suggest opportunities for interdisciplinary research as well as independent investigation by natural scientists and economists.
Flood control projects other than channelization have been proposed for the Basin. Evaluation of these projects with the procedure used in this study could provide data relevant to their evaluation. Another extension which might prove useful would be the analysis of other land uses and/or other uses in combination with agriculture.

Finally, the decision making process is a subject which deserves study. Empirical research on the weighing of varied opinions and available data on crop prices through the planning horizon, the impact of modifications on currently unquantifiable parameters, and the value of these parameters is needed. An equally important topic is the appropriate organization of the decision making process so that all groups which will be affected by the decision can effectively participate.
LITERATURE CITED
LITERATURE CITED


APPENDICES
Appendix A
This study was concerned with the quality of the natural environment as one parameter in the welfare of society. An alternative approach is to isolate this parameter, attempting to measure environmental quality and then assess the impact of human actions upon it.

Ciriacy-Wantrup and Parsons (10, p. 3) suggest that an investigation of environmental quality should begin with "the identification of relevant dimensions of quality and evaluation." The literature suggests three relevant dimensions: aesthetics (29), content, and performance (19). This Appendix briefly discusses each of these dimensions and, in addition, considers a more general descriptive technique.

**Aesthetics**

Krutilla (25) has argued that the uniqueness of a resource gives it a value regardless of other characteristics it may possess. One potential source of this value is the aesthetic worth of the resource due to scarcity. This concept is supported by the hypothesis that man is stimulated by the intensity, novelty, complexity, variations, and incongruity of an experience (57). If the value of aesthetics is assumed to lie in the stimulation of mankind, scarcity would be a factor in the novelty of an experience and thus in its aesthetic value.

Using this approach, Leopold and Marchand (29) evaluated a number of California river landscapes. Twenty-eight physical, biological, and human interest factors which were believed to contribute to aesthetic value were identified; these were rated on a scale of uniqueness with the scarce factors receiving higher score values than the
factors which frequently occurred in the sample. A difficulty in using this technique is that scarcity is not an essential element in quality; a very common resource such as air may be of very high quality. In addition, this method appears to be highly subjective; the scarcity of a factor may depend greatly upon sample size and the particular observations included in the sample.

A second possible approach to the evaluation of aesthetics involves showing photos to a sample audience. In using this method, aesthetic reactions are recorded either by interview (39) or by the more esoteric practice of measuring pupil dilation with the premise that an increase in pupil size above normal for a given amount of light is associated with aesthetic pleasure (53). Using photos as the subject matter has been criticized by West (54) on the grounds that a photograph, like a painting, is a personal interpretation and that aesthetic reactions will be influenced by the photographer's skill as well as by the scene. West also points out that audience reactions will be influenced by the choice of black and white photos as against color photos. The question of the trueness of color in a photograph might also be raised.

Content

The dimension of content may be interpreted as relating to the amounts of pollutants in the environment. Pollution is an outstanding public concern; it appears fair to say that no aspect of environmental quality has received more research attention. A large body of pollution related economic literature exists. However, pollution is not the

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1For a review of post World War II literature, see Mishan (32).
issue in many environmental debates and thus this body of work may be of little aid in dealing with a specific problem.

A second possible interpretation of content relates to the diversity of the environment. Diversity is biologically important, as illustrated by the ecological dogma that a variety of plant and animal life is essential to a stable ecosystem. Tubbs and Blackwood (42) utilized this principle in developing maps for land development planning in England. In this approach, an area is divided into ecological zones and each zone is given a subjective value based upon the rarity and diversity of species.

Diversity is also important to the human species. In the words of Kenneth Boulding (6, p. 10): "We do not want a constant state to be maintained, we want fluctuations, otherwise there would be no demand for variety in food, in scene as in travel, in social contact, and so on." Dubos (16, pp. 38-39) feels that variety is important for human health; he states: "Certain important traits in man's nature cannot develop normally or remain in a healthy state without constant stimulation and challenge."

Watt (52) presents some basic mathematical tools of use in measuring and comparing diversity, but assessment criteria are lacking; "as diversified an environment as possible" would logically appear to lead to representation by every possible species in the ideal environment.

