AN ECONOMIC ANALYSIS OF SMALL WATERSHED PROJECT EVALUATION PROCEDURES

THESIS FOR THE DEGREE OF PH. D.

MICHIGAN STATE UNIVERSITY

JOHN VONDRUSKA

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of the requirements for

Ph.D. degree in Agricultural Economics

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ABSTRACT

AN ECONOMIC ANALYSIS OF SMALL
WATERSHED PROJECT EVALUATION PROCEDURES

By

John Vondruska

In evaluating and justifying investments in small watershed projects, the Soil Conservation Service (SCS), an agency of the United States Department of Agriculture, employs numerous assumptions and procedures. The effects of changes in these procedures and assumptions are studied using the technique of sensitivity analysis. Two models are presented and used. One model is a systematization of SCS procedures for estimating agricultural (crop) benefits and is used to study benefit sensitivity to underlying crop-enterprise and hydrological variables. The second model is used to study the effects of change in SCS assumptions on benefit and cost timing, patterns and annual flow rates; interest rates; and capital investments for 12 Michigan projects.

In addition, the historical background of the small watershed program is considered to help explain the dual emphasis on soil and water conservation, and water resource development, particularly flood control. Federal-local cost-sharing arrangements are detailed, including the importance of ACP (Agricultural Conservation Program) payments as an element of Federal cost. Department of Agricultural and Congressional policy preferences and their effect on project selection, planning and

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evaluation are also discussed. Besides this, the SCS annual benefit cost ratio and alternative, non-SCS investment criteria are studied from the conceptual standpoint.

While there may be some question as to which should be used and which is most sensitive, all of the studied investment criteria produced data that are sensitive to a host of agency assumptions and procedures. Using SCS interest rates (with as many as four rates per project and with the rate sets differing over the period 1959-68, when SCS originally evaluated the 12 projects), a 12-project net present value sum of about $20 million is obtained, approximately equivalent to the sum based on using a single rate of 4%. Increasing the interest rate to 12% reduced this sum to a negative value, as would a 50% decrease in project-credited farm income at 5% interest, or a 100% increase in capital costs at 5% interest. Other significant changes include alterations in SCS assumed benefit and cost timing, patterns and cash flow rates.

Project-credited farm income (the difference between with and without project farm income) is sensitive to changes in underlying crop-enterprise and hydrological variables. This hydrological sensitivity is significant because: (1) the directly affected category of agricultural benefits, floodwater damage reduction benefits, accounts for about one-half of the national aggregate of all project benefits; (2) hydrological data are much less objective than is sometimes thought; and (3) agricultural floodwater damage reduction benefits receive policy preference and emphasis, even though they are but one form of project-credited farm income, all forms of which depend essentially on increased crop output.

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ACKNOWLEDGMENTS

The author would like to express his appreciation to several people who helped make this study possible. Robert S. Fellows, SCS Assistant State Conservationist in Michigan provided permission to use SCS in-file documents for the studied watershed projects. Members of the SCS Planning Party in Michigan offered helpful comments and took the time to explain and discuss various SCS procedures. They include Loren Oshel, Planning Party Leader; Arlo Benzmann, Justin Murray and John Okay, economists; Russell Baurle, Keith Bakeman and H. A. Amsterburg, engineers and hydrologists. John Okay was particularly helpful in providing suggestions and comments on various ideas and in reading various draft versions of this study.

The author's guidance committee chairman, Dr. A. Allan Schmid, provided many constructive suggestions and asked pertinent questions that helped shape the study. Comments by other committee members were also helpful, that is, by Drs. Lester Manderscheid, Milton Steinmueller and Larry Connor. In addition, Dr. Ray Hoglund assisted in evaluating some crop enterprise data and in preparing such data for use in chapters 5 and 6. Dr. Jim Beard provided similar assistance for lawn grass sod. Drs. Ernest Kidder and George E. Merva reviewed chapter 5 from the hydrologist's viewpoint.

In terms of manuscript preparation, Miss Jacqueline Kelly constructed the illustrative figures, Mrs. Mary Helen Ives helped improve the clarity

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Mrs. Beverly Sager typ
author, are on the sta
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of the text, and Miss Mary Vartabedian, Mrs. Ellen Rosenberg and Mrs. Beverly Sager typed the final copy. These people, as well as the author, are on the staff of the Division of Economic Research, National Marine Fisheries Service, U.S. Department of Commerce.

Particular appreciation is expressed to the author's wife, Ellen, who provided encouragement and for the duration of this study, our income.

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CHAPTER I

INTRODUCTION

This is a study of government agency procedures for evaluating small watershed projects which are installed in rural areas to assist farmers in overcoming flood, drainage and irrigation problems. This is not to deny the installation of these projects in urban areas, nor is it to deny their provision of services for recreation, water supply, pollution abatement and other uses. In fact there is evidence to suggest that small watershed projects are becoming less oriented to providing services that primarily benefit farmers. This is true both in Michigan and for the United States as a whole. However, at the time this study was begun in 1967 agency plans for projects in Michigan related largely to serving agriculture and the same is true for agency plans across the country.

Although the small watershed program has the potential of becoming multiple purpose in character, like the large watershed programs of such agencies as the Corps of Engineers, the Bureau of Reclamation and the Tennessee Valley Authority, the legislated constraint limiting individual planning units (projects) to watersheds of 250,000 acres (about 400 square miles) may offset some of this potential. Of course, several projects can be for contiguous watersheds, so long as each has a separate watershed work plan.

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The Soil Conservation Service (SCS) has been delegated primary responsibility for planning and developing small watershed projects so far as the Federal Government is concerned. Yet, other Department of Agriculture (USDA) agencies help provide the package of Federal services marshaled to assist local beneficiaries. The Federal Government provides project planning assistance, technical assistance in the application of conservation practices, investment underwriting (in the sense of Federal assumption of part of the investment cost), and financial assistance (in the way of loans to local project sponsors and individual land-owning beneficiaries, with the terms of the loans being more favorable than for loans available from regular, commercial lending institutions). These Federal services relate to the initial installation of small watershed projects. Unlike large basin flood control counterparts, as planned by the Corps of Engineers, small watershed projects for flood prevention (and other purposes) are operated and maintained by local project sponsors rather than by the Federal Government.

The Soil Conservation Service (SCS), as its name implies, views its mission in the conservation framework. SCS sees the small watershed program in the same light. Both the agency and the program began in 1933 under authority of the National Industrial Recovery Act. This emphasizes the economy stimulating aspect of the program, common to other public works programs. Under this 1933 legislation the program would have been temporary in nature. It was given permanence under the Flood Control Act of 1936 as an upstream, small watershed counterpart of the Corps of Engineers' downstream, large basin program. Except for work in eleven river basins for which general plans were approved in the 1944 F

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approved in the 1944 Flood Control Act, SCS authority under the 1936 Flood Control Act was repealed by the passage of the Watershed Protection and Flood Prevention Act of 1954 (Public Law 566, 83d Congress, 68 Statutes 666), commonly called PL 566. This new authority imposed size limits on watersheds for which single projects could be planned and on reservoir size (flood detention capacity if it is intended to temporarily hold back floodwater so as to prevent overflow onto the floodplain). PL 566 also transferred congressional control and funding away from the public works domain to the agricultural domain, except in the matter of approval of projects with larger reservoirs (over 4,000 acre feet and up to the 25,000 acre feet limit for single reservoirs in PL 566 projects). Incidentally, the move to agricultural committee control and agricultural funding actually began in 1953 with the approval of $5 million in the USDA budget specifically for a system of pilot small watershed projects located across the country, reportedly to test the "ultimate worth" of the small watershed approach. Such a goal may be questioned, because the small watershed program had been operational since 1933.

The Michigan small watershed projects considered in this study were planned by SCS under authority of PL 566, as amended. In all, 12 projects are studied in chapter 7, although one project serves as the primary example in other chapters. The source of data consists of the SCS watershed work plans (short, mimeographed, loose-bound, semi-public documents) and the SCS in-file Planning Party work sheets (of detailed computations, called in-file SCS documents or documentation to distinguish them from the work plans).

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Although the first Michigan small watershed project (under PL 566) was planned in 1957, SCS in-file documentation has been forwarded to the SCS central storage unit and it was not available for examination by the author in the SCS Planning Party offices. Contrary to the agricultural orientation of most other PL 566 projects in Michigan, this first project was geared to providing flood control for the small city of Cheboygan, located at the tip of Michigan's lower peninsula, near the Straits of Mackinaw and the Mackinaw Bridge crossing to the upper peninsula. SCS was not yet able to make available the in-file documentation for the Maple River project group in central Michigan, because the plans for this primarily recreational group of projects were still in the process of being reviewed and revised within the agency.

The 12 studied Michigan projects were justified largely on the basis of their agricultural benefits. Nationally, the composition of agricultural benefits differs in emphasis, comparing the relative importance of agency-defined categories of benefits for Michigan and the United States as a whole. Nationally, FWDRB (floodwater damage reduction benefits) are more important than EB (enhancement benefits). Both kinds of agricultural benefits relate to the project-credited increase in net farm income. The separation and emphasis of FWDRB relates to the policy directives issued by the House Agricultural Committee and by the Department of Agriculture, as discussed in chapter 2.

SCS procedures for computing PL 566 project agricultural benefits are described in chapter 3 using numerical data for an example project. The procedures are formulated into a mathematical model that has been w

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model that has been written into an operational computer program, as used in chapters 5 and 6. While the details of this computer program are not presented, the mathematical formulation of the SCS model in chapter 3 provides a basis for posing questions about the effect of a host of hydrological, watershed, crop enterprise and other more general economic variables. The author's SCS model allows the duplication of SCS computational steps leading from such data as individual crop prices, costs, yields and planting patterns to the production of average annual benefits and the SCS annual benefit cost ratio. The development of capital cost and operations cost data for the project works of improvement is not considered in the author's SCS model. Furthermore, the emphasis is entirely on agricultural primary benefits. Secondary agricultural benefits, redevelopment benefits (even for agricultural areas) and other kinds of benefits are outside the scope of this study.

The author's SCS model of chapter 3, as used in chapters 5 and 6, takes certain data aggregates as given. For example, even though SCS economists develop costs for various crop enterprises from individual production item costs, the SCS economists' crop enterprise cost aggregates are taken as data inputs for the author's SCS model. Crop costs can be adjusted in the SCS model of chapter 3 by the application of cost adjustment factors. Altering factor of production combinations would be more difficult, requiring computation of entirely different crop cost aggregates. This sort of change is more of a computational burden than may appear at first glance. For the development of EB (enhancement benefits

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In addition to the author's model of SCS agricultural benefit computational procedures of chapter 3, a second set of mathematical formulations are used. SCS economists do not actually compute benefit and cost data for all years in the evaluation period (t = 1, ..., T), and this is reflected in the SCS model of chapter 3. They use some short—cut procedures adapted for use with desk calculators. However, with access to a high speed digital computer, the burden of calculation is reduced. Specifying net cash flows for all years in the evaluation period is a conceptually preferable approach, given the type of variations from SCS assumptions and procedures studied in chapter 7. SCS—assumed benefit and cost timing, pattern and rate data are changed in chapter 7. Also, the effect of different discount rates is studied. In addition to the SCS annual benefit cost ratio, other investment criteria are used, notably the net present value and internal rate of return. Data computed for altered assumptions for these investment criteria are then compared to analogous data for base-estimate assumptions.

Chapters 5 and 6 are complete studies in themselves, but they may be viewed as providing a rationale for changing the SCS-computed benefit data in chapter 7. Chapter 5 considers the relationship between FWDRB (floodwater damage reduction benefits) and underlying hydrological variables and assumptions. Chapter 6 considers the relationship between all categories of SCS-computed agricultural benefits and underlying crop enterprise variables (such as yields, prices, costs and pl

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prices, costs and planting patterns). The variables studied in chapters 5 and 6 determine the level of project-credited farm income, which is one of the data inputs for the investment criteria formulations of chapter 7.

Chapter 4 is a discussion of national efficiency-criterion investment rules and some conceptual problems related to their use in project evaluation. This chapter is not intended to be a review of literature for the field of public investment analysis. It does provide a rationale for studying both benefit and cost data and discount rate data assumed in agency evaluations.

Chapter 8 is an integration and summary of previous chapters.

Agency-Computed Versus Base-Estimate Data

Where the comparison is relevant and plausible, the author's base-estimate data approximate analogous SCS data. Generally, base-estimate data reported in chapters 5-8 are benefits, benefit cost ratios or numerical expressions for other investment criteria (such as project net present values, internal rates of return or present value benefit cost ratios). Except for undiscounted net cash flow data, this final-step data is the only kind developed for chapter 7. On the other hand, the author's detailed SCS model, used in chapters 5 and 6, essentially duplicates the step-by-step computations explained in chapter 3. For purposes of analysis with this detailed, sequential model of SCS procedures, and to assist in the initial debugging of the computer program for it, intermediate data was added to the computer print-out sheets. Very little of this detailed, intermediate data is presented in chapters 5-8.

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Nevertheless, having the SCS step-by-step data and analogous computer output data proved quite valuable. Considerable effort was made to precisely duplicate the SCS results at every step leading eventually to the base estimates reported in chapters 5 and 6. However, as can be seen by comparing data in Tables 3.9, 6.1, and 7.1 for the North Branch of Mill Creek project (or Mill Creek project, for short), and by comparing data in Appendix, Table 3, for the 12 studied PL 566 projects, the author's base-estimate and agency-computed results differ slightly. Agency-computed total annual average benefits for the Mill Creek project are $286,020, compared to the base-estimate total of $282,065. Since average annual costs are used as SCS model input data, they are the same in both cases, $40,520, leading to benefit cost ratios of 7.06/1 and 6.96/1, respectively. The simplified computations of chapter 7 provide a second base-estimate benefit cost ratio for the Mill Creek project, 7.35/1.

Why do the results differ? First, because the SCS economist used intermediate data for some crops in the Mill Creek project evaluation, the author found it necessary to develop SCS model input data for these crops. Had the SCS economist gone back to the same stage in the chain of computations, he would have obtained different intermediate data than he actually used. What the SCS economist did resulted in a considerable saving of time and did not affect the results significantly. Secondly, it appears that the SCS economist made some minor computational errors. Because the SCS economist's and the author's step-by-step computations agree precisely for several crops, and because the diffe

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To reiterate, for the North Branch of Mill Creek project, the SCS economist's total annual average benefits, $286,020 and benefit cost ratio, 7.06/1 are quite close to author's base-estimate data, $282,065 and 6.96/1, respectively. Differences in benefit sub-categories are relatively larger, but they have been reconciled, as indicated here.

For the base-estimate data of chapter 7, another answer is required for the question: Why do the agency-computed and the author's base-estimate data differ? Comparison is possible only for benefit cost ratios of the SCS type (shown in Appendix, Table 3), although the author also uses the term base estimate in chapter 7 when referring to the data for non-SCS investment criteria. As indicated in chapters 3 and 7, SCS economists do not actually compute various cash flows for all years in the evaluation period ($t = 1, ..., T$, where $T = 50$ or $T = 100$, depending on the project). Since cash flows are needed for all years for other investment criteria, the author decided to use this approach also in formulating approximations of the SCS benefit cost ratios. This consistency of approach has certain conceptual advantages that will not be discussed here. However, this departure from strict use of SCS procedures should not give rise to any significant differences in results. Examination of the two sets of benefit cost ratios (in Appendix, Table 3) will show that differences are generally slight, usually less than ±5%, some of which could be explained by rounding effects in the chain of computations.

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In other cases, it appeared that the SCS economists had made some computational and procedural errors. Since the 12 projects were evaluated over the period 1959-68, it was not possible for the author to discuss these apparent errors with the particular economists who had performed the original evaluations. That is, some of the SCS economists had been transferred from the SCS Planning Party in Michigan to other positions within the agency, transfers being a common personnel practice in most agencies of SCS size.

In a few cases, it appeared that project plans may have been changed midway through the evaluation. This entails recomputation. Given the long chain of computations involved in evaluating a PL 566 project investment, one can appreciate the desire to salvage as much as possible of what has already been done. While SCS economists are usually quite systematic in their calculations--a requirement of the agency for purposes of review--a change in project plans can upset the most systematic of people. In such cases it was sometimes difficult for the author to determine which SCS data, assumptions and computational arrangements had actually led to the results shown in the work plan for the project.

To summarize, the author's base estimate data correspond quite closely to analogous data computed by the SCS Planning Party economist who performed the original project evaluation. The rather insignificant differences may be due to errors of computation by either the author or the SCS economist. The precise agreement for parts of the Mill Creek project computations and the closeness of the final results lends credence to the assumption that the SCS model of chapter 3 is in fact an accurate representation of SCS evaluation procedures. This

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Hypotheses

Two hypotheses have been used as guides in this study.

Hypothesis 1 is as follows: SCS annual benefit cost ratios and other investment criteria data for PL 566 projects are quite sensitive to numerous underlying assumptions and procedures. These assumptions and procedures relate to crop enterprise, hydrological and other variables having to do with the timing, pattern and achievement rates for project costs and benefits.

Hypothesis 2 may be stated as follows: If one is willing to specify values for some of these variables, it is possible to alter the apparent worth of PL 566 projects considerably from that based on SCS assumptions. It is not the purpose of this study to specify what assumptions should have been used or what assumptions should be used in SCS evaluations. However, it is intended to show how possible alternative assumptions would affect the apparent worth of PL 566 projects. Indeed, the matter of assumptions is one over which reasonable men disagree. This does not detract from the point that what assumptions are used can affect investment rates and the welfare of people.

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CHAPTER II

THE SMALL WATERSHED PROGRAM

This chapter is intended to briefly survey the nature and context of the PL 566 program, and the topics include: program emergence, Public Law 566, conservation and PL 566, planning and coordination, flood versus drainage problems, and summary.[1]

Program Emergence

The SCS small watershed program has dual roots in the conservation and water resource legislation of the 1930's, legislation then aimed primarily at overcoming severe and widespread income and unemployment problems.

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[1]References for this chapter include: Robert J. Morgan, Governing Soil Conservation (Baltimore: Johns Hopkins Press for Resources for the Future, 1965); R. Bernell Held and Marion Clawson, Soil Conservation in Perspective (Baltimore: Johns Hopkins Press for Resources for the Future, 1965); Charles M. Hardin, Food and Fiber in the Nation's Politics, Vol. III of Technical Papers, National Advisory Commission on Food and Fiber (Washington, D.C.: USGPO, 1967), esp. sec. 4 ("Soil Conservation Programs"); Luna B. Leopold and Thomas Maddock, The Flood Control Controversy (New York: The Ronald Press, 1954); USDA, SCS, The Watershed Protection Handbook (Washington, D.C.; SCS, 1967, hereafter, WPH; USDA, SCS, Economics Guide for Watershed Protection and Flood Prevention (Washington, D.C.: SCS, 1964), hereafter, Economics Guide. The last two references are periodically updated, by page or section, and this will be indicated; also, both have now been issued in several editions, and earlier editions will be cited if relevant.

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Partly because of his efforts in the late 1920's and early 1930's to dramatize the problems of soil erosion, Hugh Hammond Bennett became the head of one of the many new agencies organized in 1933, shortly after the inauguration of President Franklin D. Roosevelt.

> It is widely believed that the dust storms of 1934 and 1935 provided the impetus for initiating the Soil Conservation Service; in fact, erosion control was started as an emergency federal public works project to relieve unemployment under the direction of Harold L. Ickes who was both Secretary of the Interior and administrator of the federal works program.[2]

The program was popular with congressmen and by 1936 SCS was directing 450 CCC (Civilian Conservation Corps) camps and 151 conservation demonstration projects.[3] CCC and WPA (Works Progress Administration) people did most of the work, although some labor and material was provided by farmers. Five-year farmer contracts were used, and they serve as a precedent for present day conservation-practice agreements (not contracts) in the SCS-PL 566 context.

Congress passed PL 46 in 1935, transferring the Soil Erosion Service (SES) from the Department of Interior to the Department of Agriculture, and renaming it the Soil Conservation Service (SCS). PL 46 is the basis for present day SCS conservation planning and technical

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[2] Quoting Morgan, pp. 1-2. The National Industrial Recovery Act of 1933 authorized soil erosion control work to help relieve unemployment, see Hardin, p. 146. SCS and the conservation-demonstration projects program were given permanence under PL 46 of 1935 (see note 4), although these projects were no longer funded by Congress after World War II.

[3] Morgan, p. 42.

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[4] Sec. 1, Publi
U.S.C. 590a-590f);
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[5] Morgan, pp. 1

assistance especially to farmers.[4] In PL 566 projects these services are funded largely by PL 46 appropriations, with supplemental acceleration funding under PL 566. Similar assistance for PL 566 projects is also provided by the Forest Service. Financial assistance in the form of ACP (Agricultural Conservation Program) payments is administered by the Agricultural Stabilization and Conservation Service (ASCS, not SCS). ASCS also administers farm price and income support programs. Its beginning traces to the Soil Conservation and Domestic Allotment Act of 1936, an act passed by Congress technically as an amendment to PL 46, after the Supreme Court declared the original Agricultural Adjustment Act (AAA) unconstitutional (for reasons of control over agricultural production). Thus, there are several agencies involved both in conservation and in small watershed projects, all within USDA, and some amount of historical conflict between them should be noted.[5]

Flood Control Projects and SCS

To use an SCS explanation, the small watershed or upstream program essentially fills the gap between the on-farm (ASCS and SCS) and the downstream, large-basin programs. SCS did some small watershed work even before the passage of the 1936 Flood Control Act, probably in the form of conservation demonstration projects, but most SCS work outside of PL 566 traces to this 1936 Act.

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[4] Sec. 1, Public Law 46, 74th Cong., 1 Sess., 49 Stat. 163, 164 (16 U.S.C. 590a-590f); hereafter, PL 46. This act is called both the Soil Erosion and Soil Conservation Act of 1935.

[5] Morgan, pp. 144-157; Hardin, pp. 154-164.

The 1936 Flood Control Act is often cited nowadays as benchmark legislation, but it should be noted that it was then intended in part to overcome Depression unemployment and income problems. It approved work broadly planned in the Corps of Engineers' "308" reports, made under the auspices of the 1927 and 1928 Rivers and Harbors Acts. These reports were by no means project plans or proposals, but they were the most complete and comprehensive river basin studies then available. These reports also served as a basis for the Tennessee Valley Authority Act of 1933.

The Flood Control Act of 1936 states:

> 1. That flood control is a proper federal function and that the federal government should improve or participate in the improvement if the benefits to whomsoever they may accrue are in excess of estimated costs.
>
> 2. That a flood control program is justified if the lives and social security of people are otherwise adversely affected.

Needless to say, these provisions have prompted considerable debate. The same can be said for the 1938 Flood Control Act that went another step and removed local responsibility for financial participation in Corps-built <u>reservoirs</u>. Under the 1936 Act, local governments had to provide land, operate the completed project, and free the Federal government from responsibility for damage suits in connection with projects. These requirements now apply only to so-called "local" works (meaning levees and channel improvements) in the Corps, flood control context, be

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control context, because of the 1938 Flood Control Act;[6] they are similar to those for SCS work under PL 566.

Until repeal by PL 566, SCS had survey authority under the 1936 Flood Control Act. Work is still in progress on projects outlined in SCS survey reports for eleven minor river basins, as approved in the 1944 Flood Control Act. SCS had been given authority in 1937 to survey upstream areas of basins then authorized for Corps of Engineers downstream surveys. Little SCS construction was funded until after World War II.

Small watershed projects may be built under PL 566, 1944 Flood Control Act, 1953 Pilot Watershed appropriation or possibly other authority.

The 1953 Pilot Watershed Appropriation

By 1953 the small watershed program had been underway for several year. SCS had prepared about 50 surveys, some of which were submitted to Congress that year; and plans existed for basins ranging in size

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[6]Leopold and Maddock, pp. 83-104.

In 1927 Congress directed the Corps and the Federal Power Commission to inventory the hydroelectric power potential of the nation's rivers. The list of streams was the result of Congressional authorization of 1925 for the two agencies, and it was published in House Document 308 of the 69th Congress; hence, the name "308" reports in connection with the surveys of these rivers authorized in 1927. See Ben Moreell, Our Nation's Water Resources--Policies and Politics (Chicago, Illinois; The Law School of the University of Chicago, 1956), pp. 42 and 67. Also, see Roland McKean, Efficiency in Government Through Systems Analysis (New York: John Wiley and Sons, Inc., 1958), p. 18.