**Performance**

Performance is a criteria of evaluation more familiar than aesthetics or content to an economist.² The performance of an economic unit

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²The assessment procedure used was performance related: The
may be measured by comparison with a standard (such as perfect competition in evaluating market performance) or by using the concept of efficiency—the amount of output per unit of input.

Given a standard, performance might be measured in terms of the output of a product of interest, or in terms of ratios of environmental products. The difficulty in this approach is in establishing acceptable standards so that the existing state can be compared with the desired state. Standards would depend upon values which are not universally agreed upon except in extreme cases.

The concept of efficiency is not readily adapted to the assessment of the natural environment. A basic requirement for this type of analysis is the quantification of inputs and outputs. Data on biological processes and the interrelations of species are often incomplete; the size of this observational task is staggering. In addition, many important relationships are not observable because of an inability to measure them and others are not recognized as being important with the current state of knowledge.

Descriptive Techniques

A fourth method of quality assessment is to gather information on all probable environmental changes associated with a given project. The changes are described in an environmental impact statement for use by the decision-makers.

The U.S. Geological Survey has developed an information matrix system which serves as an example of the use of this approach (30).

estimated opportunity costs evaluate the "performance" of the land and related resources in the Obion-Forked Deer floodplain with money as a common unit of measure.
The matrix contains on one axis actions which cause environmental impact and on the other axis the existing environmental conditions that might be affected. Each interaction involved in the project is evaluated. Within the matrix a number from one to 10 is assigned to indicate the relative magnitude of the impact and another number from one to 10 indicates the relative importance of the impact (10 is the greatest and one the least). The display matrix is seen as the "heart" of the evaluation, serving as the abstract of the text of the environmental impact statement.

The procedure has the virtue of separating as much as possible the more factual information on the magnitude of the impact from the more subjective assessment of the importance of the impact. The evaluation of importance involves some degree of preference, or bias. A weakness is that the procedure does not indicate to whom the impact is important. An additional problem is that a project may have positive impact on some environmental parameters and negative impact on others; arriving at the total environmental impact through summing the effects on individual parameters would appear to be a difficult task.
Appendix B
Table B-1. Crop Distribution by Soil Productivity Group on Forest Land Converted to Agricultural Use Between 1964 and 1971, Obion-Forked Deer Floodplain, 1971

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil Productivity Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Acres</td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>4523</td>
<td>9472</td>
</tr>
<tr>
<td>Corn</td>
<td>21</td>
<td>64</td>
</tr>
<tr>
<td>Cotton</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Pasture</td>
<td>43</td>
<td>150</td>
</tr>
<tr>
<td>Miscellaneous$^a$</td>
<td>43</td>
<td>171</td>
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<tr>
<td>Total</td>
<td>4651</td>
<td>9878</td>
</tr>
</tbody>
</table>

$^a$Includes rice, milo, small grains, truck crops, and idle cropland.

Table B-2. Representative Acre Weights by Soil-Productivity Group Computed from 1971 Crop Distributions, Obion-Forked Deer Floodplain

<table>
<thead>
<tr>
<th>Crop</th>
<th>Entire Floodplain</th>
<th>Forest Land Cleared Between 1964 and 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPG-5</td>
<td>SPG-6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>0.707</td>
<td>0.861</td>
</tr>
<tr>
<td>Corn</td>
<td>0.051</td>
<td>0.025</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.041</td>
<td>0.017</td>
</tr>
<tr>
<td>Pasture</td>
<td>0.161</td>
<td>0.067</td>
</tr>
<tr>
<td>Miscellaneous(^a)</td>
<td>0.040</td>
<td>0.030</td>
</tr>
</tbody>
</table>

\(^a\)Includes rice, milo, small grains, truck crops, and idle cropland.
Table B-3. The Agricultural Output Price Sets Used in the Estimation of the Present Values of Development

<table>
<thead>
<tr>
<th>Price Set</th>
<th>Soybeans (bu.)</th>
<th>Corn (bu.)</th>
<th>Cotton (lb.)</th>
<th>Pasture (grazing day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2.50</td>
<td>1.20</td>
<td>0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>Low Median</td>
<td>3.25</td>
<td>1.45</td>
<td>0.265</td>
<td>0.125</td>
</tr>
<tr>
<td>Average</td>
<td>4.00</td>
<td>1.70</td>
<td>0.31</td>
<td>0.15</td>
</tr>
<tr>
<td>High Median</td>
<td>4.75</td>
<td>1.95</td>
<td>0.365</td>
<td>0.175</td>
</tr>
<tr>
<td>High</td>
<td>5.50</td>
<td>2.20</td>
<td>0.40</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Table B-4. Estimated Average Flood-Free and Flooded Crop Yields Per Acre by Soil Productivity Group, Obion-Forked Deer Floodplain