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[7] See Leopold a
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[8] The Watershed
Law 566, 83d Cong.,

from 14 to 53,000 square miles, compared to a maximum of 400 square miles for PL 566 projects. However, because of the big-small dam, upstream-downstream controversy, and possibly for other reasons, $5 million was appropriated in 1953 for SCS pilot watershed work, as part of the agricultural rather than flood control budget. Leopold and Maddock cite a House report indicating that Congress had in mind a "pilot plant" of 50 demonstration projects to test the ultimate value of the upstream work, although SCS small watershed work had been underway since even before the Flood Control Act of 1936.[7]

Public Law 566[8]

Despite controversy, PL 566 passed Congress in the summer of 1954, shortly before elections. Public works committee approval is not required unless a project has a reservoir exceeding 4,000 acre feet, the maximum being 25,000 acre feet, as will be discussed shortly.

Except for size restrictions, PL 566 has emerged as an analog of the multi-purpose authorities granted to the Bureau of Reclamation and the Corps of Engineers. Reservoirs can be constructed for a variety of purposes.

Federal financing of PL 566 flood-prevention construction is not quite the equivalent of Corps of Engineers' cost-sharing rates for flood-control reservoirs which are financed entirely by Federal funds.

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[7] See Leopold and Maddock, pp. 208-210 and 230-232; Morgan, pp. 179-189.

[8] The Watershed Protection and Flood Prevention Act of 1954, Public Law 566, 83d Cong., 2d Sess., 68 Stat. 666.

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Thus, PL 566 reservoirs are on a par with Corps of Engineers local flood protection works (levees and channel improvements), for which local interests must provide land and eventually operate the project. Under PL 566, Federal cost-sharing rates are lower for non-flood-control purposes, and some functionally categorized costs may be Federal, local or shared, as shown in Table 2.1.

Classification of project costs is important in determining the eventual Federal-local cost-sharing ratios and to some extent in determining loans and advances that may be made. Advances may be made for site preservation and the provision of industrial and municipal water supply. Site preservation advances must be repaid with interest prior to the initiation of construction. Municipal and industrial water supply "advances" are interest free for up to 10 years (i.e., prior to the first usage of the new supply), and they may be used to finance up to 30% of the cost assigned to this purpose (to be born locally, without any other form of Federal assistance). Loans to cover the local sponsors' share of project costs may range up to five million dollars, and they are made by the Farmers Home Administration for up to 50 years at the so-called Federal long-term bond interest rate.[9]

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[9] _WPH_, sec. 103.041; PL 566, sec. 8.

Regarding interest rates, project costs (SCK only) are amortized at 4.875% in fiscal 1970, and enhancement benefits are computed at this rate (see chapter 7). However, for fiscal 1970 FHA loans to local sponsors are made at 3.342%, and soil and water conservation loans to _eligible_ farmers are to be made at 5% for 40 years; see USDA, FHA, _FHA Pamphlet PA-705_, revised August 1969 (Washington, D.C.: USGPO, 1970).

Table 2.1. Payment of PL 566 Small Watershed Project Costs by Federal and Local Project Investors.

SCS function classification of cost item	Federally paid	Locally paid	Comment
Conservation practice or land treatment costs			Enter numerator benefit-cost ratio only if counted as ACK and ACOM.
Application	Via ACP	Partly	ACP may cover about 50% of the cost.
Technical assistance	Usually	Rarely	Paid from PL 46 (SCS only) and Forest Service funds; f...

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Conservation practice or land treatment costs			Enter numerator benefit-cost ratio only if counted as ACK and ACOM.
Application	Via ACP	Partly	ACP may cover about 50% of the cost.
Technical assistance	Usually	Rarely	Paid from PL 46 (SCS only) and Forest Service funds; funds to accelerate, PL 566.
Operation-maintenance	None	All	100% local.
Structural measure (main-stream engineering works) costs			Enter denominator of benefit-cost ratio as SCK and SCOM.
Construction (contractor)	Shared	Shared	100% Fed. for flood prevention; up to 50% Fed. for other purposes, except municipal and industrial water supply which is 100% local.
Installation services	Mostly	Some	100% Fed., except for minimum basic recreation and fish-wildlife facilities (up to 50% Fed.) and municipal and industrial water supply (100% local).
Land	Some	Mostly	100% local, except for recreation and fish-wildlife (up to 50% Fed. for fee simple only) and municipal and industrial water supply (100% local).
Admin. of contracts	Shared	Shared	Until 1969 SCS provided technical services; local sponsors, "administrative, legal and clerical." Since 1969 local sponsors may request SCS to provide all.
Op.-maintenance (SCOM)	Some	Mostly	100% local, except for SCS inspections (first 3 years and after big floods thereafter) and SCS advice.
Other costs: planning, loans	Shared	Shared	Planning costs are "non-project" PL 566 overhead costs; see text on loans

Source: PL 566. WPH, sec. 103.031 (rates), sec. 101.051 (revised, Jan. 1969, SCS participation in adm. of contract costs), and secs. 115.042-.062 (SCS assistance in SCOM, revised, March 1969).

Federal-Local Cost-Sharing Ratios: A Case Example

A case example may be the best way to illustrate alternative cost-sharing ratios for PL 566 projects, although the resulting ratios may not be representative of the program in Michigan or nationally. National data will be presented for purposes of comparison. The case example data are shown in Table 2.2.[10] Transferring non-PL 566 technical assistance costs to the Federal side of the scales for the data shown in Table 2.2 gives a ratio of Federal, 34%, and local, 66%.[11] Compared to the national data, 60:40, the Michigan example project at 34:66 represents a much better degree of local participation, exceeding even the 50:50 ratio envisioned in the original PL 566 legislation of 1954, with all ratios expressing the percentage of Federal cost first.[12]

However, a second ratio can be computed for the example project, and it is almost an exact reversal from the first at Federal, 64%, and local, 36%. This ratio counts ACP payments and planning as Federal costs, whereas the SCS ratios do not consider ACP payments because they are non-PL 566 costs, and count planning costs as non-project

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[10] SCS watershed work plans show land treatment and structural costs only. For this project SCS estimates of capital costs for land treatment ($1,330,310, for the 73 square mile watershed area) and the "associated cost" investment ($1,310,321, for the 14 square mile project-benefited area) are coincidentally about equal, disregarding diminution of the latter for partial and delayed completion of the investment.

[11] In Table 2.2, PL 566 funds total $731,587, and other, $1,504,655, as shown in the work plan table. Transferring non-PL 566 Federal funds (i.e., PL 46 and Forest Service, or "going program" funds) to the Federal side; Federal $770,067, and other, $1,466,175. From this the percentages are as follows: Federal, 34.4% (0.344 = $770,067 / $2,236,242), and local, 65.6%.

[12] USDA, SCS, D.A. Williams (SCS Administrator), letter to state conservationists (top SCS officers in each state), subject: "Federal Assistance in Watershed Projects," SCS Advisory WS-28, November 18, 1965.

Table 2.2. Summary of Various Kinds of Project Costs, North Branch of Mill Creek Watershed, Michigan

Kind of cost	Category shown in work plan		Counted in B/C ratio computations
	PL 566 funds	Other funds	
Structural costs (project benefited area only, 15 sq. mi.)			
Construction	$501,304	$125,341	$626,645
Installation services	105,903	- - - -	[illegible]

Table 2.2. *Summary of Various Kinds of Project Costs*, North Branch of Mill Creek Watershed, Michigan

Kind of cost	Category shown in work plan: PL 566 funds	Category shown in work plan: Other funds	Counted in B/C ratio computations
Structural costs (project benefited area only, 15 sq. mi.)			
Construction	$501,304	$125,341	$626,645
Installation services	105,903	- - - -	105,903
Land, adm. of contracts	- - - -	173,384	193,184
Subtotal	$607,207	$298,725	$905,932
Associated costs (project benefited area only, 15 sq. mi.)			
On-farm tile	- - - -	- - - -	$1,071,990
On-farm land preparation (for former woods & pasture)	- - - -	- - - -	158,385
Inter-farm tributary drains	- - - -	- - - -	79,946
Subtotal	- - - -	- - - -	$1,310,321
Land treatment costs (watershed area, 73 sq. mi.)			
Drainage	- - - -	$977,250	(only if assoc.)
Other conservation practices	- - - -	159,050	- - - -
Technical asst., SCS	$113,280	27,840	- - - -
Technical asst., Forest Service	11,100	10,640	- - - -
Subtotal	$124,380	$1,205,930	- - - -
Total (struct. + land treatment costs = $2,236,242)	$731,587	$1,504,655	- - - -
Assoc. & struct. ($1,310,321 + $905,932 =)	- - - -	- - - -	$2,216,253
Annual costs for denominator of B/C ratio			
Amortized (50-year, 2-5/8%) structural costs ($905,932)	- - - -	- - - -	$32,740/year
Op. & maintenance costs (for struct. items only)	- - - -	- - - -	7,780/year
Total, as used in denominator of B/C ratio	- - - -	- - - -	$40,520/year

Source: USDA, SCS, documentation for North Branch of Mill Creek watershed, reaches 1 and 2 only.

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[15]USDA, ASCS,
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(PL 566 overhead) costs.[13] With other assumptions, different ratios could be computed, such as if limitations on ACP payments were taken into account, but in the author's view the ratio given here is at least more indicative of Federal cost sharing than the agency type ratios.[14] To be sure, several limitations might reduce the Federal proportion of costs of PL 566 projects when ACP payments are counted: (1) the unavailability of ACP payments for established legal drains under the Michigan Drain Code; (2) the limitation on maximum ACP payments, $2,500 per person per year for non-pooling practices, and $10,000 per person per year for pooling practices;[15] (3) lack of ACP funds due to Federal budget or program restrictions; and (4) farmers' willingness to apply conservation practices without benefit of ACP cost-sharing assistance. On the other hand, while the usual maximum ACP cost-sharing rate is 50%, it is interesting to note in the PL 566 context that flood-control type conservation practices have a higher rate of assistance (such as 80% for practice C-7) than tile drainage (30-50% in Michigan, practice C-10). Rates higher than 50% may be used

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[13] WPH (1961 ed.), sec. 1131.4 states that planning costs are not to be counted in the benefit cost ratio.

[14] Planning costs are difficult to estimate on a by-project basis, but they may be in the $20,000 to $50,000 range. Using the ACP rates for 1965 (source, see note 15), and the list of practices in the example project's work plan table 1, ACP payments were estimated as $633,195. Estimated Federal costs are $1,453,262 ($731,587, as shown in Table 2.2; plus $38,480, non-PL 566 technical assistance costs; plus $633,195, estimated ACP payments; plus $50,000, estimated planning costs). The Federal percentage would be 63.6% ($1,453,262/$2,286,242, the denominator including the total shown in Table 2.2, $2,236,242, as shown in the work plan, plus $50,000, estimated planning costs).

[15] USDA, ASCS, State Office in Michigan, Agricultural Conservation Handbook for 1965, Michigan (East Lansing, Michigan: ASCS, November 1964), sec. 3, item H.

for practices "which have long lasting conservation benefits," and/or if an "increased rate of cost-sharing is essential to introduce a greatly needed new conservation practice."[16]

EDA Grants

Special Federal grants may be available for small watershed projects (1944 Flood Control Act and PL 566 projects) in areas that qualify for assistance under the Public Works and Economic Development Act of 1965 (PL 89-136, sec. 101). The minimum local rate of participation for costs subject to EDA underwriting is set at 20%, and the converse is that the maximum rate of Federal assistance would be 80%.[17] In practice this would increase the rate for all SCS project purposes, except flood prevention which is already at the 100% Federal rate.

An Economic Development Administration grant was requested for the East Branch of Sturgeon River project, Dickinson County, Upper Peninsula, Michigan (SCS work plan dated February 1966). Counting costs subject to underwriting with an Economic Development Administration grant (i.e., construction, installation service and administration of contract costs, and excluding land costs), the Federal government would have paid 45.4%, without the grant, and 75.9% with the grant, approaching the 80% maximum allowed.

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[16] Ibid. and sec. 10.

[17] WPH (1967 ed., revision dated June 1968), Appendix 13: "Memorandum of understanding between the Economic Development Administration--Department of Commerce and the Soil Conservation Service--Department of Agriculture."

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Cost Allocation

Under PL 566, the financial question of who pays for what is determined by: (1) Federal-local cost-sharing ratios for various functional and purpose cost categories; (2) the assignment of project costs to these cost categories; and (3) joint-cost allocation rules.[18]

Reservoirs: For ease of explanation, SCS prefers the use of facilities method for allocating joint reservoir costs to project purposes.[19] Specific costs (for items used exclusively for one purpose) are first deducted; then remaining (joint) costs are allocated according to the physical capacity assigned to each purpose. For the alternative justifiable expenditure method (also called the specific-cost remaining benefit method), the allocation base is the lesser of two numbers, either the benefit of a purpose, or the cost of serving that purpose with an alternative, single-purpose structure, each with specific costs deducted.[20] The separable-cost remaining benefit method is similar, except that separable rather than specific costs are used in the initial deduction.[21]

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[18] See PL 566, sec. 3. Cost sharing rules are contained in: (1) WPH (1967 ed., relevant section amended as of Jan. 1969); (2) Economics Guide, ch. 10 (some pages amended as of Feb. 1968).

[19] Capacity serving more than one purpose is divided equally. Sedimentation capacity is assigned to flood prevention only if downstream sedimentation problems are alleviated, otherwise it is ignored.

[20] For example, if the benefits for irrigation are $40,000; direct costs, $5,000; and the cost of a single-purpose irrigation structure, $25,000, the allocation base for irrigation would be $20,000.

[21] Separable-costs are defined as the difference in cost for a multiple purpose structure with and without the purpose in question when it is added last. Specific-costs are those used exclusively for one purpose.

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Channel improvement: SCS procedures for allocating joint channel improvement costs, usually between flood prevention and drainage, have been reduced in number and changed (in 1968 and 1969). The equal division method requires little explanation, and it is different than the older method shown in Table 2.3. The modified relative area method is more complex.[22]

Contractor Payment Ratios

SCS develops contractor payment ratios for inclusion in the signed PL 566 project's work plan agreement between the Federal government and the local sponsors. Before discussing their derivation in Table 2.3, it may be useful to describe the SCS development of the various, functional items of cost to be used.

Two basic cost estimates are used in PL 566 project work plans: one, for land costs, is based on SCS or local sponsor appraisal of land values; the second, for construction costs, is developed by the SCS in-state Planning Party engineers, and it serves as a basis for estimating all other non-land costs for installing the structural measures. The SCS engineers use bid abstracts for other projects in the area, local material prices, and other costing resources common to

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[22] The modified relative area method is used only if flooding and drainage are joint problems on part of the project-benefited area of the watershed. Wet land is defined as that portion of the area served by the channel already having or requiring on-farm drainage; and the non-wet portion is the remainder of this area. The proportion of the channel cost allocation to flood prevention is determined by the ratio:

$$\frac{\text{(acreage of non-wet land served by the channel)}}{\text{(total acreage served by the channel)}}$$

Remaining costs (i.e., those not allocated to flood prevention using the area rule), are allocated to flood prevention and drainage on an equal basis.

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the engineering profession. Other non-land functional cost items are computed with rule-of-thumb percentages from the basic construction cost estimate, as shown in the following data for the channel improvement in reaches 1 and 2 of the North Branch of Mill Creek watershed (prices for 1961).

Construction cost		
Basic engineering estimate	$434,516	
Contingency allowance, 15% of $434,516	65,177	
Construction cost, subtotal	$499,693	S
Installation service cost		
Engineering, 10% of $499,693	49,969	F
Subtotal	(549,669)	
Other, 5% of $549,669	27,483	F
Administration of contract cost		
5% of $499,693 (construction)	24,984	L
Land costs (easements and rights of way)	93,780	L
Total installation cost for this structure, excludes both planning costs and land treatment costs	$695,909	S

These costs paid from Federal (F), local (L) or shared (S) funds, as shown in the last column.

The allocation process will be discussed in several steps:

Step 1: Since benefits were used as an initial allocation base to divide the cost for all structures (including the flood water

Table 2.3. *Cost Allocation, Channel Improvements* for Reaches 1 and 2, North Branch of Mill Creek Watershed.

Cost item	Flood prevention costs			Drainage costs			Total costs		
	PL 566	Other	Total	PL 566	Other	Total	PL 566	Other	Total
Allocation base from benefits			64.9%			35.1%			100.0%
Allocated cost[a]			$545,200			$295,064			$840,264
Less floodwater retarding struct.			-144,355						-144,355
Allocated channel cost, total			$400,845			$295,064			$695,909
Resulting channel allocation base			57.6%			42.4%			100.0%
Allocation of channel costs: 57.6% flood prevention and 42.4% drainage									
Construction	$287,725	----	$287,725	(See below)		$211,870	(See below)		$499,693
Instl. Services									
Engineering	28,782	----	28,782	$21,187	----	21,187	$49,969	----	49,969
Other	15,830	----	15,830	11,653	----	11,653	27,483	----	27,483
Adm. of contract	-----	$14,391	14,391	-----	$10,593	10,593	----	$10,593	24,984
Land	-----	54,017	54,017	-----	39,763	39,763	----	93,780	93,780
Subtotal	$332,437	$68,408	$400,845	$32,840	$50,356	$295,064	----	----	$695,909
Applicable current allocation base, drainage				45%	55%	100%			
Allocated total drainage costs				$132,770	$162,285	$295,064			
Less drainage costs allocated above				-32,840	-50,356	----			
Resulting division of drainage contract costs				$ 99,939	$111,929	$211,870			
Construction	$287,727	-----	$287,725	$ 99,939	$111,929	$211,870	$387,764	$111,929	$499,693
Resulting base for sharing actual contractor costs between Federal and local							77.6%	22.4%	100.0%
Total costs	$332,437	$68,408	$400,845	$132,799	$162,285	$295,064	$465,216	$230,693	$695,909

Source: USDA, SCS, work plan and documentation, dated February 1962.

[a]Allocation based on percentages shown, $545,330 and $294,934; $130 later shifted; error in work plan.

retarding structure)[23] in reaches 1 and 2, the percentages 64.9%, flood prevention, and 35.1%, drainage, were applied to this cost $840,264).[24]

Step 2: After deducting the flood retarding structure's cost, a second allocation base was derived for the channel improvement costs only, 57.6% flood prevention, and 42.4% drainage and applied to all functional cost items. In combination with the by-purpose, by-function cost-sharing ratios, this allocation is sufficient to separate PL 566 and other costs assigned to flood prevention, but an additional allocation is needed to separate drainage construction costs.

Step 3: At the time the work plan was originally completed (in 1962), SCS regulations required that other (non-PL 566) funds bear 55% of all costs allocated to drainage. Already allocated functional cost items (from step 2) for drainage were then deducted. The result is the division of drainage construction costs between PL 566 and other funds.

Step 4: Construction costs are then summed, for PL 566 and other funds, and the result determines the contractor paying ratio, 77.6% Federal and 22.4% local for this work. While the contractor paying ratio

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[23] The flood retarding structure costs (for reaches 1 and 2) were allocated and divided in a less elaborate manner, simply using PL 566 cost-sharing ratios for functional cost items, for all of the costs were allocated to flood prevention. The channel improvement costs for reach 3 were allocated using a different base than was used for reaches 1 and 2.

[24] See ch. 3. For this project, FPB = FWDRB + 1/2 MILUB + 1/2 LUCB: AWMB (drainage only) = 1/2 MILUB + 1/2 LUCB.

is based on estimated costs, it becomes the basis of sharing actual costs; as such it becomes part of the legal, work plan agreement between the Federal government and the local sponsors.

Flood Prevention Dominance

The 1967 House Agricultural Committee policy statement, requiring that flood prevention be the dominant purpose of all PL 566 projects the Committee approves, is less restrictive than it seems.[25]

First, because flood prevention receives a higher degree of Federal underwriting than other purposes, its dominance is consequently more certain when relative PL 566 cost for structures is used as a criterion.[26]

Second, not all PL 566 projects must be approved by the House Agricultural Committee. The act requires that Congressional approval must be obtained if the Federal contribution to construction cost exceeds $250,000, or if overall capacity of any single reservoir exceeds 2500 acre feet. Below these limits, stated in PL 566 itself, construction fund allocation may be administratively approved within SCS. If any one reservoir has a capacity in excess of 4,000 acre feet, construction must be approved by the public works rather than the agricultural committees of both Houses of Congress. (The maximum size

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[25]See USDA, SCS, D.A. Williams, SCS Administrator, Watershed Memorandum 86, subject; "Flood Prevention in Watershed Projects," dated September 28, 1967. Attached is a letter from W.R. Poage, Chairman of the House Agricultural Committee, to Speaker of the House, John W. McCormack, dated July 31, 1967.

[26]On this basis, the project cited in Table 2.3, would be 76% flood prevention compared to 64% when all structural costs (PL 566 and other) are considered, and 65% in terms of benefits.

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is 25,000 acre feet at present, as stated in PL 566, although the original maximum was only 5,000 acre feet). According to the cited SCS memorandum, the House Agricultural Committee restriction does not apply to projects which can be administratively approved within SCS because of their small size and cost, or which must be approved by the Public Works Committee because of their large reservoirs.[27]

In the summer of 1967 came another restriction on the PL 566 program, issued by the Department of Agriculture.[28] It restricts watershed developments that are primarily intended to either bring new land into production or to increase output of crops already in surplus; and emphasizes multiple purpose projects, significantly omitting any restriction on floodwater damage reduction benefits (FWDRB). Also, this statement eliminates restrictions of any sort on projects in low-income or depressed rural areas, and stresses coordination of various Departmental assistance or subsidy programs to speed the conversion of land uses from surplus crop production to non-surplus crop production or non-agricultural uses.

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[27] PL 566, sec. 2, item 2. For example, the Mill Creek project, mentioned in the preceding footnote, had an overall structural capital cost (SCK) of $905,932. Of this, the Federal contribution was $607,207. Deducting installation service costs from the Federal cost, $501,304 remains as the PL 566 contribution to construction costs; since this exceeds $250,000, the project could not be administratively approved within SCS and required approval by congressional committees. Approval was obtained from the agricultural committees, for the reservoir had a capacity of 1670 acre feet which is less than the 4000 acre feet capacity signaling Public Works Committees approval.

[28] USDA, SCS, SCS Administrator, D. A. Williams, Watershed Memorandum 84, Supplement 1, subject: "Surplus Crop Production," dated August 25, 1967. Attached is a letter to the Secretary of Agriculture (Orville Freeman), from John A. Baker, Assistant Secretary of Agriculture for Rural Development and Conservation, dated July 18, 1967.

An Overview

Taking the Department's and the House Agriculture Committee's statements together, it would appear that flood prevention is to be the clearly dominant purpose of PL 566 projects in terms of PL 566 costs for structures, and this is not necessarily in conflict with the Department's emphasis on multiple purposes in terms of benefits, because the higher degree of Federal underwriting for flood prevention means that it can more easily dominate among the purposes in terms of costs. Significantly, if one is looking for a sense of complementarity with the Committee's statement, there is no restriction on FWDRB (reduced losses from flooding). However, the restriction that project benefits can not result primarily from bringing previously uncropped land into crop production has been extended to include the flood prevention portion. Yet, the Department's policy statement makes no mention of non-FWDRB flood prevention benefits associated with more intensive land use of already cropped land (MILUB-FPB). However, MILUB-irrigation and MILUB-drainage must be associated with furthering "efficient use of water and related land resources," rather than with increasing crop production per se.

Conservation and PL 566

In a typical PL 566 project, conservation (land treatment) practices receive considerable emphasis. They are partly financed by ACP payments. Technical assistance for their application is provided by USDA personnel, from SCS (PL 46 funding) and the Forest Service. Accelerated application is funded from PL 566; this may be necessary if a project would place too heavy work loads on regular, in-county USDA personnel. Application in critical areas is apparently not well understood and is to be distinguished from that in non-critical areas. In this section the role of conservation districts, farmer agreements and SCS emphasis will also be considered.

Critical Area Land Treatment

For small watershed projects, Hugh Hammond Bennett, first SCS administrator and founder, indicated that it was first thought to be necessary to complete 100% of the critical, runoff-reducing and erosion-reducing land treatment on the watershed drainage surfaces above a planned flood-detention reservoir prior to initiating any construction on the structure. However, Bennett later indicated that this prerequisite could be reduced from 100% to 80%. Morgan incorrectly compares these percentages to the one mentioned in PL 566, 50%, which refers to the proportion of land above a detention structure that must be under agreement "to carry out recommended soil conservation measures and farm plans."[29]

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[29]The quotation is from PL 566, sec. 4, item 5.