<table>
<thead>
<tr>
<th>Crop</th>
<th>Flood-Free</th>
<th></th>
<th>Flooded</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPG-5</td>
<td>SPG-6</td>
<td>SPG-7</td>
<td>SPG-5</td>
</tr>
<tr>
<td>Soybeans</td>
<td>30</td>
<td>26</td>
<td>19</td>
<td>19.8</td>
</tr>
<tr>
<td>(bu.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>65</td>
<td>60</td>
<td>38</td>
<td>42.9</td>
</tr>
<tr>
<td>(bu.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>750</td>
<td>705</td>
<td>556</td>
<td>555</td>
</tr>
<tr>
<td>(lb.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td>180</td>
<td>160</td>
<td>140</td>
<td>126</td>
</tr>
<tr>
<td>(grazing days)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Output Price Set and Crop</th>
<th>Flood-Free</th>
<th></th>
<th>Flooded</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPG-5</td>
<td>SPG-6</td>
<td>SPG-7</td>
<td>SPG-5</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>77.07</td>
<td>75.51</td>
<td>73.72</td>
<td>73.96</td>
</tr>
<tr>
<td>Corn</td>
<td>96.56</td>
<td>86.78</td>
<td>78.56</td>
<td>92.96</td>
</tr>
<tr>
<td>Cotton</td>
<td>149.43</td>
<td>143.93</td>
<td>128.83</td>
<td>135.58</td>
</tr>
<tr>
<td>Pasture</td>
<td>54.11</td>
<td>52.49</td>
<td>51.08</td>
<td>53.84</td>
</tr>
<tr>
<td><strong>Low Median</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>78.20</td>
<td>76.49</td>
<td>74.43</td>
<td>74.70</td>
</tr>
<tr>
<td>Corn</td>
<td>97.37</td>
<td>87.53</td>
<td>79.13</td>
<td>93.50</td>
</tr>
<tr>
<td>Cotton</td>
<td>151.12</td>
<td>145.41</td>
<td>130.08</td>
<td>136.82</td>
</tr>
<tr>
<td>Pasture</td>
<td>54.34</td>
<td>52.69</td>
<td>51.26</td>
<td>54.00</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>79.32</td>
<td>77.46</td>
<td>75.14</td>
<td>75.44</td>
</tr>
<tr>
<td>Corn</td>
<td>98.19</td>
<td>88.28</td>
<td>79.60</td>
<td>94.04</td>
</tr>
<tr>
<td>Cotton</td>
<td>152.81</td>
<td>147.10</td>
<td>131.33</td>
<td>138.07</td>
</tr>
<tr>
<td>Pasture</td>
<td>54.56</td>
<td>52.89</td>
<td>51.43</td>
<td>54.16</td>
</tr>
<tr>
<td><strong>High Median</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>80.45</td>
<td>78.44</td>
<td>75.85</td>
<td>76.18</td>
</tr>
<tr>
<td>Corn</td>
<td>99.00</td>
<td>89.03</td>
<td>80.08</td>
<td>94.57</td>
</tr>
<tr>
<td>Cotton</td>
<td>154.49</td>
<td>148.68</td>
<td>132.58</td>
<td>139.32</td>
</tr>
<tr>
<td>Pasture</td>
<td>54.79</td>
<td>53.09</td>
<td>56.51</td>
<td>54.31</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>81.57</td>
<td>79.41</td>
<td>76.57</td>
<td>76.93</td>
</tr>
<tr>
<td>Corn</td>
<td>99.81</td>
<td>89.78</td>
<td>80.55</td>
<td>95.11</td>
</tr>
<tr>
<td>Cotton</td>
<td>156.18</td>
<td>150.27</td>
<td>133.83</td>
<td>140.57</td>
</tr>
<tr>
<td>Pasture</td>
<td>55.01</td>
<td>53.29</td>
<td>51.78</td>
<td>54.47</td>
</tr>
</tbody>
</table>

The returns to management were computed as 5 percent of the total revenue, creating the variation among price sets. The variation between costs under flood-free and flooded conditions within a price set reflects the difference in returns to management and reduced harvest costs.