Critical runoff and sediment producing areas must be distinguished from other watershed areas. Not all watersheds have these critical areas; they are absent in most flatland areas such as Michigan, and seem to be peculiar to certain geographical areas of the country with special soil, topography and rainfall combinations. The Southern Plains seems to be one such area. Reservoirs built in such areas have been subject to extremely rapid and unexpected sedimentation fill-in, owing to lack of erosion control in the watershed areas contributing runoff to the reservoirs.

Morgan drives his criticism home by adding;

> There was, and is, no statutory requirement that any land actually be treated. Local sponsors have a supposed obligation to effectuate agreements for completing and maintaining these projects, but, since this responsibility does not have to be met, there is little ground for believing that it always will be met.[30]

However, SCS regulations indicate that SCS expects 75% of the critical-area land treatment to be completed concurrently with the construction of flood control structures on the main stream. Thus, 75%, not the 50% in PL 566 itself, may be compared with Bennett's 100% and 80% figures, as the current, expected measure of runoff and erosion control in critical areas above flood detention structures. As a matter of fact, these SCS regulations negate the PL 566 legislative requirement: (1) if erosion and other problems in the area above the flood detention structure would not adversely affect the structure (in terms of design, cost, and operation-maintenance); and (2) if farmers in the specified area are soil conservation district cooperators.[31]

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[30]Comparison and quotation from Morgan, pp. 188-189; also, see pp. 178, 299 and 300.

[31]See WPH, 1967 ed., sec. 104.03; sec. 1110, 1961 ed., is virtually identical.

Farmer agreements with soil conservation districts are made on three different levels.

In stage I, the farmer merely signs an agreement with the district, indicating his interest in following conservation-oriented practices. This makes him eligible for assistance from the district, since he is then a district cooperator; that is, the SCS technician can then aid him in installing various conservation practices.

Stage II means that the farmer has allowed the SCS technicians to examine his land and perform a conservation survey upon which a map of land capabilities could be prepared.

In stage III the farmer agrees to accept and execute the basic conservation plan.

These comments are based on Morgan's discussion, pp. 156-168.

Critical erosion and runoff areas in the watershed drainage area above flood-detention-structure sites are not a problem in most relatively flat areas, such as Michigan.[32] In regions where these critical areas are a problem, farmers can apply to their county ASCS office for Federally-funded ACP payments to cover up to 80% of the cost of such critical-area conservation practices.[33] In addition, PL 566 funds are available to supplement ACP and other "going program" funds "for planning and application of land treatment measures" in critical areas and elsewhere, if there is a lack of funds under these other national programs (underline added).[34] However, PL 566 itself stipulates that the overall Federal technical and cost-sharing assistance under PL 566 shall not exceed that available under other national programs.[35] Therefore, either under ACP or PL 566, it appears that the Federal government will pay up to about 80% of the cost of installing critical-area treatment measures, if classified as land treatment practices in the project work plan. Different rates of assistance apply for other types of land treatment practices in non-critical areas of the watershed; 50% may be a roughly typical rate under the ACP program, but specific rates are both lower and higher.

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[32] SCS work plans for PL 566 projects in Michigan usually indicate that field investigation revealed that sedimentation damage and problems area not serious.

[33] Assuming that the 80% Federal cost-share for ACP practice C-7 (structures for erosion control) for Michigan for 1965 is typical. Source; USDA, ASCS, State Office in Michigan, Agricultural Conservation Program Handbook for 1965 (East Lansing, Michigan, ASCS, November 1964). National ACP practice C-6 (storage dams for erosion control) is not listed in the ACP Handbook for Michigan.

[34] WPH, sec. 104.04.

[35] Compare Ibid. and PL 566, sec. 3, item 4.

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Alternatively, critical-area conservation practices may be classified essentially as flood prevention structural measures, rather than as land treatment measures in the PL 566 work plan dichotomy. In this case, the Federal government pays for 100% of the installation cost, excluding land, administration of contract (until 1969), and operation-maintenance costs, all of which are paid by the local sponsors.

Non-Critical Area Land Treatment

Adjoining the SCS administrative regulation requiring that 75% of the critical-area land treatment be completed concurrently with the installation of the mainstream structural measures is a counterpart regulation concerning land treatment in the project-benefited area which is usually in the valley lowlands. It states that SCS "will determine" that a high proportion of the farmers on the land benefited by the project structural measures for irrigation or drainage--flood prevention is omitted--will agree with the local soil conservation district or equivalent, not SCS, to "develop" farm conservation plans, which are prepared by the in-county, local SCS technician.[36]

The Role of Conservation Districts

Soil conservation or other similar districts now cover virtually all of the United States, with the exception of a few areas that either lack interest in agriculture or oppose the SCS approach.

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[36] WPH, sec. 104.036, item 3.

The agreement by the farmer with the district to develop the SCS conservation farm plan means that the farmer would be in stage III of progressive planning which is discussed in footnote 31.

In the PL 566 context, districts lack taxing power and therefore can not be financially responsible for the local share of project costs. They may be effective in promoting projects locally, and in making various local contacts necessary in this effort.[37]

Farmer agreements with districts have already been discussed.[38]

SCS Emphasis on Land Treatment

Since the cited PL 566 legislative and SCS administrative regulations are specified in terms of farmer-local district agreements, rather than in terms of legally binding contracts, one could argue that these agreements, not land treatment and conservation per se, are by subterfuge the condition upon which Federal assistance is provided to local people.

On the other hand, SCS has traditionally prided itself as being a, if not the, leading Federal agency interested in promoting and planning soil and water conservation. SCS regulations accentuate land treatment by discussing it in the opening paragraph of the section on watershed planning.[39] Land treatment has been emphasized in directives from the SCS Administrator, who, in one extensive directive on the subject, states:

> All Service employees must recognize the necessity for adequate land treatment in watershed projects. Needed actions must be taken to insure that each watershed project when completed will

[37] Morgan, ch. 12, especially pp. 338-342.

[38] See footnote 30.

[39] WPH, sec. 104.00.

> be a "showcase" of sound land use and treatment. The quantity and quality of conservation treatment on the land should be an identifying mark of any completed watershed project.[40]

An advisory notice from the SCS Administrator suggests that on-site inspections of watersheds usually reveal an adequate amount of land treatment. Subsequently, he comments that SCS policy has and will continue to stress "that land treatment is the keystone of watershed development."[41]

Planning and Coordination

PL 566 calls for special consideration of surveys and plans of the Department of the Interior with respect to the conservation and development of fish and wildlife resources.[42] A PL 566 project may be affected when consultation so requires in relation to legislative authorities of other departments, as stipulated in Presidential Executive Orders.[43]

The Corps, generally, has responsibility for larger (downstream) watersheds with drainage areas of 250,000 acres or more, and SCS, for smaller (upstream) watershed areas. In addition, for urban areas,

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[40] USDA, SCS, SCS Administrator, D. A. Williams, Watershed Memorandum-70, subject: "Watershed Land Treatment," dated November 5, 1964, p. 1.

[41] USDA, SCS, SCS Administrator D. A. Williams, Advisory Notice W-748, subject: "Watershed Protection (PL 566)--Land Treatment Measures in Watershed Work Plans," dated September 28, 1962.

[42] PL 566, as amended, sec. 12.

[43] The small watershed authorities are; the Flood Control Act of 1944 (58 Stat. 887), as amended, for the eleven river basins; nationally, including the 50 states, Puerto Rico and the Virgin Islands, PL 566 of 1954 (68 Stat. 666) as amended.

The reclamation acts are; the Reclamation Act of 1902, as supplemented and amended (43 U.S.C. 391); the Small Reclamations Project Act of 1956, as amended (43 U.S.C. 422a-k).

The Flood Control Acts of 1917 (39 Stat. 948), 1928 (45 Stat. 534), and 1936 (49 Stat. 1570), all as amended.

Corps has responsibility, if major damage would occur ($2,000,000 or more); SCS, if minor damage would occur ($750,000 or less); and responsibility is subject to negotiations and further guidelines, if intermediate damage would occur ($750,000 to $2,000,000). Urban damage is decided on the basis of a flood sufficient to inundate "substantially the entire flood plain."[44]

Water resource development activities are divided among several federal agencies. Several Presidential Commissions have proposed a single agency, but perhaps the best that can be expected is inter-agency coordination. The present Water Resources Council is apparently the first to receive congressional sanction, although inter-agency groups date to 1939. While this topic has a rather interesting history, it will not be considered further here.

The Tennessee Valley Authority Act of 1933, as amended (16 U.S.C. 831, et seq.).

[44]See USDA, SCS, SCS Administrator, D. A. Williams, Watershed Memorandum 75, subject: "Agreement with Corps of Engineers with Respect to Flood Protection by Engineering Works," dated December 14, 1965.

This memorandum transmitted the Corps-SCS agreement dated September 23, 1965. This agreement was a condition for favorable action by the Senate Committee on Agriculture and Forestry on Public Law 89-337 (approved November 8, 1965), amending PL 566, which increased the limitation on flood detention capacity for PL 566 project reservoirs from 5,000 to 12,500 acre feet. Overall capacity for PL 566 reservoirs is 25,000 acre feet, including capacity allocated to all purposes. These limitations refer to single reservoirs, and a project may involve several reservoirs.

Flood Versus Drainage Problems

Floods may connote disaster to many people, and their control takes on the meaning of such terms as national interest, national defense and national welfare.[45] Disastrous flood losses that attract national news coverage usually occur in large river valleys, but less dramatic losses in smaller, upstream areas may account for over half of the annual flood damages for the United States, according to SCS estimates.[46] There is the impression that the downstream program is intended to control large, disaster-type floods; the upstream program, frequent floods. Yet, neither program affords complete protection.[47] Both the Corps of Engineers and SCS employ low-probability design floods, and justify protection works on the basis of reduction in mathematically expected annual damages, to which low-probability floods

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[45]The preamble to PL 566 states in part: "erosion, floodwater and sediment damages in the watersheds of the rivers and streams of the United States, causing loss of life and damage to property, constitutes a menace to the national welfare."

[46]Erwin C. Ford, Woody L. Cowan and H. N. Holtan, "Floods--and a Program to Alleviate Them," in USDA, Water: The Yearbook of Agriculture, 1955, (Washington, D.C.: USGPO, 1955), pp. 171-176. The authors use data for 1952, for floodwater and sediment damage, of which the upstream portion is 56% for the United States. Upstream damages, $557 million, were estimated by SCS from studies of 77 watersheds covering 52% of the continental United States, over a 15 year period. Downstream damages were estimated as $500 million. Leopold and Maddock criticized an earlier, 1945 SCS ratio, 75% upstream and 25% downstream, as being based on a hypothetical watershed, some assumptions and extrapolation. See Luna B. Leopold and Thomas Maddock, Jr., The Flood Control Controversy (New York: The Ronald Press, 1954), pp. 186-188.

[47]Leopold and Maddock, p. 239.

contribute very little. High-probability, low-damage floods contribute most to expected annual damages for a given location, perhaps 80% for 10-year and more frequent, smaller magnitude floods.[48]

However, Leopold and Maddock argue that there is a conflict in goals: projects are quite successful in promoting land development, but only partially successful in meeting loss reduction objectives, for protection is never complete. Some protection spurs floodplain development which becomes the basis for demands for more protection. They argue that zoning and other non-structural methods for avoiding losses are seldom proposed, because such methods conflict with local interest in land development and real estate value promotion.[49] Some 10 years later a Presidential Task Force stated:

> Studies of flood plain use show that some flood plain encroachment is undertaken in ignorance of the hazard, that some occurs in anticipation of further Federal protection, and that some takes place because it is profitable for private owners even though it imposes heavy burdens on society.
>
> Large numbers of soundly conceived, economically justified flood projects have been built. As a result, vast flood damages have been prevented. However, vital actions needed to complement the structural protection effort have been absent. In consequence, the Nation faces continuation of a dismal cycle of losses, partial protection, further induced (through submarginal) development, and more unnecessary losses.[50]

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[48]This refers approximately to the area to the right of the 10-year frequency line in Figure 3.1. For Figure 3.1, damages for the 1, 2, 5 and 10 year floods may be obtained by summing the damages shown in the last column of Table 3.4; $36,288/$45,410 = 0.799 or about 80%. This represents the rectangular-area method of approximating the area under the SCS damage frequency curve.

[49]Leopold and Maddock, pp. 239-240.

[50]U.S., Office of the President, The Task Force on Federal Flood Control Policy, A Unified National Program for Managing Flood Losses, House Document No. 465, 89th Cong., 2d Sess. (Washington, D.C.: USGPO, 1966), pp. 11-12.

Leopold and Maddock (who are hydraulic engineers, not economists) point out that flood protection projects were originally promoted on the basis of disaster relief, with many of the flood control acts following floods of major proportions. To emphasize the point, they indicate that the terms flood prevention and flood control are misnomers for flood protection which is never meant to imply complete protection. They propose that the program be stripped of the implications of disaster-relief benefits. Concentrating on the idea that flood protection projects have become relatively highly subsidized forms of land development, they outline the successive retreat in the requirements for local financial participation, going from the 1917 to 1938 Flood Control Acts, and propose local participation in proportion to benefits. They touch on the idea of comparative development advantages and cost for different areas.[51]

If flood protection is motivated and supported as a means of Federal-paid land development for local beneficiaries, is it any different than drainage or irrigation in an agricultural setting?

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[51]Leopold and Maddock, pp. 144 and 240-244. The study of comparative costs and advantages is different in purpose and viewpoint than that of project evaluation and justification. The former may require significant changes in data and procedural assumptions in agency evaluations. See Vernon W. Ruttan, The Economic Demand for Irrigated Acreage (Baltimore: Johns Hopkins Press for Resources for the Future, 1965), pp. 85-88.

This question is relevant to the discussion of SCS procedures for evaluating flood and drainage problems, for disparate Federal cost-sharing, planning approval (USDA) and construction approval (congressional) rules necessitate separating flood prevention and drainage benefits and costs. Although the whole matter could be left as a question of policy, some conceptualizing may be useful. In particular the nature of loss and flood-hazard effects on farm managers and land use (cropping patterns) are of interest.

FWDRB are computed by SCS using the simplifying assumption of homogeneous cropping patterns in economic reaches, which are sub-parts of the project-benefited area. Yet, for the North Branch of Mill Creek watershed (the example in chapter 3), it appears that SCS's sampled farms with a higher proportion of land in woods, idle and permanent pasture uses, and less land in crop uses were located nearer the river, although the author could not precisely locate the sampled farms on the watershed's map. If this is so, it indicates that the SCS simplifying assumption of homogeneous land use and cropping patterns disguises farm manager perception of flood hazards and consequent loss-avoidance reactions. Existence of uncropped land nearer the river is consistent with the hydrologists' view of the manner in which rivers develop and use floodplains to handle overbank flows.[52]

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[52]Leopold and Maddock, ch. 2. Channels carry normal flows, and floodplains cope with occasional excess flow. Natural floodplain heights are determined by reasonably frequent, not rare flows. Hoyt and Langbein studied overbank flow at 140 locations in 36 states and found that, on the average, minimum damage stage coincided with the degree of overbank flow that is equaled or exceeded every two years.

Land use near the river is relevant in estimating FWDRB, because of dependence on frequently-flooded land, even though an entire reach may be inundated by say 25 or 50 or 100 year floods. That is, only the land near the river is flooded often enough to affect management behavior in an expected sense.

Furthermore, the assumptions of the SCS model base FWDRB largely on mid-growing-season flood losses, when values subject to loss are highest, but if these occurred as envisioned in the model, one would expect loss avoidance reaction by farmers. Rather, evidence for Michigan suggests that spring flood losses are more likely; their regularity could prompt loss-avoidance reactions in the form of late planting.

Because FWDRB are based largely on without-project damages for relatively frequent floods (say 10 year and smaller floods),[53] it is relevant to ask if these floods are perceived as being any more or less subjectively certain than drainage or irrigation problems.

Definitionally, flooding implies river overflow, whereas impaired drainage relates to high water tables, although in the SCS "abnormal rainfall" construct, stream overflow is not the only cause of flood problems.[54] However, this construct does not appear to be used in

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[53]See footnote 48.

[54]See WPH, sec. 105.0Q;

To differentiate flood prevention from drainage on flat lands, flood prevention is any undertaking for the conveyance, control and disposal of surface water caused by abnormally high direct precipitation stream overflow, or floods aggravated by or due to wind or tidal effects.

SCS evaluations of FWDRB. Crop growth, management decisions and farm income can be affected by excess moisture in the root zone, that is root zone flooding, regardless of whether the water is from river overflow, abnormal precipitation, high water tables or other causes. The distinction has been made important in terms of Federal cost-sharing for PL 566 projects, although the rationale for this remains unclear.

As indicated in chapter 3, FWDRB are only a portion of the project-credited farm income, conceived as loss reductions rather than as gains. Enhancement benefits (EB) and the included farm income are conceived as gains. FWDRB are computed by taking into account the expected annual extents of flooding, with and without the project, on an assumed flood-free situation; of course, the watershed is not flood-free. Similarly, "drainage damage reduction benefits" or "irrigation damage reduction benefits" could be computed as analogs to FWDRB (floodwater damage reduction benefits), assuming well-drained or adequately-irrigated conditions, and taking into account the project effects or loss reductions.

Flood protection, drainage and irrigation are different ways of achieving increased farm income and crop production. The policy-based preferential cost-sharing treatment of flood protection is no assurance that it is the least costly or most effective way of achieving the objectives of increased farm income and output. This preferential treatment does of course work to the advantage of land owners whose water problems can be classified as flood rather than drainage or irrigation problems.

Summary

The small watershed program was begun as part of the public works effort to increase income and employment during the Depression, under the conservation and demonstration projects work of the Soil Erosion Service (SES) in 1933. Emphasis on conservation has since distinguished it, for reasons of SCS interest and possibly of defense in the rivalry with other agencies. The small watershed program has been carried on under five authorities: the 1933 National Industrial Recovery Act, the 1935 Soil Conservation Service Establishing Act (PL 46), the 1936 Flood Control Act (especially the survey approval for the eleven flood prevention watersheds in the 1944 Flood Control Act), the 1953 Pilot Watershed Appropriations (in the Agricultural Appropriations Act), and finally PL 566 of 1954.

Congressional public works committee approval was required under the Flood Control Acts (and still is for 1944 Flood Control Act projects), but is required only for larger PL 566 projects, those with reservoirs exceeding 4,000 acre feet and up to the legislated maximum of 25,000 acre feet. Otherwise, congressional agricultural committee approval is the rule, except for very small PL 566 projects, with reservoirs of less than 2,500 acre feet capacity or with Federal construction cost less than $250,000. These alternative project approval routes are critical, for the House Agriculture Committee will approve projects only if flood prevention is the unmistakeably dominant purpose in terms of Federal construction cost. This is less constraining than it appears at first glance, because there are other cost components, and because Federal cost sharing is higher for flood prevention.

Likewise, the Department of Agriculture's 1967 policy statement does not appear too constraining. Surely, all forms of land use change benefits (LUCB), including the flood prevention sub-category as well as irrigation and drainage as in the past, are now restricted, but only in the sense that they can not dominate other categories of benefits. No restriction is placed on MILUB-FPB or on FWDRB, although MILUB-drainage and MILUB-irrigation must be for "efficiency," rather than to increase surplus crop production.

None of these USDA restrictions apply to projects built in designated, low-income or high-unemployment areas. However, even with special Economic Development Administration (EDA) grants, the rate of Federal cost sharing for a predominantly non-flood prevention PL 566 project is likely to be lower in such an area than for a project elsewhere with flood prevention purposes dominating.

Conservation is of primary interest to the Soil Conservation Service. In the context of small watershed projects the SCS, along with the Forest Service, plans land treatment practices. The Agricultural Stabilization and Conservation Service (ASCS) provides financial assistance for application of these practices. Conservation practices add up to an important investment for small watershed projects, possibly exceeding that for structural measures. Thus, ACP payments can constitute a significant Federal investment, but they are usually ignored in SCS computations of Federal-local cost-sharing ratios, possibly because they are administered by another agency, and possibly because SCS can not guarantee a specified percentage of ACP assistance.

CHAPTER III

THE SCS MODEL

This chapter is concerned with SCS procedures for evaluating agricultural benefits, an emphasis based on that of the PL 566 program.[1] These procedures are formulated into a model that is employed in the sensitivity analysis of chapters 5 and 6; they are further studied in chapters 5-7. This chapter is divided into several sections: (1) an overview; (2) FWDRB and hydrology; (3) FWDRB estimation: computational steps; (4) enhancement benefits estimation: computational steps; (5) project costs; (6) obtaining the benefit cost ratio; (7) data inputs, sources and assumptions; (8) net project effects; and (9) summary.

An Overview

The SCS model's investment criterion may simply be expressed as: B/C = (annual benefits) / (annual costs). This ratio must exceed 1:1 to justify the investment economically, including both Federal and local components, although other criteria must also be met. Project structural costs for the major mainstream project works, are counted

[1]See Appendix, Table 5, for benefit data.

in the denominator of this ratio, but associated costs for the complementary, on-farm and inter-farm works, are deducted from project-credited farm income in the numerator.[2] In the PL 566-SCS context, the watershed is a complete surface drainage basin, usually without any additional upstream drainage area, and legislatively limited to 250,000 acres (about 400 square miles), although projects may be planned to adjoin one another. For the North Branch of Mill Creek project, which will be used as an example in this chapter, the watershed includes 73 square miles, but only 14 square miles are contained in the smaller project benefited (or project benefit or interdependent) area. The project benefited area is in turn subdivided into more or less homogeneous areas, known as economic reaches, on the basis of economic variables, notably cropping patterns and type of agriculture. Several hydrological reaches are typically included in one economic reach.

This presentation of the SCS model will depend extensively on previous work by the author.[3] In systematizing the SCS procedures into

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[2]The idea that benefits should exceed costs is expressed in PL 566, sec. 5, item 1, and traces to the Flood Control Act of 1936, the previous authority for the small watershed program, as discussed in ch. 2. Investment criteria are further discussed in chs. 4 and 7. Relating Federal-local cost sharing (discussed in ch. 2) to the SCS investment criterion, it would appear that this criterion incorporates mixed budget constraints. Both structural and associated capital costs include local and Federal components, assuming consideration of ACP payments in the latter (see cost data for 12 Michigan PL 566 projects, Appendix, Table 1).

[3]John Vondruska, Estimating Small Watershed Project Benefits: A Computer Systematization of SCS Procedures (East Lansing, Mich.: Dept. of Agric. Econ., Michigan State Univ., Feb. 1969), Agric. Econ. Report 120.

Table 3.1. Outline of Benefit Computational Categories, Simplified.[a]

Benefit components calculated as FWDRB and enhancement benefits	Benefit components calculated as net income changes[b]	Benefits calculated as the overall change in net income; no components
1. FWDRB = damage difference due to the project. Damage under either degree of hazard is the loss (in gross income or as an increase in production costs) relative to an assumed flood-free (zero-hazard or no-loss) situation.	1. FWDRB analog is the change in net income due to flood reduction alone, calculated as follows: [Net income, flood-free & poorly-drained conditions] - [Net income, with flooding & poorly-drained conditions]	B [Net income, flood-free & well-drained conditions] - A [Net income, with flooding & poorly-drained conditions]
2. Enhancement benefits are computed for already cropped (MILUB) & previously uncropped (LUCB) land, as shown in column 2; they are due to drainage and flood hazard reduction and related input and output changes.	2. Comment same as in column 1. Compute enhancement benefits as follows: [Net income, flood-free & well-drained conditions] - [Net income, flood-free & poorly-drained conditions]	
Benefits = 1 + 2	Benefits = 1 + 2	Benefits = B - A

[a]Associated cost deductions, adjustments for partial and delayed achievement of the with-project farm income levels, and flood prevention-agricultural water management benefit separations are ignored.

[b]Three levels of net income are computed, but a fourth might lead to a different allocation to the FWDRB analog; the fourth is for well-drained, but flooded conditions.

a model, what is believed to be typical SCS practice has been selected for presentation here, although it should be realized that some procedures are alternatives to others.[4]

Agricultural Benefit Evaluation Alternatives

To evaluate the benefits of the total package of investments and changes associated with a PL 566 agricultural project, one needs an estimate of the change in net farm income. Associated costs are deducted; then an adjustment is made to reflect the partial and delayed achievement of the with-project net income level, and the result becomes the numerator of the SCS benefit cost ratio. See column 3, table 3.1.

However, in addition to distinct and separate cost allocations SCS usually categorizes agricultural benefits into several components, for congressional and administrative approval may depend on the importance of various kinds of benefits as indicated in chapter 2. Compared to the process of estimating overall net-income change benefits, different assumptions are employed if FWDRB (floodwater damage reduction benefits) are estimated separately. Hydrological data on flood occurrence and estimates of crop damage are needed. Initially, flood-free (zero hazard) conditions are assumed, then damages for the expected annual extent of flooding are computed for

[4]See USDA, SCS, Economics Guide (Washington, D.C.; SCS, March 1964). USDA, SCS, Watershed Protection Handbook, Part 1: Planning and Operations (Washington, D.C.; SCS, August 1967). USDA, SCS, National Engineering Handbook, Section 4, Hydrology, Part I: Watershed Planning (Washington, D.C.; August 1964), prepared by Victor Mockus. In common with SCS practice, abbreviations will be used; Economics Guide, WPH, and NEH-4, respectively.

both with and without project hydrological conditions. This method of separating FWDRB and enhancement benefits[5] is shown in column 1 of Table 3.1.

Alternatively, an analog to FWDRB may be computed, along with enhancement benefits, without using hydrological data, using the approach shown in column 2, Table 3.1. FWDRB are a partial estimate of the aggregate of net income changes associated with moving from the crop production levels without the project (high flood hazard and poor drainage conditions for most Michigan projects) to those with the project (for low flood hazard and artificially well-drained conditions). With reduced flood hazards--flood protection is never 100% complete--net returns in addition to FWDRB accrue to farmers in the benefited area who make drainage and other investments, and who otherwise intensify production. However, these several effects are essentially joint economic products or services of the total project investment. Unless a structural improvement is made for surface water control, improvements in sub-surface water control are of no use.

If flooding and impaired drainage are joint problems in the watershed, SCS economists are cognizant that enhancement benefit

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[5]Enhancement benefits incorporate effects that may be attributed to flood prevention or drainage or irrigation or any combination of these. SCS separates them from FWDRB for policy reasons, although this presents some conceptual problems, as indicated in ch. 2. FWDRB are recomputed as a part of redefined enhancement benefits in ch. 7, in a study of 12 Michigan PL 566 projects. Project structural (SCK) and associated (ACK) investments are insufficient to achieve these benefits, for farm managers are assumed to intensify and change land use. That is, ordinary crop inputs (seeds, fertilizer, chemical sprays and other inputs) are assumed to be used at an increased rate; cropping patterns may be changed; and previously uncropped land may be cropped. Of course, SCS deducts the costs of these changes, but their effect on the value of output still requires that they be completed, as assumed by SCS.

separations can't be made through deduction from observed values, especially in flatland areas.[6] As a matter of agency policy a 50:50 division was used for the example project:

Flood prevention benefits (FPB) = FWDRB + 1/2 MILUB + 1/2 LUCB;

Drainage benefits = 1/2 MILUB + 1/2 LUCB.[7]

Even if FWDRB are not separated, such as for watersheds where channel work only is planned (i.e., no floodwater retarding structure, meaning a dam with a temporary, flood-holding reservoir), this policy-based separation may be made if flooding and impaired drainage are joint problems. The relevant computational routine and assumptions are specified in column 3, Table 3.1.

While the necessary discussion is too extensive for this overview, it should be pointed out that, besides separating benefits, SCS procedures may tend to emphasize FWDRB, which are project-credited increments in net farm income only, and may tend to de-emphasize enhancement benefits, which are project-credited farm income, as reduced for partial and delayed achievement of the with-project level of output. This will be considered in more detail in chapter 7. The policy context of the emphasis on FWDRB is given in chapter 2. Crop price, cost, yield and other assumptions are discussed in chapter 6.

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[6]Interview with John L. Okay, economist with the SCS Planning Party in Michigan, June 1969, on the topic of project evaluation in flatland areas, such as Michigan.

[7]For the example project a benefit-based allocation of costs to flood prevention and drainage was used, but current (1970) SCS regulations require separate benefit and cost allocations (see ch. 2).

FWDRB and Hydrology[8]

The SCS Economics Guide prescribes four methods of estimating the economic value of flood reduction; one of these has already been discussed as the net-income change analog of FWDRB, and another is similar, but for areas without defined stream channels. The two remaining methods are alternative ways of estimating FWDRB, the chief difference between them being the way in which the SCS hydrologist determines the expected extent of flooding (in physical terms). In both of these methods, a damage-frequency curve is developed: several convenient probabilities of occurrence are selected, related damage values are computed, and the paired probabilities and damage values are used as plotting points for the continuous curve, with the area under the curve representing expected annual damage.

Plotting-point floodwater damage (FWD)	=	Composite acre value (CAV, typical acre loss value in the floodplain)	x	Plotting-point acreage flooded (AF)

In relating acreage flooded to the selected plotting-point probability of occurrence, the SCS hydrologist uses either:

(1) In the storm-rainfall frequency method, flood data are based on intense rainfall (storm) event frequencies of occurrence, related

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[8]References for this section include:
Harold O. Ogrosky, "Hydrology of Spillway Design; Small Structures--Limited Data," Journal of the Hydraulics Division, ASCE (American Society of Civil Engineers), vol. 90, no. HY3, Proceedings Paper 3914, May 1964, pp. 295-310. Also, see Harold O. Ogrosky and Victor Mockus, "Hydrology of Agricultural Lands," sec. 21 in Ven Te Chow, ed., Handbook of Hydrology: A Compendium of Water Resource Technology (New York; McGraw-Hill Book Co., 1964). Harold Ogrosky is Chief, Hydrology Branch, Engineering Division, SCS, USDA, Washington, D. C. Victor Mockus is the author of the SCS Hydrology Handbook, NEH-4 (see note 4). Also, see Ven Te Chow, "Statistical and Probability Analysis of Hydrological Data," sec. 8 in Ven Te Chow, ed., Ibid.

rainfall data, watershed measurements, and some assumed storm and watershed conditions. This method is widely used by SCS, owing to the lack of historical flood data for most small watersheds.

(2) In the historical method, flood data are based on actual time series data for such variables as peak floodwater discharge rate (measured in cubic feet per second), related water-surface stage (water-surface elevation in feet, as measured at a stream gaging station), and related point rainfall (measured at a nearby recording rain gage for a geographic point, hence the name point rainfall data). Newspaper accounts, actual measurements, and local residents may be called upon for information on the extent of flooding, and this is related to the frequency data for the historical rainfall or stream gage data.

Statistical and probability concepts are used in both methods. The terms probability of occurrence, frequency of occurrence and return period all refer to the same concept, and relate to continuous variables (not discrete variables), and continuous statistical frequency distribution functions (not discontinuous or step functions). For example, for the location of the North Branch of Mill Creek watershed, Michigan, the 25-year return period, 6-hour intense rainfall is 2.90 inches (point estimate), according to the Weather Bureau reference map. In other words, there is a 4% chance (ex ante) during any one year that, for this location, the 6-hour duration intense rainfall will equal or exceed 2.90 inches, where the annual, ex ante probability of occurrence, P = 1 / (return period in years) = 1/25 = 0.04 or 4%. The same concepts may be applied to damage, stage, acreage-flooded, rainfall and other variables. In the storm-rainfall frequency method, intense-rainfall event frequencies are assigned to all of these other variables, given the relationships and assumptions of the SCS model. The selected return periods are the 1, 2, 5, 10, 25, 50 and sometimes 100 year return periods, and the associated annual, ex ante probabilities of occurrence are 1.00, 0.50, 0.20, 0.10, 0.04, 0.02 and 0.01, respectively.

For engineering design purposes, rainfall, stage and discharge amounts of unstated, but implicitly much smaller probability of occurrence are used. Suffice it to say that flood damage estimation and engineering design criteria development are concerned with opposite ends of the flood or rainfall frequency distribution, roughly speaking.[9]

SCS (Storm-Rainfall) Frequency Method

This method employs Weather Bureau intense rainfall event, that is storm rainfall event data, and some rather complex relationships and assumptions to develop peak floodwater discharge rates. More discussion, a critique and sensitivity analysis are presented in chapter 5. Briefly, the process is as follows:

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[9]Special Weather Bureau studies have been commissioned by SCS and the Corps of Engineers for the purpose of studying what is called probable maximum precipitation (PMP) for all parts of the United States. For the location of the North Branch of Mill Creek watershed, the 100-year, 6-hour, point rainfall estimate is 3.50 inches; the 1-year, about 1.50 inches; by interpolation, the author estimated the 1000-year (P = 0.001) amount as about 5.2 inches; but the probable maximum precipitation is 24.0 (twenty four) inches! Design floods for various components of a dam may be based on 25-year, 50-year, 100-year, or some combination of 100-year and probable maximum precipitation (which has no explicit probability assigned, except to say that it is extremely rare). Corps of Engineers designs may be based on what is called a standard project flood which is based on low-probability rainfall, assumed watershed conditions and some observations of actual floods in the region.

Step 1. For the specific watershed location, storm duration, and selected probabilities of occurrence, determine the intense rainfall amounts from the Weather Bureau reference, TP-40.[10] Adjust these point rainfall amounts downward, if the watershed area exceeds 10 square miles, the diminution being proportional to watershed area. The storm duration, in hours or minutes, is equated approximately with the watershed time of concentration (Tc), which is the time required for water to travel from the most distant point along its natural course to the watershed outlet.

Step 2. Using the SCS rainfall-runoff relationship, determine the depth of runoff (in inches) for the several storm rainfall depths. In this step, watershed soils are classified into one of four hydrological soil groups; plant cover types are surveyed; ground slope and other conditions are determined; and, assuming "average" soil moisture levels (AMC-II), and mid-growing season plant growth, the appropriate runoff curve number (CN) is selected. The higher the runoff curve number, the greater the depth of runoff for any given amount of rainfall. In terms of variables, barren land will produce more runoff than heavily pastured or wooded land; coarse (sandy) soil permits more infiltration and

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[10] See U. S. Weather Bureau, Rainfall Frequency Atlas of the United States for Duration from 30 Minutes to 24 hours and Return Periods from 1 to 100 Years, Technical Paper No. 40, by David M. Hershfield (Washington, D. C.: USGPO, May 1961); commonly called TP-40 by SCS. Or see U. S. Weather Bureau, Two to Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States, Technical Paper No. 49, by John F. Miller (Washington, D. C.; USGPO, 1964); commonly called TP-49 by SCS. These and other studies were specially commissioned by SCS.

therefore less runoff than heavy (fine-particle, clay) soil; and wet or frozen ground lets rainfall runoff, while dry ground allows infiltration.

Given the adjusted storm rainfall amounts, go to the proper table or graph for the determined runoff curve number, enter at an indicated rainfall amount and read off the related runoff amount on the other axis. Repeat this process for each of the rainfall amounts.

Step 3. Rate the stream channel and valley at various points along the stream length. For this step, valley and stream-channel cross-sectional profiles, slopes (stream gradients), channel roughness, and other factors are determined by field measurement and inspection. Various rates of flow are compared with the resulting cross sectional channel-valley capacity, and a stage-discharge curve is drawn, showing the water surface stage (elevation in feet) for various discharge rates (in cubic feet per second). Secondly, the stage-area inundated relationship is developed for each hydrological reach.

Step 4. Taking into account the runoff depths in the watershed for the selected series of storms, and the drainage area contributing to each hydrological reach, route each of the resulting floods progressively downstream through all reaches. The water volume (in cubic feet) is represented by a triangular hydrograph's area, with time measured along the triangle's base, and rate of flow measured perpendicularly (vertically) upward from the base (in cubic feet per second). Each hydrological reach has an inflow hydrograph from the reach immediately upstream, and an inflow hydrograph for any sidestreams and local runoff occurring within the reach. The flows are added. The peak rate of flow, that is the rate for the peak of the hydrograph, is of interest according to the unit hydrograph theory, which was developed some 30 years ago.[11]

The peak floodwater discharge rate for each of the selected storms is entered on the stream rating curves for the hydrological reach in question, and the stage is read off. In turn the stage-area inundation curve serves to convert stage to area inundated.

Summary: For estimating FWDRB and flood damages on an expected annual basis, this process yields a series of paired acreages flooded and frequencies of occurrence. While the frequencies are basically for rainfall amounts produced by storms, the relationships and assumptions of the SCS model make them applicable to the acreages flooded and damage amounts.[12] The series of paired frequencies and damage amounts are used to plot the SCS damage-frequency curve for each economic reach and for both the with and without project situations. The differences in damage constitute the FWDRB.

SCS Historical Method (for Time Series Flood Data)

The historical and frequency methods are similar in many respects, as already indicated. Both involve the development of damage-frequency

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[11]For discussions of the methodology, see for example: Chester O. Wisler and Ernest F. Brater, Hydrology, second edition (New York: John Wiley and Sons, Inc., 1959); Daniel W. Mead, Hydrology--The Fundamental Basis of Hydraulic Engineering, second edition (New York: McGraw Hill Book Co., 1950).

[12]These assumptions are studied in Ch. 5.

curves. The basic difference is that in the historical method the paired series of damage values and frequencies are based on hydrological analysis of a time series of historical peak floodwater discharge data for the stream in question, rather than on simulated or synthesized discharge rates and storm-event (intense-rainfall-event) frequencies of occurrence.

Since stream gaging stations are rarely located at ideal spots for a proposed project, data must be developed. The transient nature of economic values, that is their non-homogeneity through a time series of damage data, makes it necessary to develop data for acreages inundated only. As in the frequency method, the damage done by a particular extent of flooding is therefore determined as the product of acreage flooded and the composite acre value (typical acre loss value) in agricultural areas. One difficulty with this method is that the time series of discharge data may not represent homogeneous hydrological conditions, such as if man-made developments have altered the stream, or if the valley plant cover has been changed, such as from forests or other native growth to cultivated crops, or from pasture to row crops, or from agricultural to urban uses.

SCS Modified Historical Method

In practice SCS uses combinations or variants of the storm-rainfall frequency and historical (time series flood data) methods. A simplified historical method is used to estimate non-crop enterprise damages for small watersheds; this relatively unimportant item consists of damage to roads, bridges, railroads, utility lines, buildings, farmsteads and other property in rural areas. Local people, old newspaper accounts, and recorded flood series for nearby streams provide a basis for estimating two or three plotting points for a rough damage-frequency curve.

FWDRB Estimation: Computational Steps

The estimation of agricultural FWDRB (floodwater damage reduction benefits) involves several computational steps that take into account flood, watershed and crop-enterprise variables and assumptions, both hydrological and economic. The computational process leads to a set of flood damage values, each of which is paired with an ex ante probability of flood occurrence. These paired values identify plotting points for the SCS damage-frequency curve (Figure 3.1). In agricultural floodplains, the chief source of flood loss is associated with crop enterprises which rank far below urban residential, commercial and industrial property in terms of potential loss. However, the damage estimation process in an ex ante sense is more complex for crop enterprises, because both the values subject to loss and the probability of flood loss vary during the growing season.

Monthly, 100% Flood Loss Values: Step 1

In this step, two-week loss values are averaged into monthly loss values (accounting for the factor 0.5 in the following algebraic formulation). The initial assumption of 100% flood loss is a computational convenience, and means that the growing crop is completely destroyed (late season losses), or that whatever has been done in the way of cropping practices must be repeated (early season losses). The 100% flood loss (FDM) has the following more specific meaning. Early in the season, replanting costs (RPC) represent the only loss.

Later, a yield reduction occurs, because of late planting, resulting in an added loss. Still later, the gross value of the original crop in the field (P - AVC, price less average variable cost), less avoided costs (AVDC), represents the loss. If a substitute crop can still be planted, the original crop loss is reduced by whatever can be gained in the form of net returns. SCS assumes that about two weeks are required to allow fields to dry sufficiently to permit normal cropping practices to be performed.

The following algebraic formulation is designed for a computer, and all variables have a value specified for each two week period. SCS economists usually perform the computations for without-project conditions only (j = 1, see note 15).

$$FDM_{m,k,j} = \sum_{i}^{2} \{0.5 \times PUNH_{i,m,k} \times [PC_{i,m,k} \times Y_{k,j} \times (P_k - AVC_k) - AVDC_{i,m,k} - PCA_{i,m,k} \times Y_{ks,j} \times (P_{ks} - AVC_{ks}) + RPC_{i,m,k,j}]\}$$

Briefly the variables are defined as follows:[13]

FDM: monthly, 100% flood loss value, per-acre, by crop and crop production intensity level.

PUNH: portion of the crop unharvested

PC: portion of the original crop expected not to yield; see PCA; the complement of PCA for any given crop.

Y; crop yield per acre.

P: crop price per unit of output.

AVC; crop variable cost per unit of output.

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[13]Variable names and subscripts are used consistently in this description of FWDRB and enhancement benefits. Illustrative computations for FDM for the 16 two-week periods in the growing season are shown in Vondruska, pp. 11-12.

AVDC; non-AVC avoided cost per acre.

PCA; portion of the substitute crop expected to yield; see PC.

RPC; replacing cost per acre.

Subscripts are:

m: month; m = 1, ..., 8.

k: crop; for this project k = 1, ..., 17.

ks: substitute crop; numerically, ks ≠ k.

i: one of two two-week periods in a month.

j: watershed condition, either without the project (j = 1), meaning flood-free but poorly-drained conditions, or with the project (j = 2), meaning flood-free and well-drained conditions; the associated production intensity levels. Example project computations of FWDRB assume j = 1.

By-Crop Annual Loss Values: Step 2

In this step the 100% monthly loss values obtained in step 1 as an average of two-week loss values (the averaging process is summarized in Table 3.2) are weighted and adjusted to obtain the annual loss values. Two operations are involved.

Given the 100% monthly flood loss values, the FDM's, it is necessary to adjust for the effect of limited destruction in terms of depths of inundation, of which there are two for the example project. To form an annual per-acre loss value (CFD) for a given depth of inundation (id), crop (k) and level of crop production intensity (j), weight the monthly values (FDM's) by the monthly probability of flood loss occurrence (PM) and the depth adjustment factor (D);

$$CFD_{id,k,j} = \sum_{m} (FDM_{m,k,j} \times D_{m,id,k} \times PM_m).$$

Table 3.2. Loss Value Computations, Corn for Grain.

Item	April	May	June	July	Aug	Sept	Oct	Nov	Annual
Loss									
1	$4.45	7.30	31.70	70.50	70.50	70.50	52.88	3.53	Loss
2	$4.45	22.38	69.16	70.50	70.50	64.86	14.10	-0-	Value, or
Average monthly, 100% loss, FDM value, (loss 1 + loss 2)/2, $'s.									CFD,
	4.45	14.84	50.43	70.50	70.50	67.68	33.49	1.76	for corn,
Depth adjustment factor, D for 0-2 ft., D for 2+ ft. inundation									in
1	-0-	.50	.75	.64	.42	.22	.28	.34	$'s.
2	-0-	.55	1.00	1.00	.80	.55	.60	.70	
Monthly probability of flood loss occurrence, PM.									
	.05	.26	.21	.16	.11	.05	.16	-0-	
Weighted monthly losses; annual losses (CFD's), two depths, $'s.									
1	-0-	1.93	7.94	7.22	3.26	.74	1.50	-0-	22.59
2	-0-	2.12	10.59	11.28	6.20	1.86	3.21	-0-	35.26

Source of original data (modified slightly): USDA, SCS, documentation for the North Branch of Mill Creek watershed, Michigan. Output and input prices are on a projected long term basis, using 1960 data. This data is for corn for grain (corn for silage is treated as a separate crop) on a per-acre basis.

Composite Acre Values: Step 3

The annual loss values, CFD's, for each crop from step 2 are multiplied by the proportion of the floodplain planted to that crop (R), and the arithmetic products for all crops are summed to form the composite acre loss value (CAV):

$$CAV_{id,ir,j} = \sum_{k} (CFD_{id,k,j} \times R_{k,is,ir}).$$

The CAV's are estimated for depths of inundation (subscript id), economic reaches (ir), and levels of crop production intensity (j). Selected planting pattern data (R) are shown in Table 3.3. In computing FWDRB the "situation" subscript ("is" in $R_{k,is,ir}$) is specified in the computer subroutine to obtain the proper cropping pattern, as discussed elsewhere (see Vondruska, pp. 57-58). For the example project, SCS used only the CAV's for the lower level of crop production intensity, necessitating an adjustment in the enhancement benefits (see FWDC in Table 3.7).[14]

Table 3.3 Composite Acre Values, Depth 1.

Crop	Proportion of the flood zone in this crop, $R_{k,is,ir}$		Annual loss value for this crop, $CFD_{id,k,j}$		Summation
Corn	0.082	x	$22.59	=	$1.85
Wheat	0.065	x	$17.17	=	$1.12
Potatoes	0.238	x	$121.16	=	$28.83
Other crops	. . .		. . .		. . .
Total, or composite acre value, CAV				=	$69.72

Source: USDA, SCS, documentation for the North Branch of Mill Creek watershed, Michigan, February 1962. Output and input prices are on a projected long term basis, using 1960 data. For economic reach 1 and depth 1 (0-2 ft. inundation).

Estimated Flood Damages: Step 4

Expected annual floodwater damages (FWD) are computed for both with and without project conditions in the watershed (subscript it), by economic reach (ir), given the composite acre values (CAV's, typical acre loss values) for the floodplain area, and the plotting-point acreage flooded (AF). Damage values are computed for each of the selected probabilities of flood occurrence; the related pairs are used

[14]The computational routine used by SCS to compute FWDC is given in Vondruska, p. 56, and in note 4, ch. 6.

as plotting points for the damage-frequency curve (Figure 3.1). Alternatively, the area under the curve may be approximated as the sum of rectangular areas (Figure 3.1), with one area for each plotting point (ist = 1, ..., 6 for this project):

$$FWD_{it,ir} = \sum_{ist} FW_{ist} \left[\sum_{id} \underbrace{(AF_{id,ist,it,ir} \times CAV_{id,ir,j})}_{\text{Value of damage done by one extent of flooding.}} \right]$$

Damage represents the height of the rectangle, and selected-flood weights (FW's, see Table 3.4), the width.

Adjusted Flood Damages: Step 5

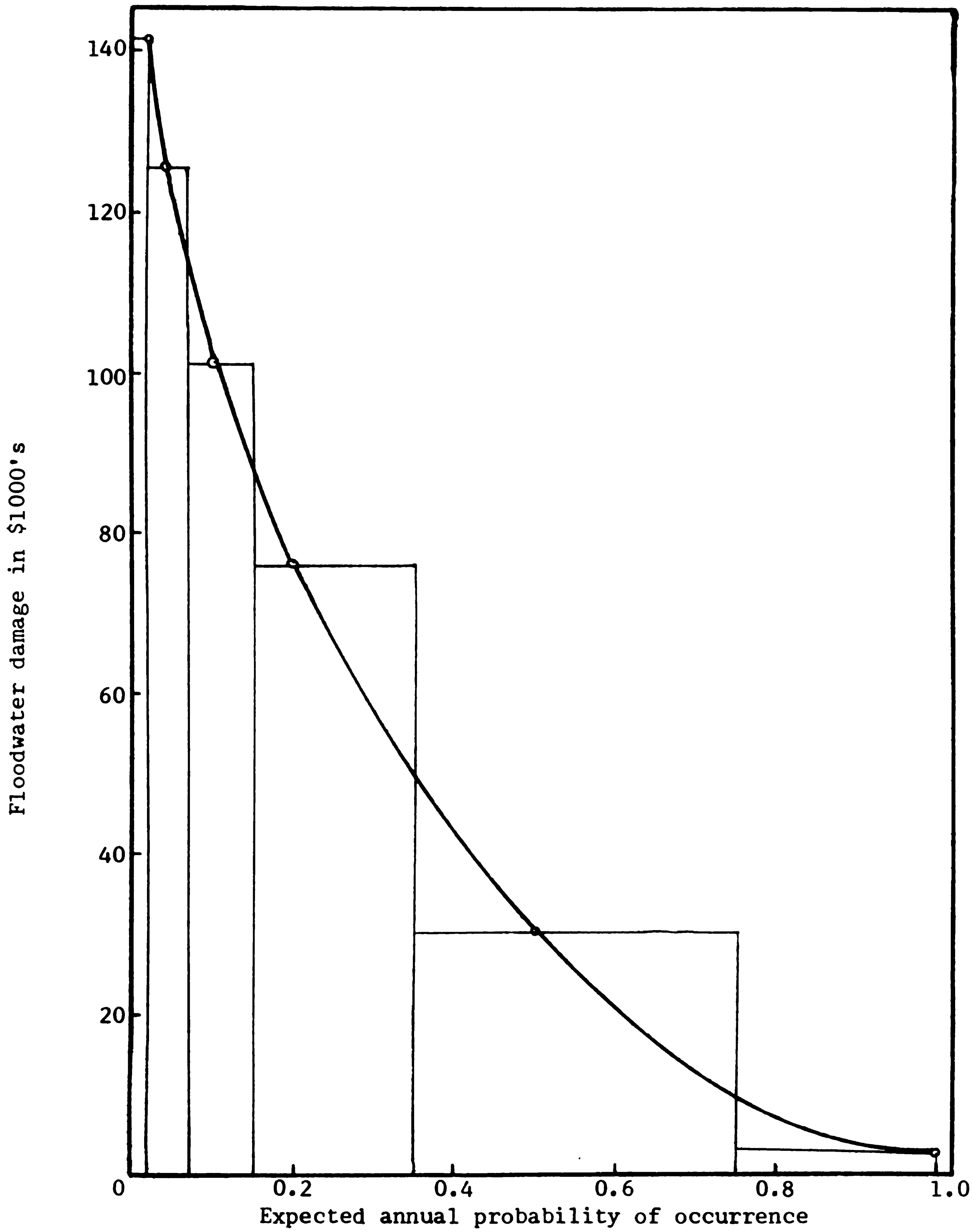
For the example project an upward adjustment was made in the floodwater damage (FWD) value obtained in step 4 to take account of flood recurrence during the growing season and the difference between the largest or most extensive flood and the most damaging flood, as shown in Table 3.4. These adjustments are significant, but an explanation requires more background in hydrology than can be presented here; further discussion is deferred to chapter 5, except to note that there may be implicit as well as such explicit adjustments in the underlying hydrological data.