Table B-6. Estimated Annual Costs of Project Design and Construction and Annual Construction Cost as a Percentage of the Total Construction Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost in Dollars&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>283,500</td>
<td>---&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>648,000</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>1,294,380</td>
<td>8.9</td>
</tr>
<tr>
<td>3</td>
<td>1,134,000</td>
<td>7.8</td>
</tr>
<tr>
<td>4</td>
<td>1,134,000</td>
<td>7.8</td>
</tr>
<tr>
<td>5</td>
<td>1,134,000</td>
<td>7.8</td>
</tr>
<tr>
<td>6</td>
<td>1,458,000</td>
<td>10.2</td>
</tr>
<tr>
<td>7</td>
<td>1,782,000</td>
<td>12.3</td>
</tr>
<tr>
<td>8</td>
<td>1,944,000</td>
<td>13.4</td>
</tr>
<tr>
<td>9</td>
<td>1,944,000</td>
<td>13.4</td>
</tr>
<tr>
<td>10</td>
<td>2,010,420</td>
<td>13.9</td>
</tr>
<tr>
<td>Total</td>
<td>14,766,300</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Values are in 1971 dollars as computed with a composite construction cost index (44, p. 677).

<sup>b</sup>No construction is scheduled for year zero.

Table B-7. The Value Sets Used in the Estimation of the Present Values of Preservation

<table>
<thead>
<tr>
<th>Valuation Level</th>
<th>Forest Products (Cubic foot)</th>
<th>Non-Specialized Recreation Activity Day</th>
<th>Specialized Recreation Activity Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (WRC)</td>
<td>0.23</td>
<td>0.75</td>
<td>2.50</td>
</tr>
<tr>
<td>Average (WRC)</td>
<td>0.26</td>
<td>1.50</td>
<td>4.75</td>
</tr>
<tr>
<td>High (WRC)</td>
<td>0.29</td>
<td>2.25</td>
<td>7.00</td>
</tr>
<tr>
<td>Low (UCOWR)</td>
<td>0.23</td>
<td>0.75</td>
<td>15.00</td>
</tr>
<tr>
<td>Average (UCOWR)</td>
<td>0.26</td>
<td>1.50</td>
<td>17.50</td>
</tr>
<tr>
<td>High (UCOWR)</td>
<td>0.29</td>
<td>2.25</td>
<td>20.00</td>
</tr>
</tbody>
</table>

^Stumpage values per cubic foot in 1971 dollars as computed with the wholesale price index for lumber and wood products (48, p. 552).

^Includes sport fishing, small game hunting, and general recreation.

^Includes big game hunting and waterfowl hunting.


VITA

George Francis Smith was born in Batavia, New York, on July 16, 1941. He attended elementary schools in Greeley, Colorado, Omaha, Nebraska, Caledonia, New York, and New Haven, Connecticut. He graduated from Notre Dame High School at West Haven, Connecticut in 1959. The following September he entered the University of Connecticut, and in June, 1963 he received a Bachelor of Science degree in agriculture. After graduation, he joined the Peace Corps as a Volunteer and was assigned to a vocational agriculture school in Archidona, Ecuador.

Upon completion of his Peace Corps service in 1965, he accepted an International Technical Training Fellowship at Montana State University. He completed the Master of Science degree in August 1967 with a major in agronomy and a minor in agricultural development. Following graduation, he was employed by the Peace Corps as an Agricultural Program Technical Representative in Santa Cruz, Bolivia.

Upon completion of his contract with the Peace Corps, he entered the Graduate School at The University of Tennessee in September, 1970. He received the Doctor of Philosophy degree with a major in agricultural economics in June, 1974.

The author is a member of Alpha Zeta, Gamma Sigma Delta, Sigma Xi, The American Agricultural Economics Association, and The Southern Agricultural Economics Association.

He is married to the former Ruth Belén Torres of San Juan, Puerto Rico. They have one son, George "Jorgito" Francis III.