FWDRB: Step 6

The with-project and without-project flood damages are compared, and the difference represents floodwater damage reduction benefits ($FWDRB_{ir} = FWD_{1,ir} - FWD_{2,ir}$):

Without-project flood damages, reach 1	\$60,055
With-project flood damages, reach 1	5,177
FWDRB	\$54,878

Figure 3.1. SCS Damage Frequency Curve.



Source: Table 3.4.

Table 3.4 Annual Probable Flood Damages.

Flood return period[a]	Annual probability[a]	Acres flooded two depths[b] (AF)	Per-Acre damage or loss, annual (CAV)	Unweighted damage, dollars (AF x CAV)	Rectangular area approx. weight (FW)	Weighted contribution to expected annual damage
50-year	0.02	1863	$69.72	$129888		
		155	74.32	11520		
				$141408	0.02	$2828
25-year	0.04	1702	$69.72	$118663		
		97	74.32	7209		
				$125872	0.05	$6294
10-year	0.10	1430	$69.72	$99700		
		25	74.32	1858		
				$101558	0.08	$8125
5-year	0.20	1080	$69.72	$75995		
		-0-	74.32	-0-		
				$75995	0.20	$15199
2-year	0.50	443	$69.72	$30886		
		-0-	74.32	-0-		
				$30886	0.40	$12354
1-year	1.00	35	$69.72	$2440		
		-0-	74.32	-0-		
				$2440	0.25	$610
Total					1.00	$45410

Adjustment for flood recurrence (1.15) and for the "most damaging versus the largest" floods (1.15), or (1.15 x 1.15 =) 1.3225
Probable annual damage, without-project, adjusted $60055

Source: USDA, SCS, documentation for the North Branch of Mill Creek watershed work plan. Crop input and output prices on a projected long term basis, using 1960 data. Data for economic reach 1, without the project.

[a]Expected annual probability of occurrence (P) equals 1 / (return period, years). Return period and recurrence interval (years) are synonymous. All refer to points along the SCS damage frequency curve (as in Figure 3.1) for the continuous variable, damage. For example, P = 0.04 that damage will equal or exceed $125,872. Probability (P) is sometimes called an exceedance probability by hydrologists.

[b]Depth 1, 0-2 feet inundation; depth 2, inundation over 2 feet.

Given the computation-reducing, simplifying assumptions used by SCS, the model does not take account of managerial-reaction to the reduction in flood hazard on the estimated FWDRB, $54,878. The two estimates of flood damage are for projected, but without-project economic conditions in the watershed, with the difference in damages, that is the FWDRB, being due to the difference in expected annual physical extent of flooding. In other words, the same composite acre values (CAV's, or typical acre loss values) for the floodplain have been used throughout the computational process for the example project.[15]

FWDRB Estimation: Summary

FWDRB (floodwater damage reduction benefits) account for only a part of total project benefits. According to the assumptions used by SCS for the example project, FWDRB do not reflect the economic activity (management) effect of reduced flood hazards, for FWDRB essentially

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[15]Managerial, cropping pattern and other changes for the with-project economic condition of the watershed would result in a higher CAV. Obtaining a second CAV set is quite a computational burden; therefore, SCS approximates the effect in aother way (see note 4, ch. 6 and Vondruska, p. 56, on FWDC computations).

With-project damages (FWD_2) are higher than the $5,177 indicated here, by $1,223). Thus, FWDRB are $1,223 too high. SCS takes this difference into account, not by reducing FWDRB, but by reducing enchancement benefits (see the FWDC deduction, $1,223, in Table 3.7). However, the two deductions are not equivalent in effect on total project benefits; a deduction of $1,223 from FWDRB would have a greater impact, because the deduction from enhancement-benefits net income is actually reduced in subsequent manipulations (in obtaining the data in col. 7 from that in col. 6, Table 3.7).

Given the assumptions about achievement of the with-project level of farm income, as used by SCS, this procedure seems acceptable. However, the SCS assumptions are discussed further in ch. 7.

represent the effect of project-caused differences in the expected annual extent of flooding in purely physical terms on the projected (futuristic), but without-project economic condition of the watershed. Thus, in this case, the same economic values, as reflected in the composite acre values (CAV's or typical acre loss values) for the floodplain, were used by SCS to compute both with and without-project floodwater damages (FWD). Hence, the difference in damages, FWDRB, is due solely to a reduction in the physical extent of flooding.

However, reductions in flooding result in a variety of changes in watershed economic activity, and in increases in net income in addition to those counted as FWDRB. Thus, reduced flood hazards are assumed to cause farm managers to shift to a higher crop production level, and, in the case of Michigan projects, to make additional capital investments in land improvements, such as for drainage, land clearing, field leveling and shifts from non-crop to crop uses of farm land. The net income changes forthcoming are called enhancement benefits, which are in addition to FWDRB, and they will be considered in the next section. The separation of the two is made for policy reasons, and depends upon hydrological data on flooding in the case of FWDRB, although a FWDRB-equivalent could be estimated as a net income change, much like enhancement benefits in terms of computational routine.

Enhancement Benefit Estimation: Computational Steps

As shown in Table 3.1 at the beginning of this chapter, overall project benefits may be obtained as the difference between net farm income with the project and without the project for the affected part of the watershed, but, for policy reasons, SCS separates various categories of benefits. FWDRB (floodwater damage reduction benefits), as discussed in the preceding section, constitute one form of net income improvement, although they are conceived conversely as damage or loss reductions. Of course, notwithstanding the consequent policy implications, project benefits as a whole could be conceived and computed either as damage reductions (due to removal of excess water problems, meaning poor drainage or flood problems, or to the removal of other limitations to intensification crop production or cost reduction), or, alternatively, as enhancements (due to production intensification or cost reduction).

In any event, in the computational and conceptual alternative chosen by SCS for the North Branch of Mill Creek watershed, Michigan, and for most projects in Michigan, FWDRB are computed as the difference in floodwater damages associated with the reduction in the expected annual physical extent (acreage) of river overflow on the watershed in its without-project, but projected (futuristic) economic condition. A net-return-change equivalent of FWDRB may be computed:

$$\left[\begin{array}{l}\text{Net income change}\\ \text{due to flood}\\ \text{damage reduction}\\ \text{alone}\end{array}\right] = \left[\begin{array}{l}\text{Net income under}\\ \text{flood-free \& poorly-}\\ \text{drained conditions}\end{array}\right] - \left[\begin{array}{l}\text{Net income with}\\ \text{flooding \& poor}\\ \text{drainage}\end{array}\right]$$

To FWDRB or the net return equivalent of FWDRB must be added the net return improvements, which SCS calls enhancement benefits (EB) and which are associated with more intensive land use (MILU) of already cropped farm land, and with land use change (LUC) for previously uncropped farm land. This second class of income improvements is, conceptually, the result of management reaction to reduced flood hazards, improved drainage outlets, and new irrigation water supplies, all project effects:

$$\left[\begin{array}{l}\text{Net income change}\\ \text{due to more inten-}\\ \text{sive \& changed}\\ \text{land use}\end{array}\right] = \left[\begin{array}{l}\text{Net income under}\\ \text{flood-free \& well-}\\ \text{drained conditions}\end{array}\right] - \left[\begin{array}{l}\text{Net income under}\\ \text{flood-free \& poorly-}\\ \text{drained conditions}\end{array}\right]$$

An example of the computational details for this second kind of benefits, enhancement benefits, follows.

Computing the Net Return Change: Step 1

Flood hazard reduction makes possible changes in farm practices and investments, both of which can increase net farm income. One subclass of these enhancement benefits (EB) is called more intensive land use benefits (MILUB). For example, flood relief can allow the farmer to switch from lower valued to higher valued crops, apply variable inputs (seed, fertilizer, sprays, etc.) at a higher rate, and perform cropping practices in a more timely fashion. (Planting, spraying, harvesting and other activities must be delayed for days--SCS assumes 14 days--after a flood or heavy rain.). With the flood hazard reduced, drainage outlets provided, and irrigation water supplies provided, all largely at Federal expense via a PL 566 project, managers may find it profitable to drain or irrigate their land, typically taking advantage of ACP payments, another Federal cost (that would not likely be incurred without the PL 566 project).

A second class of enhancement benefits, land use change benefits (LUCB), are computed in a similar fashion, and they relate to land that had been uncropped without the project. The project mainstream works make it economical to clear some land formerly in woods, or to prepare and plow land that was formerly in permanent pasture and idle uses. The value of the former production of LUC land is usually counted as zero.

Net returns are computed using the following formulation. Illustrative computations are shown in Table 3.5, although the order of arithmetic operations is changed.

$$NR_{ir,is} = \sum_{k} \{[Y_{k,j} \times (P_k - AVC_k) - AFC_{k,j}] \times AB_{ir,is} \times R_{k,is,ir}\}$$

Net returns (for is = 1, j=1; for is = 2 or 3, j = 2)	Per-acre net returns for one crop, using the yield and costs sets for either the lower (j = 1) or higher (j = 2) intensity of crop production.	The acreage planted to one crop

The variables are (for details, see Vondruska, pp. 54-58):

NR: net returns

Y: crop yield per acre.

P: crop price per unit of output.

AVC: average variable cost per unit of output.

AFC: non-AVC costs, per acre.

AB: acreage benefited (see Table 3.6).

R: portion of an area planted to a crop (see Table 3.6).

Subscripts are:

ir: economic reach.

is: situation (see Table 3.5).

k: crop.

j: crop production intensity level, either without the project (j = 1), under flood-free and poorly-drained conditions, or with the project (j = 2), under flood-free and well-drained conditions; refers to yields and related costs.

Table 3.5. Obtaining Net Returns (NR), Reach 1.

Crop	Price P	Cost AVC	Unit	Yield Y	Cost AFC	Acres	Output value	Costs	Costs	Total costs	Net returns
	--$/unit--			-per acre-	$		$	$	$	$	$
	1	2	3	4	5	6	7	8	9	10	11
	Computed as:					ABxR	1x4x6	2x4x6	5x6	8+9	7-10
Net returns for MILUB, $NR_{ir,1}$[a]											
Corn	1.40	0.24	bu	65	30.99	327	29757	5101	10134	15235	14522
Potatoes	1.75	0.90	cwt	219	158.28	952	364854	187639	150683	338332	26532
Others						...	. . .			. . .	. . .
Total, without-project NR						3663	1993004			1698669	294335
Net returns for MILUB, $NR_{ir,2}$[b]											
Corn	1.40	0.24	bu	84	39.67	309	36338	6229	12258	18487	17851
Potatoes	1.75	0.90	cwt	293	166.56	970	497368	255789	161553	417352	80016
						...	. . .			. . .	. . .
Total, with-project MILUB NR						3663	2375926			1924491	452435
Net returns for LUCB, $NR_{ir,3}$[b]											
Corn	1.40	0.24	bu	84	39.67	29	3410	585	1150	1735	1675
Potatoes	1.75	0.90	cwt	293	166.56	93	47686	24529	15490	40014	7672
						...	. . .			. . .	. . .
Total, with-project LUCB NR						332	218423			180377	38046

Source: USDA, SCS, documentation for North Branch of Mill Creek watershed, Michigan, dated February 1962; prices are on a projected long term (PLT) basis using 1960 data; reach 1.

[a] $NR_{ir,1}$ assumes flood-free and poorly-drained conditions ($Y_{k,1}$ and $AFC_{k,1}$ data).

[b] $NR_{ir,2}$ and $NR_{ir,3}$ assume flood-free and well-drained conditions ($Y_{k,2}$ and $AFC_{k,2}$ data).

As shown in Table 3.5, without-project net returns are \$294,335. They are the same as MILUB net returns NR_1 and are computed assuming flood-free, but poorly-drained conditions (using Y_1 and AFC_1 data). MILUB net returns NR_2 are \$451,435; they are computed assuming flood-free and well-drained conditions (using Y_2 and AFC_2 data). MILUB net returns are computed for the previously cropped area (3663 acres).

LUCB net returns are computed for the previously uncropped acreage (332 acres); they are \$38,046 (based on Y_2 and AFC_2 data). This assumes a zero value for the output of this land in the without-project condition. The area used (332 acres) was obtained by SCS, as shown in Table 3.6.

Not all of the net return increases developed in this step are assumed to occur; downward adjustments are discussed in step 3.

Table 3.6. Obtaining LUCB Acreage, Economic Reach 1.[a]

Land use	Without-project acreage	Conversion for LUCB	LUCB acreage	With-project acreage
Crops	3663	---------	------	3995 (3663 + 332)
Permanent pasture	50	50 x .90 =	45 } 81	5
Idle farmland	40	40 x .90 =	36 }	4
Farm woods	335	335 x .75 =	251	84
Miscellaneous	160	- - - - - -	- -	160
	4248		332	4248

Source: USDA, SCS, documentation for North Branch of Mill Creek watershed, Michigan, dated February 1962.

[a]In computing $NR_{ir,is}$ for economic reach 1 (ir = 1), $AB_{ir,is}$ = 4248 acres for is = 1 and is = 2 (for MILUB) and $AB_{ir,is}$ = 332 acres for is = 3 (for LUCB). For more details, see Vondruska, pp. 54-58.

Deductions; Step 2

The net returns computed in Step 1 are summarized in Table 3.7, and the change (col. 3) is computed. As previously indicated, enhancement benefits (EB) are partially net benefits, because associated costs are deducted (including both ACK and ACOM components, Table 3.7, col. 4). Recall that no such deduction was made from FWDRB (floodwater damage reduction benefits). Also note that structural costs (both SCK, capital, and SCOM, operation-maintenance components) are counted in the denominator of the SCS benefit cost ratio for evaluating PL 566 projects; these costs will be considered shortly.

The second deduction, FWDC (Table 3.7, col. 5) relates to the assumptions used by SCS in computing FWDRB. For this project FWDRB

Table 3.7. Summary of Net Returns and Enhancement Benefits.

Item	NR_1 $	NR_2 $	NR change $	Assoc. costs $	FWDC $	EB-100% $	Enhancement benefits (EB)[a] $
	1	2	3	4	5	6	7
Computed as:			2-1			3-4-5	
For MILUB on previously cropped 3663 acres							
	294335	451435	157100	35904	985	120211	85707
For LUCB on previously uncropped 332 acres							
Total	-0-	38046	38046	5701	238	- - -	- - -
P,I	-0-	9283	9283	865	58	8360	7106
Woods	-0-	28763	28763	4836	180	23747	17431
Total	294335	489481	195146	41605	1223	152318	110244

Source: USDA, SCS, documentation for North Branch of Mill Creek watershed, Michigan, dated February 1962; reach 1.

[a]Enhancement benefits in column 7 are obtained from the EB-100% data in column 6 as shown in Table 3.8.

were computed using a single composite acre value (CAV, based on Y_1 and AFC_1 data), with these benefits due solely to the project-credited decrease in acreage flooded. Farming at the higher, with-project output levels (based on Y_2 and AFC_2 data) increases with-project damages (FWD_2) above the level assumed in computing FWDRB.[16]

As previously indicated in this chapter, and as will be considered in the sensitivity analysis of chapter 7, these deductions may be interpreted as serving to emphasize FWDRB and to de-emphasize enhancement benefits (EB).

Data for LUCB in Table 3.7 reflect the SCS division (see Table 3.6) into portions for previously uncropped land formerly in pasture and idle uses, and in farm woods.

Obtaining Enhancement Benefits (EB): Step 3

After the enhancement benefit (EB) component of project-credited farm income has been reduced for associated costs and possibly other items, there remains what the author calls EB-100% (the data in Table 3.7, col. 6). However, SCS typically assumes that the with-project level of farm income (NR_2) corresponding to this EB-100% will be only partially achieved over a period of 15-20 years.

In terms of cash flow concepts, a certain portion of the EB-100% annual rate is assumed to accrue in each year in the evaluation period. Typically, SCS assumes that these annual EB cash flows increase in the

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[16]What the author calls FWDC (floodwater damage change) SCS calls "adjustments for remaining flood damage to higher values"; see Economics Guide, ch. 4, pp. 13-14; SCS Table 4.4 there is similar to a combination of the author's Tables 3.5 and 3.7, and includes a deduction for this item.

approximate fashion of a decreasing-rate growth curve (concave from below) over a 15-20 year period, after which they remain constant, usually at less than the EB-100% rate. Actually, SCS uses a linear (rectangular), segmented approximation of a growth curve, with three, straight-line segments for the example project, as shown in Figure 7.3.

For the example project, counting from time zero, when construction is initiated, 35% of the EB-100% rate is achieved by year 5, after a 5-year installation period; an additional 25% by year 10;[17] and another 20% by year 20, for a total of 80% for years 20-50. However, SCS typically assumes "instant installation";[18] thus 35% of the EB-100% rate is achieved at time zero (rather than by year 5), 60% by year 5 (instead of year 10), and 80% by year 15 (rather than by year 20). The differences between EB growth polygons are shown in Figure 7.4.

As described in chapter 7, cash flows are computed by the author for each year. Yet, SCS economists typically do not compute cash flows for each year. Visualizing the series of cash flows as a polygon, as in Figure 7.3, the SCS short-cut involves slicing it into a few horizontal segments, rather than into vertical segments (one vertical segment for each year). A horizontal segment's portion of EB-100% is first computed, then a "discount factor" is applied, along with a

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[17] Data for Mill Creek for MILUB only, see Appendix, Table 2.

[18] See WPH, sec. 102.0211; Economics Guide, ch. 4, p. 13, is more conservative. The effects of discarding this and other related assumptions are studied in chapter 7 for 12 Michigan PL 566 projects.

further adjustment for distant-time segments. An illustration is shown in Table 3.8.[19]

Table 3.8. Computation of EB from EB-100%, MILUB Data.

Item	Time zero	Yrs. 1-5	Yrs. 6-15
EB-100%	$120,211	$120,211	$120,211
Segment %	X.35	X.25	X.20
	$ 42,074	$ 30,053	$ 24,042
Discount	(None)	For 5 yrs.	For 10 yrs.
factor	- - -	X.914	X.818
	$ 42,074	$ 27,468	$ 19,666
Present value of 1, 5 yrs. hence			X.82193
			$ 16,165
Sum ($42,074 + $27,468 + $16,164 =)			$ 85,707

Source: USDA, SCS, documentation for the North Branch of Mill Creek watershed, Michigan, dated February 1962; MILUB data only, for reach 1; interest rate of 4%, evaluation period of 50 years.

The EB amount for MILUB at the bottom of Table 3.8 is the same as that shown in Table 3.7 (col. 7) and Table 3.9.

Enchancement Benefit Estimation: Summary

In the preceding section, floodwater damage reduction benefits were computed as the effect of reduction in the extent of expected annual acreage flooded in physical terms for the without-project, projected (futuristic) economic condition of the watershed. Enhancement benefits, covered in the present section, represent the additional

[19] The discount factor for years 6-15 should be .6431, as computed in accord with Economics Guide, Appendix A, rather than .6723 (.818 x .82193), as shown in Table 3.8. This error affects the author's computations in chapter 6, and many SCS computed benefit cost ratios in Appendix, Table 3. Discussion with John Okay, economist with the SCS Planning Party in Michigan, in October 1970, indicated that this error has been recognized and that it no longer affects SCS evaluations.

income made possible by the complementary: (1) main project works; (2) on-farm and inter-farm (associated cost) works; and (3) management choices which intensify crop production. Project effects on farm income will be reviewed later in this chapter. The process of totalling all of these benefits, allocating them to officially designated purposes, and obtaining the benefit cost ratio will be considered following a brief discussion of project costs.

Project Costs

Project costs have already been discussed in chapter 2, and the presentation here is related to their use in formulating the benefit cost ratio. Structural costs for the mainstream project works are counted in the denominator of the ratio. Associated costs for the complementary on-farm and inter-farm works are deducted only from the enhancement-benefit, project-credited farm income, not from the project-credited farm income counted as FWDRB. Both structural and associated costs have capital and operation-maintenance components; both include Federal and local items of cost, if ACP (Agricultural Conservation Program) payments are counted as an item of Federal cost. Several interest rates are used in the computations.[21]

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[21]Costs for the example project are shown in Table 2.2; those for 12 Michigan PL 566 projects in the Appendix, Table 2, where the example project is cited as the Mill Creek.

Abstracting from Table 2, in the Appendix and from discussion in ch. 7, for the example project, costs were amortized as follows: structural capital costs (SCK), at 2 5/8%, over 50 years; associated capital costs (ACK), on-farm, at 6%, over 50 years; and associated costs (ACK), inter-farm, at 5%, over 50 years. A fourth rate, 4% was used to compute enhancement benefits. The single-rate equivalent of these multiple rates used by SCS is about 3.0%; that is, this rate will produce about the same benefit cost ratio (see Table 7.3, col. 4).

Obtaining the Benefit Cost Ratio

Annual benefit and cost data are summarized and categorized, and the benefit cost ratio is obtained, as shown in Table 3.9. The benefit categorization into flood prevention (FPB) and agricultural water management (AWMB) is made for policy reasons.[22]

It may be useful to discuss the different kinds of FWDRB shown in Table 3.9. Crop and pasture FWDRB are the dominant kind of FWDRB for PL 566 projects in agricultural areas. To obtain total direct FWDRB ($79,787), other FWDRB must be added, and this includes the effect of reduced damages to farm and non-farm buildings, roads, fences, equipment, utility lines, and other property in the flooded area. Indirect FWDRB ($7,979) relate to inconvenience reduction in the area; they are not an estimate of property-damage-reduction benefits, but rather take into account the effect of avoided interruptions in business and service activity.[23]

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[22] Benefits were used by SCS to allocate costs for the example project, but other methods are now used. See chapter 2.

[23] SCS computed indirect FWDRB as 10% of direct agricultural FWDRB; source of percentage, Economics Guide, ch. 3, pp. 31-32. Suggested ranges are as follows; agricultural, 5-10%; residential, 10-15%; commercial and industrial, 15-20%; highways, bridges and railroads, 15-25%; and utilities, 15-20%. For agricultural direct damages, the "percentage probably will be much higher when irrigation and drainage facilities are damaged. The indirect damage should be determined on a case basis when these facilities are involved."

Table 3.9. Summary of Annual Benefits and Costs.

Kind of benefit	Econ. reach 1	Econ. reach 2	Reaches 1 and 2	Econ. reach 3	Project total
Enchancement benefits (EB, from Table 3.7)					
MILUB	$85,707	$47,721	$133,428	$1,056	
LUCB	24,537	40,485	65,022	1,278	
Total	$110,244	$88,206	$198,450	$3,314	
Floodwater damage reduction benefits (FWDRB, from Table 3.4)					
FWD_1	$60,055	$25,223	$85,288	($106)[a]	
FWD_2[b]	5,177	1,632	6,809	(2)	
FWDRB	$54,878	$23,601	$78,479	($104)	
Flood prevention benefits (FPB)					
Crop & pasture FWDRB			$78,479		$78,479
Other FWDRB (property)			1,310		1,310
Subtotal (direct FWDRB)			$79,787		$79,787
Indirect FWDRB (10%)			7,979		7,979
Subtotal (all FWDRB)			$87,768		$87,768
FWDRB attributed to land treatment (estimated as 4% of above subtotal)[b]			3,512		3,512
			$84,256		$84,256
MILUB FPB (1/2 of MILUB above)			$66,714	$518	$67,232
LUCB FPB (1/2 of LUCB above)			32,511	1,139	33,650
Total FPB			$183,481	$1,657	$185,138
Agricultural water management benefits (AWMB, not itemized in work plan)					
1/2 of MILUB above			$66,714	$518	$67,232
1/2 of LUCB above			32,511	1,139	33,650
Total AWMB			$99,225	$1,657	$100,882
Total annual benefits (FPB + AWMB)			$282,706	$3,314	$286,020
Annual structural costs (from Table 2.2)			37,372	3,148	40,520
Benefit cost ratio			7.56/1	1.05/1	7.06/1

Source: USDA, SCS, documentation for North Branch of Mill Creek watershed, Michigan, dated February 1962.

[a]Because economic reach 3 crop and pasture FWDRB were only $104, the SCS economist added them to MILUB.

[b]Positive valued item is deducted.

All FWDRB are totaled ($87,768), and a deduction is made for the estimated effects of the flood-reducing land treatment practices. The basis of this deduction (the 4% shown in Table 3.9) is developed by the SCS Planning Party hydrologist.[24]

The remaining FWDRB ($84,256) are added to MILUB and LUCB to form the numerator of the benefit cost ratio. Before this final summation takes place, MILUB and LUCB are divided into FPB (flood prevention benefit) and AWMB (agricultural water management benefit) categories for policy reasons, although they are joint benefits.

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[24]Information is not available on how the percentage was determined for this project. However, according to John Okay, economist with the SCS Planning Party in Michigan, in an interview on May 15, 1970, these deductions for FWDRB attributed to land treatment are now in the 5-8% range for Michigan PL 566 projects. They are based on estimated changes in the hydrological runoff curve number (CN), but they are not traced through the FWDRB estimation process. (See ch. 5 on CN-FWDRB sensitivity).

The conservation practices in question are less likely to be in the project-benefited lowland area of the watershed (where flooding and impaired drainage are problems) than in the upland area. With respect to computing a benefit cost ratio for them, it should be noted that in addition to the offsite FWDRB attributed to them, there are onsite benefits that include improved soil infiltration and water-holding capacity. As to costs for such a benefit cost ratio, only some of the costs listed in the PL 566 project work plan table could properly be included; such a selection would have to be based on a knowledge of the watershed.

As a matter of policy, SCS does not compute a benefit cost ratio for land treatment practices.

Data Inputs, Sources and Assumptions

Given the SCS procedures for estimating benefits, as systematized into a model here, data inputs are needed to evaluate the project investment. Some data inputs or the methods of obtaining them are specified as a matter of SCS or other Federal policy. A few data inputs are left to the judgment of in-state SCS Planning Party personnel. However, all PL 566 project evaluations are reviewed by a regional-level unit within the agency, known as an Engineering and Watershed Planning Unit (E&WPU). This unit reviews various data and procedures that may have been devised locally; also, the in-state SCS Planning Party may request its advice in advance.

For purposes of the sensitivity analysis of chapters 5-7, some of these data and procedures will be regarded as assumptions that can be changed. Chapter 4 will provide something of a conceptual backdrop for this sensitivity analysis, although much of the discussion is left to later chapters. Selected variations in crop price, cost, yield and other assumptions that affect the computed farm income are studied in chapter 6, and they are supplemented by variations in farm income directly in chapter 7. The approach of chapter 6 is detailed, like that of chapter 5, and both of these chapters use the model of SCS procedures for estimating agricultural benefits as developed in this chapter. Chapter 5 involves a detailed study of the dependence of FWDRB on hydrological assumptions (meaning SCS data and procedures). Chapter 7 is less detailed and takes basic farm income, structural and associated capital cost, and other data as computational model inputs. To avoid duplication, several topics on data and procedures will be deferred to chapters 5-7, except for some comments on data sources.

As explained more completely in chapter 6, crop prices and cost adjustment factors are based on USDA projections, either the PLT (projected long term) set prior to 1967, or the AN (adjusted normalized) set since 1967. Crop input-output ratios are based on various sources, including agricultural colleges and experiment stations, local (in-country) SCS personnel, and growers (for some specialty crops). A list of practices is prepared for each crop and for both input levels. Costs are summarized into two mutually exclusive groups, per unit of output (AVC) and per acre (AFC, non-AVC) costs. As a point of clarification, total production cost per acre = AVC (average variable cost per unit of output) x Y (yield per acre) + AFC (non-AVC, per acre costs). There are two sets of total production costs for each crop, one for each output level.[25]

Judging by SCS practice in Michigan, per-acre AFC costs for the two output levels (with and without project output levels) are based on present technology with adjustments in certain factor-use rates to achieve the projected (futuristic) output levels assumed. That is, both the with and the without project per-acre AFC costs are based on projected (futuristic) output levels.

As explained in chapter 6, base year crop costs are adjusted to conform to the projected crop price levels, but these base year costs

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[25]Costs do not include returns to land or management. The items included in AVC and AFC costs are indicated for the example project in Vondruska, p. 54. However, the categorization of certain cost items may vary among projects and even among crops for a given project, depending on the form in which the data is available.

are developed by pricing the list of inputs just discussed. Input prices are obtained from USDA, the state's agricultural college and experiment station, local suppliers, and farmers.[26]

When the example project was evaluated by SCS (in 1961-62), crop yields for the two (with and without project) output levels were based on an estimate of what was believed to be possible at the time. As shown in Appendix, Table 6, without-project crop yields for this project correspond quite well with Michigan, 1959-63 state-average yields, with some exceptions. Since that time increasingly futuristic yields have been used in PL 566 project evaluations in Michigan. In 1968-70 SCS used yields for the mid-evaluation-period year. These yields are based on projections by Michigan State University (College of Agriculture) and USDA (SCS, ERS and other) in a joint effort. These yield projections are for various soil management groups, under both drained and impaired drainage conditions, and for three dates (1980, 2000 and 2020).

Annual, per-acre yield and cost data are adequate to estimate enhancement benefits or overall net income change benefits, but monthly data are necessary to estimate agricultural FWDRB. SCS uses per unit

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[26]Input price data are contained in: USDA, Agricultural Statistics (Washington, D.C.: USGPO, various years). Also, see W. A. Tinsley, Rates for Custom Work in Michigan, Extension Bulletin E-458, revised (East Lansing, Michigan: Mich. State Univ., Cooperative Extension Service, Feb. 1967).

of output costs (AVC) directly. The per-acre costs (AFC, non-AVC) are divided on a by-month, by-practice basis. Information on planting and harvesting dates, and late-planting yield reductions is necessary. Further information is needed on by-month portions of the crop destroyed (late season, when replanting would not occur) or portions that must be replanted (earlier in the growing season). Because of the amount of computational detail in estimating FWDRB, the SCS economist may depend on previously developed data, such as for another watershed evaluation or for the region (as in the case of some field crop for the example project).[27]

Cropping patterns (R) are developed into several sets for each economic reach, one for FWDRB, another for MILUB and a third for LUCB, but they based on two, farm-survey sets. One farm survey set is for the without project condition, usually represented by present cropping patterns in the reach. The second is for the with project condition, and it is represented by present farmers' intentions, given the degree of protection afforded by the project; thus it differs by economic reach as a function of land and human factors.

Net Project Effects

In this section it will be most convenient to treat FWDRB as being unseparated, that is, as if they were counted as part of EB farm income,

[27]Percentage of crops harvested by 1/2 month intervals, monthly FDM values for several yield levels, and depth destruction factors, all for the southern and northern Cornbelt regions, are given in USDA, SCS, Engineering and Watershed Planning Unit, Milwaukee, Wisconsin, memorandum no. 3 (revised), subject, "Evaluating Floodwater Damages to Crops and Pasture," dated October 23, 1958. Depth destruction factors are available in two sets, either with "duration" (inundation lasts more than 24-30 hours), or without "duration" (inundation lasts less then 24-30 hours); they are based on SCS research.

as is done in one sensitivity analysis variation from the SCS model in chapter 7. In assessing SCS assumptions used to estimate net project effects, it must be recognized that some related questions about definitions exist, but they will be deferred, since the concern here is with project-credited farm income.

For simplicity the SCS model begins with two projected rates (levels) of farm income, input, output and cost. The shift in farm income is made possible by the complementary: (1) mainstream project works (structural capital cost or SCK investments), (2) on-farm and inter-farm works (associated capital cost or ACK investments), and (3) management choices which intensify production. Farm income rates are not projected for all individual years in the evaluation period (t = 1, ..., T, where T = 50 years or T = 100 years). Adjustments of the without-to-with project income difference to reflect partial and delayed achievement during the EB growth period are discussed in chapter 7, but they do not change the underlying SCS assumption of two income levels.

In reality farm income and related rates of input, output and cost change through time. It would be conceptually possible, but much more difficult to specify values for these variables for all years in the evaluation period (t = 1, ..., T). SCS simplifies by picking the rates for one point in time. In the older of the 12 SCS evaluations studied in chapter 7 the selected point in time is closer to project-planning time, but it is closer to the mid year of the evaluation period for more recent SCS analyses. This change in assumption is discussed in chapter 8. Since the two levels of farm income, input, output and cost are for a single point in time they do not reflect changes in underlying general technology. As a point of clarification, Figures 7.3 and 7.4 in chapter 7 may suggest a gradually increasing with-project rate of farm income in contrast with a constant without-project rate of farm income, but this gradual increase has to do with the three complementary project effects, as enumerated in the preceding paragraph. Once these effects are completed, with-project farm income accrues at a constant rate.

Summary

The basically flexible SCS model requires the use of assumed and measured data inputs. The model yields a benefit cost ratio, which is used to justify the investment economically. The focus of this chapter is on the computation of agricultural benefits, which are the main thrust of the small watershed program.

Agricultural primary benefits (not counting secondary and redevelopment benefits) consist essentially of the difference in net income for the aggregate of crop enterprises in the watershed benefited area for with and without project conditions. Projected yields and prices are assumed, and present-technology input combinations are adjusted to provide the projected yield levels. Farmer-indicated output combinations (cropping patterns) are assumed. The SCS model does not optimize these input and output combinations to maximize profits for the farm unit, nor to maximize benefits for the watershed or economic reach.

For policy reasons, SCS estimates separate categories of agricultural benefits; FWDRB (floodwater damage reduction benefits), for the river overflow zone; MILUB (more intensive land use benefits), for already cropped farm land; and LUCB (land use change benefits), for previously uncropped farm land (not for land classified otherwise). Special attention is given to the hydrological and economic aspects of FWDRB. The other two categories, LUCB and MILUB, are simpler to compute and explain.

CHAPTER IV

SOME CONCEPTUAL PROBLEMS

This chapter is intended to provide some conceptual background for the sensitivity analysis of chapters 5-7. The topics include: efficiency criterion rules, social discount rates, and sensitivity analysis--a prologue.

The purpose of the sensitivity analysis of chapters 5-7 is to study the benefit and efficiency-criterion yardstick responsiveness to changes in underlying hydrological, crop enterprise and other variables and procedures. If one cares to question the agency's assumed values for different variables, many of the assumed values can be changed with this technique. Some economists have focused on what they believed to be key variables, changed the values used, and provided some measure of possible "optimism bias" on the part of the agency. Different views on this matter are discussed under the topic of social discount rates; that is, whether discount rates or benefits and costs or both should be corrected. It would seem that both may require correction, if one views agency estimates as being biased, and if in addition the discount rates do not properly reflect one's concept of the social discount rate.

One explanation for the view that agencies provide biased data is that they are concerned with their own survival. Another is that efficiency-criterion yardsticks pay too much attention to the matter of additions to national income, and not enough to the matter of its distribution. Therefore, it is argued that agencies purposefully choose procedures and data to enhance a project's worth as measured by efficiency-criterion yardsticks to compensate for ignored effects in redistributing income.

In the first section of this chapter the matter of efficiency-criterion decision rules or yardsticks is taken up. The discussion of efficiency-criterion yardsticks, the net present value, internal rate of return and benefit cost ratio, often focuses on their usefulness as ranking devices. While ranking is de-emphasized in chapter 7, where 12 Michigan PL 566 projects are studied, the measuring quality of these devices is employed. The matter of budget constraints is also taken up in the discussion of efficiency criteria.

Secondly, the question of social discount rates is explored. Clearly, discount rates are key variables in decision-making models. However, the importance of the topic extends beyond the question of discount rates per se, for economists have used it as a vehicle for discussing risk and uncertainty, rates of return on investment, capital formation, the division of investment between public and private sectors, the allocation of resources between short and long term projects, and the provision for the "future." The whole discussion provides a convenient rationale for studying the sensitivity of investment criteria data to changes in discount rates, as well as other underlying variables, as is done in chapters 5-7.

Efficiency Criterion Rules

For independent projects, in the absence of budgetary or other constraints, A. R. Prest and Ralph Turvey summarize four investment decision rules which are based on the concept of economic efficiency, meaning the maximization of the present value of benefits less costs:

> (1) The NPV (net present value) rule: select all projects where the NPV is positive, that is where the present value of benefits exceeds the present value of costs at the chosen discount rate.
>
> (2) The B/C rule: select all projects where the ratio of the present value of benefits to the present value of costs exceeds unity at the chosen discount rate.
>
> (3) The IRR rule: select all projects where the internal rate of return exceeds the chosen rate of discount.
>
> (4) The constant annuity rule: select all projects where the constant annuity with the same present value as benefits exceeds the constant annuity (of the same duration) with the same present value as costs at the chosen discount rate.[1]

Providing benefits and costs are defined consistently, the IRR equals the chosen rate of discount when the B/C ratio equals one and the NPV equals zero. Prest and Turvey indicate that if the chosen rule is not algebraically the equivalent of these four, either error or a different maximand is involved. The SCS procedural variations from the closest of these four rules, the B/C ratio, will be discussed in chapter 7.

Ranking Divergences

Strictly speaking, the alternative decision rules just expressed are border conditions, meaning that they may be used to select or reject projects. Furthermore, these decision rules apply to independent (not interdependent) projects in the absence of budget constraints. These restrictions may also affect ranking. Does a

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[1]A. R. Prest and R. Turvey, "Cost-Benefit Analysis: A Survey," The Economic Journal, vol. 65, no. 300, December 1965, pp. 683-735, esp. pp. 703-704.

decision rules which are based on the concept of economic efficiency, meaning the maximization of the present value of benefits less costs:

(1) The NPV (net present value) rule: select all projects where the NPV is positive, that is where the present value of benefits exceeds the present value of costs at the chosen discount rate.

(2) The B/C rule: select all projects where the ratio of the present value of benefits to the present value of costs exceeds unity at the chosen discount rate.

(3) The IRR rule: select all projects where the internal rate of return exceeds the chosen rate of discount.

(4) The constant annuity rule: select all projects where the constant annuity with the same present value as benefits exceeds the constant annuity (of the same duration) with the same present value as costs at the chosen discount rate.[1]

higher numerical value of the commonly used benefit cost ratio mean that a project is preferable to another project with a lower ratio? Not necessarily. For ranking, projects with the highest NPV should be chosen. Project ranking by IRR or B/C ratio may be inconsistent with the NPV ranking.

Project ranking inconsistencies among the three prominent yardsticks of efficiency have to do with the nature of the net cash flow streams (b_t - c_t) for various years (t) in the evaluation period, and with the nature of the NPV curve. If the sign of the net cash flow streams reverses more than once, there may be more than one IRR, meaning discount rates for which the NPV is zero and the B/C ratio is unity. If the NPV is plotted vertically on a graph against discount rate on the horizontal axis, the NPV curve will pass through zero (zero NPV) at each IRR (see Figures 7.1 and 7.2).

Presentations by Otto Eckstein; Roland McKean; Jack Hirschleifer, J. C. DeHaven and Jerome W. Milliman; R. C. Jensen; and Robert Marty will be considered in relation to project ranking.

Otto Eckstein demonstrates that IRR and B/C ratio rankings will diverge because of changes in capital intensity, as expressed by the ratio of annual operations costs to initial capital costs (the O/K ratio). Given a numerical B/C ratio for a project, the IRR increases with the O/K ratio, which Eckstein ranges from O/K = 0.1 to O/K = 0.01 to reflect the differences in projects he studied. There is little question that Eckstein has touched upon an important investment characteristic. High capital intensity or long economic life is encouraged by low discount rates, as will be discussed later in this chapter and in chapters 7-8; yet, the matter is not quite that simple.

There are other investment characteristics, besides the O/K ratio, which can be varied to cause ranking divergences between the IRR, B/C ratio and NPV efficiency-criterion yardsticks. They are discussed by Jensen whose work will be taken up shortly.

In comparing Eckstein's analysis with that in chapters 7 and 8, several points should be kept in mind. Eckstein considers only a single-point (time zero) investment, by which he means capital investment and not negative net cash flows. Furthermore, his capital investment (K) excludes associated capital costs (ACK) which for the 12 Michigan PL 566 projects studied in chapter 7 are often more important than the capital costs Eckstein includes.[2] Also, PL 566 projects involve multi-period capital investments, not just single-point (time zero) capital investments. Assumption changes of several kinds, not just for the O/K ratio, can affect a project's present worth and ranking position among other projects. Of course, such changes can also result in project ranking divergences among the NPV, IRR and B/C scaling devices.

Jack Hirshleifer, J. C. DeHaven and Jerome Milliman point to the problem of multiple negative net cash flows as invalidating project

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[2]Otto Eckstein, Water Resource Development (Cambridge, Mass.: Harvard University Press, 1958), pp. 57-60. Accepting the agencies' definition of benefits, which incorporates a deduction for associated costs, Eckstein defines project costs as those that the agencies count in the denominator of the B/C ratio. Thus, his K = SCK and O = SCOM in the author's chapter 7 and Appendix, Table 1, omitting associated costs (capital component, ACK, and operations component, ACOM).

rankings by IRR.[3] This criticism also applies to marginal IRR's which were proposed by Grant (1950) and McKean (1958) for incorporating budget constraints, as will be discussed shortly. Hirshleifer, DeHaven and Milliman also simply change the net cash flows among periods (via borrowing) to criticize the IRR ranking as being inconsistent with the NPV ranking (with NPV computed at a specified discount rate).[4]

A more recent systematic treatment by R. C. Jensen, using the approach of varying net cash flows, suggests that when investment timing, scale and rate vary, the B/C ratio and IRR criteria are not suitable for project ranking. By contrast, ranking by NPV would appear to be suitable on all counts, providing the chosen discount rate is not sufficiently close to a rate for which NPV curves intersect, that is a Fisherian rate of return over cost (RRC). Jensen states:

> If conflicts occur between rankings on these criteria [the IRR and B/C ratio], and on the NPV criterion, then the latter must be accepted as appropriate unless special circumstances are obvious.[5]

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[3]From Descartes rule of signs, one positive IRR may occur for each reversal in the sign of the net cash flow stream ($b_t - c_t$). See R. C. Jensen, "Some Characteristics of Investment Criteria," Journal of Agricultural Economics, vol. 20, no. 2, May 1969, pp. 251-268, with reference to his footnote, p. 254. McKean regards multiple IRR's as being a rare problem in practice, and then only if projects are to be ranked by the IRR, or if for a group of projects a marginal IRR is to be selected, yet with all or some projects having multiple IRR's. See Roland McKean, Efficiency in Government Through Systems Analysis (New York: John Wiley and Sons, Inc., 1958), footnote 9, pp. 90-91.

[5]Jack Hirshleifer, J. C. DeHaven and Jerome Milliman, Water Supply: Economics, Technology and Policy (Chicago: University of Chicago Press, 1960), pp. 166-167.

Because of the IRR's apparent simplicity and acceptance, some of its other weaknesses will be pointed out. Roland McKean discusses the IRR as a rough test, usable only in the absence of interdependent projects and if accepted projects' re-rankings are not of concern. McKean recommends ranking by NPV.[6]

Armen Alchian discussed two peculiar conditions that are apparently necessary for IRR rankings to agree with NPV rankings of projects. One of these is mentioned by McKean with reference to both the IRR and marginal IRR; that is, the net receipts from the project must be invested at their IRR. The second condition is only implicitly recognized by McKean, ambiguously related to the first by Alchian, and analyzed by Jensen (though without reference to the first condition). This second condition is that net cash flows must have identical time paths.[7]

Robert Marty discusses the question of reinvestment of net earnings under the IRR in proposing a solution to the problem of

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[6]McKean, ch. 5; on the IRR, pp. 89-92, 117 and 122. Hirshleifer and Shapiro indicate that lack of interdependence is also a necessary condition for ranking individual projects by NPV, although this does not affect the decision when the rule is to maximize overall NPV for a group of projects. See Jack Hirshleifer and David L. Shapiro, "The Treatment of Risk and Uncertainty," U. S. Congress, Joint Economic Committee, Subcommittee on Economy in Government, The Analysis and Evaluation of Public Expenditures: The PPB System (Washington, D. C.: USGPO, 1969), vol. 1, pp. 505-530, esp. pp. 509-510, including footnote 1, p. 510. Hereafter this collection of papers, along with the companion volume 3, will be cited as JEC-PPBS.

[7]Alchian inconsistently first states that both conditions are necessary, then states that either is sufficient for IRR and NPV rankings to agree; see Armen A. Alchian, "The Rate of Interest, Fisher's Rate of Return Over Costs and Keynes' Internal Rate of Return," American Economic Review, vol. 45, December 1955, pp. 938-943, esp. p. 941.

multiple IRR's and cites other technical problems with the IRR as a project ranking device. Essentially, the IRR ranking assumes reinvestment of net earnings at the IRR, but other assumptions about net earnings may be more relevant. Marty's composite internal rate of return (CIRR) requires that opportunity rates for investment (of positive net cash flows) and borrowing (for negative net cash flows) be specified. These rates need not be the same for all time periods. CIRR and NPV rankings are said to be consistent.[8]

As a final point in this section, J. M. Keynes' IRR or marginal efficiency of capital is not the same as Irving Fisher's rate of return over cost (RRC), even though Keynes and many of his followers mistakenly equated the two. As previously indicated, Fisher's marginal RRC is the rate of discount which equates the NPV for two projects; that is, the rate at which the NPV curves intersect.[9] NPV curves are drawn for 12 Michigan PL 566 projects in Figures 7.1 and 7.2, to which the reader may wish to refer. As shown in these figures, the NPV curve for a project may form Fisherian RRC's by intersecting with the NPV curves for several other projects. Two of these 12 PL 566 projects have NPV curves that intersect twice; that is, their NPV curves form two distinct Fisherian rates of return over cost.

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[8]Robert Marty, "The Composite Internal Rate of Return" (draft copy, early 1970). The author is an associate professor, Department of Forestry, Michigan State University, East Lansing, Michigan.

[9]Alchian. Note: Fisher's computation of advantage involves the comparison of two projects: advantage = $NPV_1 - NPV_2 = (B_1 - C_1) - (B_2 - C_2) = (B_1 - B_2) - (C_1 - C_2)$, stated simply.

Summary: Because of problems of intersecting NPV curves and multiple reversals in the sign of projects' streams of annual net cash flows ($b_t - c_t$), and for other reasons, the three prominent yardsticks of efficiency, the B/C ratio, IRR and NPV may lead to inconsistent project rankings. There may be other complications. In any event, the maximization of net present value (NPV) is the direct expression of the efficiency concept, and ranking projects by NPV, with net cash flows discounted at the selected interest rate, seems to be the least problematical expression of this concept. Jensen found that the B/C ratio and IRR are insensitive to changes in investment timing, rate and pattern changes.

Although project ranking is not emphasized in chapter 7, the NPV sum for 12 Michigan PL 566 projects is used as a key indicator of the effect of various data input and procedural changes. It is supplemented with data on the IRR and agency B/C ratios.

Efficiency Criteria and Budget Constraints

McKean and Eckstein both recognized budget constraints in recommending criteria with which to evaluate government projects. Disregarding the problem of selecting project size and the best combination of interrelated ventures (that is, assuming this has been already done), McKean would present a schedule of projects for various sizes of investment budgets. For each size of investment budget, the net cash flows are discounted at the rate of interest that leaves the lowest ranked project with a zero NPV; this interest rate is called the marginal internal rate of return, that is, the IRR of the marginal project. It should be emphasized that McKean is simply proposing the maximization of present worth (NPV), but at the marginal IRR, rather than at the market rate of interest, which would be relevant in the absence of capital rationing.[10]

McKean poses the question: "What investment budget covering what costs?" He systematically evaluates the effect of three possible budgets. An agency budget constraint would favor projects with relatively large investments by other agencies. A Federal water resource budget constraint would favor projects with large local investments. McKean advocates neither, but rather a national viewpoint in which the "budget" constraint is represented by the present value of negative net cash flows, as discounted by the marginal internal rate of return.[11] To reiterate, the concept of net cash flows ($b_t - c_t$, for years in the evaluation period, $t = 1, \ldots, T$) does not distinguish components. An investment is viewed as a negative net cash flow, not as a capital cost flow. An investment may occur for any year in which cash inflows do not exceed cash outflows. McKean's definition of investment is used in the non-SCS investment criteria of chapter 7. If any "budget" constraint is involved it relates to the aggregation of cash flows for several Federal agencies, local project sponsors and individual beneficiaries. It is as if the nation were a single firm, with negative net cash flows representing demands on a single budget. This is an analogy, not a reality.

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[10]McKean, chs. 5 and 6.

[11]McKean, pp. 76-77, 114-116 and 122.

Hirshleifer, DeHaven and Milliman regard McKean's marginal IRR budget constraint device as inappropriate, for it leaves the size of the budget outside of the realm of efficiency evaluation.[12] They are more sympathetic to Eckstein's budget constraint which is a B/C ratio incorporating Federal expenditures only in the denominator.[13] Citing McKean's troucing of the B/C ratio as being conceptually inappropriate for ranking, since projects should be ranked by net present value (B - C), they argue that so long as calculations are correct this defect is relatively unimportant for project selection. They assert that:

> The major practical difficulties lie in the tendency toward optimistic inflation of B and the underestimation of C, together with the use of an excessively low interest (discounting) rate.[14]

Incidentally, they judge to be conceptually incorrect Eckstein's use of a cutoff ratio for the B/C ratio above unity as a means to offset the agencies' use of low discount rates.[15]

Eckstein's use of the B/C ratio rather than the IRR or NPV relates to the fact that it is the only one of the three that will accommodate his Federal expenditure constraint. Whereas efficiency criteria are based on the maximization of NPV, Eckstein's criterion would maximize the return to Federal investments. However, implementing this

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[12]Hirshleifer, DeHaven and Milliman, pp. 149 and 169-170; McKean, p. 85. However, see McKean, p. 19.

[13]Hirshleifer, DeHaven and Milliman, p. 150; Eckstein, pp. 63-65.

[14]Hirshleifer, DeHaven and Milliman, quoting from p. 138; also, pp. 137-138. McKean, pp. 107-118 (citing Eckstein, footnote 11, p. 110, with reference to Eckstein, pp. 53-65). Also, see Jensen for ranking.

[15]Hirshleifer, DeHaven and Milliman, p. 150; Eckstein, pp. 101-104 and 278; McKean (citing Eckstein), footnote 16, p. 117.

criterion is not as easy as Eckstein implies, at least for PL 566 projects (see chapters 7 and 8), in part because Federal expenditures in the form of ACP (Agricultural Conservation Program) payments may represent roughly 50% of the associated capital costs (ACK), which SCS counts in the numerator of the B/C ratio, as "negative benefits," to use Eckstein's term.[16]

To compute an Eckstein Federal-budget-constraint B/C ratio for PL 566 projects would require: (1) shifting the Federal, ACP-payments portion of associated capital costs (say 1/2 of ACK) to the denominator of the ratio, while leaving related operations costs (ACOM) in the numerator; (2) shifting the locally-financed portion of project structural costs (SCK) and related operations costs (SCOM) to the numerator.[17] Other problems may also arise in trying to compute Federal-budget-constraint B/C ratios for PL 566 projects, as discussed in chapter 8. Briefly, there is the question of the Federal cost involved in providing loans to cover local sponsors' shares of capital costs (both SCK and ACK) and to cover individual farmers' on-farm ACK investments. These loans are provided by FHA (the Farmers Home Administration) for varying costs to the borrower, depending on his

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[16]Eckstein discusses the rationale for the B/C ratio with a Federal expenditure constraint, pp. 53-65; mentions ACP payments, p. 60; but seems to view associated costs as entirely private (non-Federal), p. 65.

[17]Eckstein, p. 65, discusses the inclusion of project structural costs (here SCK) and related operations costs (here SCOM) in the budget constraint, because apparently these are Federal financed for the projects and agencies he considered. It should be pointed out that his description of the Corps B/C ratio fits that now used by SCS for PL 566 projects; his description of USDA procedures, even in the late 1950's appears to be incorrect.

meeting eligibility requirements. Conceivably, some projects may be built entirely on an initial outlay of Federal funds, although loan repayments would reduce the Federal cost eventually.

Hirshleifer, DeHaven and Milliman propose a third approach to project selection under capital rationing, although they do not regard it as a practically important situation, taking the view that government budgets should not be viewed as fixed, but determined by the projects up for consideration. Their algorithm is the comparison of the present value of net benefits (b - c = s) to the rationed budget cost for time zero: V_1/c_o. This fund cost (c_o) is not the same as time zero negative net cash flows as used by McKean; nor is it the conceptual equivalent of "cost" (c) as otherwise used by Hirshleifer, DeHaven and Milliman, that is, any "negative item in the stream of net benefits, as of the date the expenditure is made, ... with no distinction between capital and other costs."[18] Their formula for V_1 is:

$$V_1 = s_1 + s_2/(1 + i) + \ . \ . \ . + s_T/(1 + i)^{T-1}$$

The more usual formula for net present value, as they describe it, assumes an initial capital outlay at time outlay at time zero, but no benefits until the last part of the same period, one year hence.[19,20]

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[18]Hirshleifer, DeHaven and Milliman, p. 158.

[19]<u>Ibid.</u>, on the V/c approach, pp. 160-161, 172-173, and on the NPV rule, pp. 152-153, Definitions: s = b = c; i = the appropriate discount rate; years, t = 1, ..., T.

[20]SCS does not actually compute values using the V formula, but it provided the closest approximation of original SCS benefit cost ratios when used with underlying data for 12 Michigan projects. The two sets of ratios are shown in Appendix, Table 3. SCS procedures are described in chapters 3 and 7.

The fund constraint, their c_o in V_1/c_o, would presumably refer to the planning agency's budget. McKean's comment, already mentioned, applies: this would favor projects with relatively large expenditures by other agencies. However, again, Hirshleifer, DeHaven and Milliman do not regard capital rationing as a relevant criterion ingredient.

Summary: Both McKean and Eckstein regard capital rationing as a relevant constraint in the selection of public investment projects. The question is how to incorporate such constraints. A corollary question relates to the impact of various procedures for incorporating budget constraints on investment decision-making and the pattern of cost-sharing. McKean disgards the agency budget constraints and Federal water resource budget constraints in favor of a national, all-encompassing "budget" constraint which may not be quite the right term. In the national, efficiency-criterion formulation (meaning most conveniently the net present value formulation) for evaluating investment prospects, the "budget" constraint is in a direct sense the present value of negative net cash flows ($b_t - c_t$). This implies that the nation as a whole acts as a single entity. However, net cash flows represent an algebraic summation of positive and negative flows for separate entities, including several Federal agencies, local project sponsors and individual land owners.[21]

While they develop a budget constraint algorithm, Hirshleifer, DeHaven and Milliman basically reject the idea, for they believe that

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[21]McKean, pp. 76 and 115.

not only project selection, but the size of the budget should be open to economic evaluation.[22]

Eckstein's proposal is to include only Federal cost in the demoninator of a B/C ratio to represent the budget constraint. McKean objects to this, preferring the NPV over the B/C ratio as a scaling device. Also, he questions the inclusion of annual recurring operations costs in the denominator of the B/C ratio, because operations costs draw on future years' budgets, whereas capital costs draw largely on the current year's budget.[23]

Social Discount Rates

William J. Baumol outlines three major issues in the choice of social discount rates for the evaluation of public investment projects: (1) the level of aggregate investment by society; (2) the division of investment between the public and private sectors; and (3) the allocation of public investments between short and long term projects.

To increase the aggregate level of investment the government should decrease the yield on long-term government bonds. Baumol regards these yields as virtually riskless and approximately equal to the time preference rate, at least for some people.

Because equality between the social time preference and opportunity cost rates is possible only under restricted conditions, the social time preference rate is inappropriate for use in dividing investment between the public and private sectors. Rather, public investments should be evaluated at the rate the resources could earn

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[22]Hirshleifer, DeHaven and Milliman, p. 161.

[23]Eckstein, pp. 61-65; McKean, pp. 107-118, esp. p. 114.

in the private sector, that is, at the opportunity cost rate (of which Baumol's concept is one of four to be discussed shortly). To draw resources away from the private sector would decrease the addition to national wealth, if earnings are lower in the public sector.

With respect to the term (life) of public projects, it is sometimes argued that private markets will fail to provide enough investment in the future, and that the social rate of discount should therefore be lowered. Baumol cites Gordon Tullock on this point: an increase in long-term investment essentially involves a redistribution of income from the present to future generations, that is, from poorer to richer people, because per capita real incomes are increasing through time. Given a certain amount to invest in public projects:

> We must then ask ourselves whether there are so few diseased, illiterate, underprivileged today, so few persons who excite our sympathy that we must look to the prospectively wealthy future for a source of worthy recipients of our bounty.[24]

High discount rates have the effect of reducing the present value of distant-year benefits, both in terms of dollar amounts and relative to the present value of near-year benefits. Low discount rates have the opposite effect. None of this is to say that the future should be left entirely to the unabated dictates of relatively high private market rates of discount, such as in the case of irreversibilities (for example, poisoning of the soil, biological destruction of a lake, or damming of the Grand Canyon for hydroelectric power). Baumol argues for a public subsidy in these cases, not a low discount rate. Baumol

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[24] William J. Baumol, "On the Social Discount Rate," American Economic Review, vol. 58, September 1968, pp. 788-802, quoting from p. 800.

notes that paradoxically, conservationists are concerned about the future, but low discount rates have been used to justify engineering works which they assert have seriously threatened parklands and recreational areas.[25]

Opportunity Cost Discount Rates

Robert H. Haveman cites the social time preference and the opportunity cost concepts as the two primary contenders for the role of social discount rate.

The opportunity cost position presumes that the returns from public and private investments should be equal, and the four concepts outlined by Haveman differ in terms of the location of private sector displacement, the vehicle of displacement and the means of measurement:

(1) If only business investments are conceived as being displaced, the rate is observed as an average of before-tax returns, using as weights the percentage breakdown of business investments in plant and equipment. The vehicle is real, physical resources.

(2) If business investments and consumptions are conceived as being displaced, the rates may be observed as for (1), preceding. This view admits that the resources may go into either consumption or investment, but Haveman criticizes that business rates of return do not reflect most consumer decisions, thereby missing the locus of social cost. However, Baumol argues that the simplicity of this approach merits attention. He also contends that consumers' views

[25] Ibid., and William J. Baumol, "On the Discount Rate for Public Projects," in JEC-PPBS (see note 6), vol. 1, pp. 489-503.

about foregone consumption are expressed in the returns they provide businesses. Baumol finds the source of funds approach (approach 4 below) as unnecessarily complex.[26]

(3) If both business investment and consumption are viewed as being displaced by government investment, the costs may be estimated as the rate of return on the private investments eliminated by additional government borrowing. Havemen criticizes that the capital market is unimportant in the financing of government, relative to taxes.[27]

(4) If both business investment and consumption are displaced, increased taxes may be viewed as the vehicle. The tax incidence is traced to various parts of the business and household sectors. The observed interest rates are weighted by the relative amounts of spending displaced by the increased taxes. This alternative is preferred by Haveman and he estimates a rate of 7.3% for 1966, providing, incidentally, a wealth of supporting data. He notes that the methodology is similar to that of John V. Krutilla and Otto Eckstein for 1955, although some assumptions differ. Their rate for

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[26]Baumol, "On the Social Discount Rate," esp. pp. 791-793.

[27]Harberger estimates a rate of 10.7% ± 2% for approach 3. He defends the borrowing approach over the taxation approach by arguing that: (1) more taxes mean less borrowing, releasing funds (to the private sector) that have a yield equal to the social cost of government borrowing; (2) the rate would serve as a guide to tax policy decisions. See Arnold C. Harberger, "On the Opportunity Cost of Public Borrowing," in U.S., Congress, Joint Economics Committee, Subcommittee on Economy in Government, Hearings on Economic Analysis of Public Investment Decisions: Interest Rate Policy and Discounting Analysis, 90th Cong., 2d Sess. (Washington, D.C.: USGPO, 1968), pp. 57-65, esp. pp. 62-64.

displacements associated with personal income taxes is 5.29% (comparable to Haveman's estimate); for corporate taxes, it is 5.59%; and 5.44% overall, or 5-6%.[28]

The Social Time Preference Rate

The social time preference position differs from the opportunity cost position. Specifically, the social returns on investments are viewed as being higher than the private returns, and "on the usual logic of the externalities argument the market will not provide enough investment."[29] This position presumes that society is willing to transfer more to future consumers than it is presently doing. However, it is not clear that all proponents argue that public investments should be evaluated at this rate, without consideration of withdrawn resources from the private sector.

Eckstein has since changed his position, but in 1958 he argued that the government could use low discount rates for design and evaluation to preserve the long-time perspective, but only in combination with cutoff benefit cost ratios well in excess of 1. For example, when 2-1/2% rates were used, he suggested a cutoff ratio of 1.4 to reflect a return of 6%.[30] Kenneth Arrow seems to agree with

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[28]Robert H. Haveman, "The Opportunity Cost of Displaced Private Spending and the Social Discount Rate," Water Resources Research, vol. 5, no. 5, October 1969, pp. 947-957. Also, see John V. Krutilla and Otto Eckstein, Multiple Purpose River Development (Baltimore: Johns Hopkins Press for Resources for the Future, 1958), ch. 4.

[29]Baumol, "On the Social Rate of Discount," at p. 799.

[30]Otto Eckstein, Water Resource Development (Cambridge: Harvard University Press, 1958), pp. 90-104, esp. pp. 101-103. Hirshleifer, DeHaven and Milliman, p. 150, do not regard the 1.4 cutoff ratio for a 2-1/2% rate as equivalent to a cutoff of 1 at 6%.

Baumol that the social time preference rate should be used to guide overall investment policy, but that the higher opportunity cost rates should be used to weigh resource transfers from the private sector. This also seems to be M. S. Feldstein's position. Eckstein now appears to be in the opportunity cost camp.[31]

With respect to the nature of the social time preference rate, Feldstein presents a well documented critical review of the literature. He distinguishes the social time preference rate (STP rate) from the STP function and from the social opportunity cost rate. Even if the model's assumptions were fulfilled, the perfect capital market rate would be inappropriate, because the social and private marginal efficiencies of investment differ. Therefore, Feldstein advocates an administratively determined STP rate, recognizing the alternative of determination by public opinion and the difficulties of empirical derivation.

Conceptually, Feldstein adapts the two-period, Fisherian indifference curves for private investment decisions to the public sector, mentioning the many questions and assumptions associated with this transition. In the Fisherian indifference map's consumption space, the STP rate is the first derivative of the STP function; it is:

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[31]Baumol, "On the Social Rate of Discount," p. 799. Kenneth J. Arrow, "Criteria for Social Investment," Water Resources Research, vol. 1, no. 1, First Quarter 1965, pp. 1-8, esp. pp. 2-3. M. S. Feldstein, "The Social Time Preference Discount Rate in Cost Benefit Analysis," Economic Journal, vol. 64, June 1964, pp. 360-379, esp. p. 375. Otto Eckstein, "Interest Rate Policy for the Evaluation of Federal Programs," in U.S., Congress, Joint Economics Committee, Subcommittee on Economy in Government, Hearings on Economic Analysis of Public Investment Decisions: Interest Rate Policy and Discounting Analysis, 90th Cong., 2d Sess. (Washington, D.C.: USGPO, 1968), pp. 50-56.

> determined by the consumption level and growth rate (society's location in the consumption space) and by the slope of the indifference curve at that point (which in turn reflects the social consumption-utility function, the rate of population growth and the pure time preference rate that is applied).[32]

As previously indicated, Feldstein suggests an administratively determined STP rate, but because the government may not be able to make private investment conform with the STP rate, it should take into account the opportunity cost of withdrawing resources from the private sector. Thus, Feldstein does not actually advocate government use of an STP rate, unless in fact this is the earning rate in the private sector.

Gathering the criticisms of the use of an STP rate by government: (1) if investments (meaning the net rate of capital formation) are perceived as being too small, the proper approach is for the government to reduce the interest rate structure, thereby bringing investments into agreement with social time preferences; (2) government projects should be evaluated at the opportunity cost rate in the private sector, for to use a lower rate would be inefficient, taking resources from higher earning potentials for lower earning uses, thereby reducing the net rate of capital formation; and (3) use of low rates (below the private opportunity cost rate) to evaluate government projects encourages investments with a great bulk of their returns in the future. These criticisms do not affect the level of

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[32]Feldstein, p. 374. The STP rate can vary through time, allowing for changes in consumption level, the growth rates of population and consumption, and the pure time preference rate. The STP rate can be zero or negative; that is, it is not necessary to have a positive rate to be consistent with avoidance of zero present consumption.

government activity per se, but rather the type of government investments undertaken.[33]

Inflationary Expectations

Market interest rates incorporate some degree of adjustment for expected inflation, that is monetary depreciation. Lenders anticipate being repaid in dollars that depreciate in value. The Consumer Price Index probably overstates the degree of inflation, because of qualitative changes in commodities and because restoring the purchasing power in a lump sum would leave the consumer better off, assuming relative price changes. Lenders have historically had conservative expectations about price movements. Thus, using the annual rate of change in the Consumer Price Index would overstate market inflation expectations. Hirshleifer, DeHaven and Milliman, writing in 1960 when prices were increasing less rapidly than in 1965-1970, suggested a deduction of 0.5-1.0 percentage point from a market yield rate to account for inflation expectation. More recently, Hirshleifer and Shapiro have argued that the real yield on long-term government bonds has not changed much since then, even though the observed yield has risen from 4% (1959-60) to about 7% (1969-70). The increases are associated with inflation expectations.[34]

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[33]See J. A. Stockfisch, "The Interest Rate Applicable to Government Investment Projects," Congressional Record-Senate, September 22, 1967, pp. S13467-S13472. Also, as already cited, William J. Baumol, "On the Social Rate of Discount," American Economic Review, vol. 58, September 1968, pp. 788-802.

[34]Hirshleifer, DeHaven and Milliman, pp. 142-143. Jack Hirshleifer and David L. Shapiro, "The Treatment of Risk and Uncertainty," in JEC-PPBS (see note 6), vol. 1, pp. 505-530, esp. p. 517, including footnote 7.

Inflation represents a kind of uncertainty to lenders and investors. Morton Kamien advocates using the long-term government bond yield in project evaluations, but reduced to remove lenders' inflationary expectations. Kamien recommends the use of a riskless discount rate in conjunction with benefits and costs adjusted to their expected value, thereby accounting for uncertainty and risk. For the sake of completeness and comparison with other positions, he would compute costs and benefits after taxes. He does not advocate discount rates to approximate a social time preference rate, but takes the position already discussed; that is, overall interest rate structures should be lowered to increase capital formation.[35]

Taxes, Risk and Uncertainty

In contrast with Kamien, Baumol would use market valuations of benefits and costs, but with a "risky" before-tax rate of return on private investments. Baumol discusses various constraints which reduce investment along a conceptual marginal efficiency of investment schedule (curve). In his view, the significance of risk and uncertainty, taxes, and (by implication) inflation is that they constrain the amount of investment, thereby increasing the rate of return.

Countering such economists as Arrow and Samuelson, Baumol argues that both private and public investments are riskless from society's viewpoint. In applying business investment return rates to public projects, the private risk premium should not be removed, for it is socially irrelevant. Rather, he proposes that public projects should

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[35]Morton I. Kamien, "Interest Rate Guidelines for Federal Decisionmaking," Congressional Record--Senate, September 25, 1967, pp. S13543-S13545.

be evaluated at the social opportunity cost of transferring the resources from the private sector, meaning the rate of return on private investment, before taxes.[36]

Optimism Bias and Risk Aversion

Hirshleifer and Shapiro critique various economists' positions on risk and uncertainty, terms which they equate in meaning. Economists may recommend risk (and uncertainty) corrections in benefit and cost data, discount rates, or both. Not all economists distinguish corrections made to offset optimistic bias in the statement of outcomes and other corrections made to offset variability among outcomes. If expected value data are used for benefits and costs, corrections have been made for optimistic bias. Instead, optimistic bias corrections could be incorporated into the selected discount rate. Alternatively, optimistic bias corrections could be applied to both benefit and cost data and to discount rates.

The question then remains, should additional corrections be made for variability of outcome? In other words, is risk aversion a relevant social cost to be considered in public as well as private investment analysis?

Hirshleifer and Shapiro develop their paper by citing two hypotheses that have been advanced to explain the range in observed interest rates. The market imperfections hypothesis explains the range in rates as the effect of market segmentation. The harmony hypothesis explains the range in rates by proposing that different rates are due to the systematic and predictable influence of risk

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[36]Baumol, "On the Social Rate of Discount."

(uncertainty) variations. The two views indicate why some economists have estimated social opportunity cost discount rates by weighing returns to various segments in society, and why other economists choose rates for private investments that are similar in character to the public investment being considered.

Hirshleifer and Shapiro develop a conceptual construct for incorporating risk of the variability of outcome type into the decision making process. Their present certainty-equivalent value (PCEV) rule is the risky situation analog of the more familiar present value (PV) rule. Owing to lack of data in the proper form for application of their PCEV rule, they recommend the use of rates of return for private projects similar in risk class to the public projects being evaluated.[37]

Nevertheless, Hirshleifer and Shapiro use their PCEV concept to criticize the pooling argument which asserts that private risk aversion is a socially irrelevant cost. One explanation of pooling is that borrowing rates for an organization decline with the number of independent projects. Another explanation is that borrowing rates decline if the organization is able to spread the risks (uncertainties) of loss among more lenders.[38] In either case, the Federal Government is perceived as a better pooler than General Motors which in turn is a better pooler than American Motors. The pooling argument leads to the

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[37]As indicated in chapter 8, it is the author's judgment that finding an industry with investments similar in risk class to PL 566 projects may be a difficult task.

[38]Eckstein, Water Resource Development, pp. 95-96, and Kamien, p. S13544, prefer the risk-spreading rather than the independent-project grouping explanation for pooling.

idea of discounting expected-value benefits and costs for public projects at essentially a riskless rate. Hirshleifer and Shapiro show that this may lead to incorrect selections of projects, and advocate use of a risk-incorporating rate.[39]

Agency Practice Relating to Risk

The pooling argument appears to be the rationale for present water resource agency evaluation procedures. While one may question whether or not sufficient corrections have been applied to the benefit and cost data to overcome possible optimistic bias, the use of essentially riskless discount rates suggests that the corrections are assumed to be sufficient. Even so, Hirshleifer and Shapiro and others would use risk-incorporating rates.

The Greenbook of 1950 suggested three possible adjustments for non-predictable risk. While the Greenbook as never really granted official status as a policy instrument, it was authored by a committee operating under the joint sponsorship of the Federal water resource agencies. The Greenbook proposed the following three possible adjustments for non-predictable risk: (1) shorten the evaluation period, (2) include a risk factor in the discount rate, and (3) include safety allowances in the cost and benefit estimates. Eckstein notes that benefits for years before the 50 or 100 year cutoff are viewed as certain, whereas benefits for later years are counted as worthless. He also mentions the contingency allowance, which is part of the agencies' engineering cost estimates for projects.

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[39]Jack Hirshleifer and David L. Shapiro, "The Treatment of Risk and Uncertainty," in JEC-PPBS (see note 6), vol. 1, pp. 505-530.

While agencies seem to rely on these two adjustments for risk, Eckstein concludes his discussion by arguing that discount rate adjustments are preferable.

Hirshleifer and Shapiro indicate that the authors of the Greenbook went quite a way towards advocating discounting at risk-incorporating rates when they proposed use of rates for comparable private risk classes (i.e., "mortgage loans secured by real property or other substantial assets") in evaluating water resource projects.[40]

Federal Water Resources Agency Long-Term Discount Rates

As just indicated, Federal water resource agencies (members of the Water Resources Council) employ an essentially riskless long-term discount rate in evaluting project investments. If SCS practice is any indication, more than one rate may be used in evaluating a project, and still other rates may relate to Federal financing in the way of loans to cover local (non-Federal) capital costs, as discussed in chapters 2 and 8. Be that as it may, these agencies' long-term discount rate for use in project evaluations was increased from 2.5% (1952-60) to 4.875% (fiscal 1970), more or less in line with the general increase in interest rates in the economy.

There is evidence to suggest that the riskless rate used is intended to reflect the effect of a social time preference rate. If this is so, the use of definitions relating to long-term, U.S. Treasury obligations may distract from this policy choice and open the agencies to conceptual criticism. The 2.5% rate was proposed

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[40]Eckstein, Water Resource Development, pp. 81-90; Hirshleifer and Shapiro, in JEC-PPBS (see note 6), vol. 1, pp. 518-519.

in the Greenbook (of 1950, when it was thought that rates would soon return to the lower levels of the 1930's), and continued during most of the years when the Bubdget Bureau's Circular A-47 definition was reputedly in force (1952-1962). However, both Budget Bureau Circular A-47 (of 1952) and Senate Document 97 (of 1962) defined the discount rate in terms of the average coupon (bond face or nominal, not yield) rate paid on long-term U.S. Treasury obligations of 15 or more years in maturity at the time of original issue. For late fiscal 1969 the definition was changed to a yield rate basis for these securities with 15 or more years remaining to maturity. The new rate is not to advance more than 1/4 of a percentage point per fiscal year from the 4.625% base rate for fiscal 1969. In effect this new-definition (post-1968) system of rates relates to the concept of riskless or social time preference rates of discounting. Increases lag behind those for current long-term yields which include inflationary expectations.

Old-definition (pre-1969) rates: As stated in the inter-agency (Water Resources Council) promulgated guidelines, later published by the Senate, the rate of discount or interest for use in evaluating water resource projects:

> shall be based upon the average rate of interest payable by the Treasury on interest-bearing marketable securities of the United States at the end of the fiscal year preceding such computation which, upon original issue, had terms to maturity of 15 years or more. Where the average rate so calculated is not a multiple of one-eighth of 1 percent, the rate of interest shall be the multiple of one-eighth of 1 percent next lower than such average rate.

> This procedure shall be subject to adjustment when and if this is found desirable as a result of continuing analysis of all factors pertinent to selection of a discount rate for these purposes. (Underline added).[41]

This is an average coupon rate for securities whose original maturities were of 15 years. According to Baumol, this rate "has absolutely no relevance for the appropriate discount rate on public projects."[42] Baumol criticized the definitional use of coupon rates rather than yields, and the use of maturity length upon issue rather than the remaining time to maturity.

Furthermore, the old-definition (pre-1969) coupon rates were affected by the critically low, historical rates resulting from the Federal Reserve System's support of government security prices, prior to the Treasury-Federal Reserve accord of 1951.

The agency-defined and current-yield rates or rate ranges are as follows:

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[41] Senate Document 97, para. V-G-2. This definition is essentially the same as that reputedly used by a fewer number of agencies, from 1952 to 1962, under Budget Bureau Circular A-47. See Emery Castle, Maurice Kelso, and Delworth Gardner, "Water Resource Development: A Review of the New Federal Evaluation Procedures," Journal of Farm Economics, vol. 45, no. 4, pp. 693-704, Nov. 1963, esp. p. 702. Also, see Hirshleifer and Shapiro, in JEC-PPBS (see note 6), vol. 1, especially pp. 518-519.

[42] William J. Baumol, "On the Appropriate Discount Rate for Evaluation of Public Projects," in the Congressional Record - Senate, pp. S13692-S13696 September 26, 1967. These comments were entered in the record by Senator William Proxmire; they were given as testimony by Professor Baumol to the Joint Economic Committee Subcommittee on Economy in Government.

Years	Agency rate	Current yield
1952-60	2.5%	2.68-4.08%
1961-68	2.625-3.25% (fiscal years)	3.90-5.25% (calendar years)
1965	3.125%	4.21%
1966	3.125%	4.65%
1967	3.125%	4.85%
1968	3.25%	5.26%
1969	4.625%	6.12%
1970	4.875%	-

Incidentally, the coupon rates for long-term, marketable, Federal-government securities have been limited to 4.25% since World War I; this reportedly prevented the Treasury from issuing new long-term bonds since about 1965.[43]

Federal borrowing costs: While Federal expenditures are financed overwhelmingly by taxes, the Treasury was faced with the prospect that, for example in 1969, 46% of the marketable, interest-bearing public debt would mature within one year, and 73% within five years; thus, debt of $104-166 billion may have required re-financing, even though the net addition (or subtraction) to debt is much, much smaller. To

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[43]On the comparison of agency rates and current yields, see John V. Krutilla, "Efficiency Goals, Market Failure, and the Substitution of Public for Private Action," in JEC-PPBS (see note 6), vol. 1, pp. 279-289, esp. pp. 279-282. Also, see "The 4-1/4 Per Cent Rate Ceiling, Blessing or Curse," Monthly Economic Letter (New York: First National City Bank, May 1969), pp. 52-54. For recent rate data, see for example, U.S. Treasury, Treasury Bulletin (monthly; Washington, D.C.: US GPO, January 1970), pp. 82-85. Rate data provided by the Treasury no longer refer to the 15 year and longer maturity used in the definitions of concern here; therefore, such data are not commonly available; the published series (Ibid., p. 84):

> includes bonds on which the interest income is subject to normal tax and surtax which are neither due nor callable before a given number of years as follows: April 1953 to date, 10 years; April 1952 - March 1953, 12 years; October 1941 - March 1952, 15 years.

measure Federal borrowing costs there are several possible rate series from which to select; for example, Tresury-securities data series had yields in the 6.5% to 8.5% range on December 31, 1969, with long-term bonds being at the lower end of the range.[44]

Among those advocating Federal borrowing costs for use in evaluating water resource projects is former President Lyndon Johnson, who stated in his budget message for fiscal 1969 (given in early 1968):

> The interest rate now being used by Federal agencies in formulating and evaluating proposed water resource projects is significantly lower than the cost of borrowing by the Treasury. To improve evaluating and selection of projects, administrative action is underway to relate this rate more closely to the average estimated current cost to the Treasury of long-term borrowing. The new interest rate, which will be higher than the rate now being used, will be applied in preparing future project evaluation reports. [Underline added.][45]

New definition (post-1968) rates: President Johnson's statement prompted the new (post-1968) definition of the water resource agencies' discount or interest rate which relates to current yields, but in the sense of relationship, not equivalence:

> The interest rate to be used in plan formulation and evaluation for discounting future benefits and computing costs, or otherwise converting benefits and costs to a common time basis, shall be based upon the average yield during the preceding fiscal year on interest bearing marketable securities of the United States which, at the time the computation is made, have terms of 15 years or more remaining to maturity. Provided, however, that in no event shall the rate be raised or lowered more than one-quarter of one percent for any year....

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[44]See U.S. Treasury Department, Treasury Bulletin (monthly; Washington, D.C.: USGPO, January 1970). Remaining lengths to maturity ranged from one month or less to about 28 years (1998 maturity dates) for the cited Treasury securities series.

[45]Quotation taken from an attachment to: USDA, SCS, the Administrator, "New Discount Rates," Advisory WS-19, August 1, 1968.

> The discount rate to be used in plan formulation and evaluation during the remainder of the fiscal year 1969 shall be 4-5/8 percent, except as provided by subsection (d) of this section [for projects well on the way to being approved for construction]. (Underlines added).[46]

Thus, despite the presumed usage of current yields in the new-definition (post-1968) rates, the restriction on year-to-year changes of 0.25 of a percentage point and the fiscal 1969 base rate of 4.625% mean that slow response to market conditions is part of the new rates. The agency-defined rate for fiscal 1970 is 4.875% (the 1969 rate, 4.625% + 0.25%), but it would take the cumulative increments of 7-8 years to reach the current yield rate for mid fiscal 1970 (6.86%, January 1970).

Social Discount Rates--Summary

Discussion of discount rates seems to be the vehicle by which economists have raised many important questions about public investment analysis. It appears that most economists would use the expected value of benefit and cost streams to correct for any optimistic bias in the estimates. Some would then use a risk-free discount rate, corrected for inflationary expectations on the part of bond buyers, that is, a rate less than the current yield on long term government bonds (about 7% in fiscal 1970), perhaps 4%. This approach is not quite the same as that employed by water resource agencies, judging by economists' criticisms of the agencies' benefit, cost and discount rate data.

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[46] Ibid.

Other economists have proposed using a risk-incorporating discount rate in combination with expected-value benefits and costs, for expected values correct only for optimism bias, whereas it is also necessary to take account of private risk aversion. This brings the discussion to a much higher set of rates, based on the concept of the opportunity cost of real resources displaced from the private economy. The vehicle of displacement may be taxes or government borrowing. Some economists consider alternative returns in both consumption and private investment, and others contend that the former are incorporated in the latter. Opportunity cost rate estimates range from about 7 to 15% in the years 1968-69. For comparison, the 4% rate, preceding, would be used with after-tax expected, net values; these higher 7-15% rates, with before-tax expected, net values.

Clearly, risk, taxes and inflation are critical in the selection of rates. Baumol's presentation is lucid. The essence of risk, taxes and inflation (which is a kind of risk) is that they cause businessmen to invest less, thereby raising the rate of return (upward along the marginal efficiency of investment curve). According to Baumol and others, the private opportunity cost rate is the proper rate for discounting public investments, for the use of a lower rate is inefficient, causing the withdrawal of resources from higher to lower earning potentials. It is not possible to equate this rate with the social time preference rate, unless corporate taxes are eliminated and corporate and other business investment subsidies are initiated. Yet, if the government wants to encourage overall investment (the rate of capital formation and growth), this could be done by lowering the whole interest rate structure by the use of monetary, fiscal and debt management policies. Using low interest rates does not encourage or discourage government programs per se, but rather promotes long-lived projects.

This conceptual survey has not been exhaustive. Perhaps not enough attention has been given to the social time preference position which is the apparent rationale for the Federal water resource agencies' (Water Resources Council's) long term discount rate. Regardless of whether a social time preference or an opportunity cost rate is advocated, it is possible to study the effect of changing other variables in the agencies' evaluations, as is done in chapters 5-7, in relation to questions about possible optimism bias. Sensitivity analysis is employed to suggest the responsiveness of estimated benefits and project justification data to selected hydrological, crop enterprise and other data changes.

Sensitivity Analysis--A Prologue

One of the analyses closest in concept to using expected-value benefits is that of Freund and Tolley. They studied one economic reach of an SCS small watershed project for an agricultural area. They assign probabilities to four variables: type of agriculture, degree of damage, number of floods and stage of floods, of which the latter two are hydrological variables.

They argue that the type of agriculture (or cropping patterns in chapters 3 and 6) is the most subjectively determined of these. However, judging by the study of a Michigan project in chapter 5, Freund and Tolley do not give sufficient attention to hydrological assumptions and their effect on estimated benefits. Reviewer Cohee (An SCS agricultural economist) also makes this point. Despite this weakness, Freund and Tolley do present a frequency distribution of project benefits, showing both the expected value of benefits and the variability of benefits.[47]

The key to Freund and Tolley's methodology is being able to assign probabilities to alternative numerical values that critical variables can assume.

In the sensitivity analysis of chapters 5-7, the author does not assign probabilities to variates to form expected values for different variables. In chapter 7 different efficiency-criterion data are used to measure response to selected variable changes. Yet, no effort is made to provide some "unbiased" efficiency-criterion estimate of the worth of various projects. Such efforts are made by Haveman and Freeman.[48] Because the requirements of welfare maximization of the Paretian optimum can not be met, such adjustment efforts should not be viewed as an attempt to correct agency estimates so as to obtain the "true" addition to welfare. Benefit cost evaluations can at best only represent a proximate criterion, the addition to national income, for the theoretical criterion of addition to welfare. Furthermore,

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[47] George S. Tolley and Ralph A. Freund, Jr., "Does the State of the Data Suggest a Program for Modifying Planning and Evaluation Procedures," with comments by Melville H. Cohee and Jack L. Knetsch, in George S. Tolley and Fletcher E. Riggs, editors Economics of Watershed Planning (Ames, Iowa, The Iowa State University Press, 1961), pp. 127-150.

[48] Robert H. Haveman, Water Resource Investment and the Public Interest (Nashville: Vanderbilt University Press, 1965). A. Myrick Freeman, III, "Adjusted Benefit-Cost Ratios for Six Recent Reclamation Projects," Journal of Farm Economics, vol. 48, no. 4, part I, November 1966, pp. 1002-1012.

it can not be argued that a particular project represents the maximal addition to national income, for the selection from among all possible projects has not in fact been made.

Rather, non-agency economists criticize agency benefit and cost estimates in the hopes of eliminating what appear to be errors or biases that overstate program and project worths in terms of the addition to national income. Again, professional judgment is involved.

Operationally, economists usually appeal to market valuations of inputs and outputs for projects. However, this presumes that market prices are the result of forces that approximate those of the perfect competition model, at least in outcome. In other words, this appeal for the use of market prices relates to the ideal of Paretian optimality and welfare maximizing behavior norms. Because real world economic behavior is not in fact any where near being in accord with the competitive model, economists may attempt to correct observed market prices for the more significant divergences from what they believe might obtain under competitive conditions. Nevertheless, if any one of the conditions of the Paretian optimum is not met, there is no proof that adjustments to fulfill other conditions will in fact achieve an optimum. This is the problem of "second best."

The market valuations of interest are those for project benefits and costs. Benefits for PL 566 projects are imputed, because outputs (drainage, irrigation and flood damage reduction services) are not actually sold. The imputed values for benefits consist in part of the increase in farm income attributed to the project. That is, part of the imputed market value of the project is the increase in farm income that farmers would presumably be willing to pay for the project's services. Project costs are usually valued directly by use of engineering estimates for the works of improvement.

This inclusive concept of market valuation does not refer to prices in the narrow sense as used in agency analyses (such as crop prices, factor prices and interest rates). The imputed value of project services is based on a whole range of agency procedures, and observed and assumed data. Crop prices, factor costs, input-ouput ratios (meaning crop yields per acre and factor use rates in the SCS model), hydrological variables, investment timing, benefit and cost patterns of accrual, and a host of other variables form the basis upon which the imputed values for project services rest. The sensitivity of benefits and efficiency-criterion yardsticks to changes in these underlying variables is studied in chapters 5-7.

Again, as previously indicated, the purpose of this sensitivity analysis is not to "correct" agency valuations of project services and costs to some normative, market level, for such a norm does not exist, apart from a good deal of judgment. Still, the numbers used to represent underlying variables are matters over which reasonable men may disagree. If benefits or efficiency-criterion yardsticks are particularly sensitive to certain of these underlying variables, then there is reason to question agency valuations.[49]

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[49]A similar approach was used by Dale W. Adams in studying Michigan PL 566 projects in 1961. See Dale W. Adams, "Benefit-Cost Analysis on Public Law 566 Projects in Michigan," unpublished M.S. thesis (East Lansing, Michigan: Dept. of Agric. Econ., Michigan State Univ., 1961). Dale W. Adams, <u>The Benefit-Cost Analysis--Its Key Variables--and Public Law 566 in Michigan</u>, Agric. Econ. Dept. Publication No. 904 (East Lansing, Michigan: Dept. of Agric. Econ., Michigan State Univ., March 1963).

This process of ranging variables can not be divorced from the broader questions of the meaning and relevance of efficiency criteria, multiple objectives, especially in terms of the equity-efficiency (distribution-level of income) dichotomy, and uncertainty.

CHAPTER V

FWDRB AND HYDROLOGICAL ASSUMPTIONS

The relationship between SCS-estimated agricultural (crop) FWDRB (floodwater damage reduction benefits) and certain underlying hydrological variables will be considered in this chapter. The topical headings are: methodology, antecedent soil moisture, soil moisture and plant-growth density, annual and partial-duration series FWDRB, statistical concepts and FWDRB, point-area rainfall adjustments, monthly loss probabilities (PM's) and summary.

This is the first chapter in which the author's base-estimate approximations of SCS-computed data will be used. The differences are explained in chapter 1. Because the primary purpose of this chapter is to study the effect of hydrological assumptions on estimated agricultural (crop) FWDRB, data for other SCS categories of benefits will not be presented. Base-estimate FWDRB are $75,715 for the Mill Creek project, the example for this chapter, and they account for about one-fourth of the total annual benefits for this project, as shown in Table 6.1 in chapter 6. One rationale for the emphasis on FWDRB alone, without further complicating the discussion with benefit cost ratios and other data, is that FWDRB account for over half of the estimated benefits for PL 566 projects on a national basis (as shown by the data in Appendix, Table 5). As discussed in chapters 2 and 8, FWDRB rank highest in the 1967 Department of Agriculture policy statement of preference, which in turn is in accord with the 1967 House Agricultural Committee statement of preference, although the latter does not use benefits as a weighing mechanism.

In contrast with some measurements of benefit response to underlying assumption changes presented in chapters 6 and 7, FWDRB responses are not given in relative percentage terms in chapter 5. FWDRB responses alone are often given in percentage terms, but the underlying hydrological variables studied in chapter 5 are not amenable to meaningful expressions of change in percentage terms.

Methodology

Prior to considering the sequential process of obtaining FWDRB and the impact of hydrological variables, some adjustment factors should be explained. Recall that the area under the SCS damage frequency curve (Figure 3.1) represents expected annual floodwater damage (FWD). The difference in damages attributed to the project represents FWDRB. For the example project, crops-only FWDRB ($FWD_1 - FWD_2$) are \$75,715 (\$82,285 - \$6,570), using the author's base-estimate data, not the SCS-computed data shown in chapter 3. These data have been adjusted for the combined flood recurrence and "most damaging versus largest floods" effects, using the factor 1.3225 in Table 3.4. These two adjustments are basically hydrological in origin and will be taken up later in this chapter. Another factor is applied to obtain the FWDRB of \$75,715, but it is not hydrological in character. This is the 1.056 factor from Table 3.9, and it is based on an upward adjustment, +10% (a factor of 1.10), to obtain indirect damages and FWDRB, less a subsequent amount, 4%, to remove FWDRB attributed to land treatment measures in the original SCS evaluation. That is, this factor 1.056 is the combined result of these two adjustments (1.056 = 1.100 - 0.04 x 1.100 = 1.100 - 0.044).

Hydrological assumptions affect the computation of agricultural (crop) FWDRB at several points in the sequence of calculations explained in detail in chapter 3. The mathematical formulation for expected annual floodwater damages (FWD) will be repeated here, with only an abbreviated explanation of notation. The adjustments discussed in the preceding paragraph are applied to the FWD and FWDRB data in this chapter, but they are not shown in the following mathematical formulation for FWD. The rectangular-areas method for estimating the area under the SCS damage frequency curve is used. Simply stated, plotting-point damage (the rectangle's height) is multiplied by the variable FW_{ist} (the rectangle's width) to obtain a rectangle's area in the following formulation. This process is shown in Table 3.4. The rectangular-area damage amounts are summed to represent the damage amounts for the area under the SCS damage frequency curve (see Figure 3.1).

Expected annual floodwater damage (FWD) for one economic reach (ir), with or without the project (it) is obtained as:

$$FWD_{it,ir} = \sum_{ist} FW_{ist} \times \underbrace{\sum_{id} (AF_{id,ist,it,ir} \times CAV_{id,ir,j})}_{\text{Estimated damage done by one plotting-point extent of flooding.}}$$

FW is a rectangle width, used to weight the damage done by one plotting-point extent of flooding in obtaining the rectangular-areas approximation of the area under the SCS damage frequency curve. There is one rectangle for each of six plotting points (ist).

AF is the acreage flooded to one depth (id), for one of six plotting points (ist), with or without the project (it) and for one economic reach (ir).

CAV is the composite acre value or typical acre loss value on an annual basis for one depth of inundation (id), one economic reach, and one level of crop production (j). Recall that SCS estimated FWDRB using the without-project level of production (j = 1), necessitating the deduction of FWDC from enhancement benefits, as explained in chapter 3. On the computation of FWDC, see footnote 4, chapter 6.

The computation of the composite acre value (CAV) is as follows:

$$CAV_{id,ir,j} = \sum_{k} R_{k,is,ir} \times \underbrace{\sum_{m} FDM_{m,k,j} \times D_{m,id,k} \times PM_{m}}$$

The equivalent of CAV for one crop, indicated as $CFD_{id,k,j}$ in chapter 3.

R is the percentage of the floodplain area of one economic reach (ir) planted to one crop (k).

FDM is the monthly (m) 100% flood loss value for one crop (k) and production level (j).

D is the depth-destruction adjustment for one month (m), depth of inundation (id) and crop (k). These factors reduce the FDM loss values.

PM is the monthly (m) probability of loss occurrence.

Attention will be focused on the hydrological variables and assumptions underlying the acreage flooded (AF) data. Later in the chapter the monthly probability of flood loss occurrence (PM) will be studied. Consideration will also be given to the adjustments for the "most damaging versus largest floods" and flood recurrence during the growing season, as already mentioned.

It may be argued that cropping patterns (R) are an important variable in determining FWDRB. Freund and Tolley gave primary emphasis to this variable in their study of one economic reach of an SCS small watershed project. They contend that the cropping pattern variable (R, or what they call type of agriculture) is the most "subjectively determined" of the variables upon which FWDRB estimates depend. As indicated in the last section of chapter 4, the author is more inclined to accept reviewer Cohee's comment that hydrological variables may be just as important, and not as "objectively determined" as might appear at first glance. This is not meant as a criticism of SCS hydrologists (indeed, Melville Cohee is an SCS economist and more acquainted with SCS hydrological procedures than the author). Rather, as will be shown later in this chapter, hydrological procedures and assumptions are based on a good deal of judgment, about which there may be differences of opinion.

Before leaving the question of cropping patterns (R, or type of agriculture), it should be noted that R and FWD are probably dynamically related. Assuming other things are equal, high damages (FWD) could affect cropping patterns in such a way as to reduce losses, especially if a succession of years produced high damages. If SCS surveyed the watershed after such a series of events, without-project FWD (FWD_1) would be lower than if SCS surveyed after a series of "dry years," assuming the farmers reacted by shifting to loss-reducing cropping patterns.

Cropping pattern (R) variations are taken up in chapter 6, but in connection with all categories of agricultural benefits for PL 566 projects, not just FWDRB.

The depth-destruction adjustments (D), like cropping patterns (R) in the floodplain, are quasi-economic variables. Discussions with members of the SCS Planning Party in Michigan indicate that they were determined by SCS surveys of farming areas and/or in consultation with college of agriculture soil scientists in various parts of the United States. If the SCS-assumed depth-destruction factors (D) are reduced by applying adjustments of say 0.75, 0.50 and 0.25 (which the author did), FWDRB for the Mill Creek project are proportionately reduced from the base-estimate FWDRB of $75,715.

To summarize, primary focus in this chapter will be on the effect of hydrological assumptions and variables on estimated FWDRB. These assumptions affect the acreage flooded (AF) and monthly probability of flood loss (PM) variables, as shown in the mathematical formulation of floodwater damages (FWD), preceding. Attention will also be given to the adjustments for flood loss recurrence and the "most damaging versus largest floods."

Alternative acreage-flooded sets were obtained by varying the underlying hydrological variables: (1) intense (storm) rainfall amounts or SCS rainfall-runoff relationship curve numbers (CN's) were changed; (2) resulting runoff amounts were compared to the original (SCS) amounts to determine runoff ratios; (3) these ratios were applied to the peak floodwater discharge rates for each hydrological reach; (4) the new discharge rates were located on the stream rating curves (first, the stage-discharge curves, then, the stage-area flooded curves).[1] This was done

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[1]This approach is based on the author's study of USDA, SCS, SCS National Engineering Handbook, Hydrology, Section 4, Part I, Watershed Planning (Washington, D.C., SCS, August 1964), by Victor Mockus, SCS hydraulic engineer; commonly called NEH-4 or the SCS Hydrology Handbook by SCS personnel.

The author discussed this approach with hydrologists on the SCS Planning Party in Michigan, notably with H. A. Amsterburg, who, incidentally is a contributor to NEH-4 (see NEH-4, preface). The runoff ratios (see main text, steps 2-4) should afford acceptable approximations for without-project conditions, which largely determine FWDRB, since FWD_1 far exceed FWD_2. However, with-project conditions may not be so readily approximated: the reservoir spillways are designed for passing only a limited range of discharge, possibly less extreme in departure from the base-FWDRB rate than is suggested by the sensitivity analysis.

for all hydrological reaches, for both with and without project hydrological conditions of the watershed, and for all six plotting points for the SCS damage-frequency curve. The resulting FWDRB and FWD values are assumed to be reasonable approximations.[2] Confidence bounds will be discussed later.

Alternative runoff curve numbers (CN's) and the resulting, associated relative FWDRB levels are shown in Table 5.1 for the example project. This data will provide a basis for subsequent discussion.[3]

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[2]In addition to the limitation mentioned in note 1, the sensitivity analysis approximations are imprecise for: (1) most FWDRB increases above base-estimate FWDRB required extrapolation beyond the SCS-plotted rating curves; (2) project design capacity might be changed with changes in discharge rates, possibly resulting in lower FWDRB than indicated for reduced FWDRB, and higher FWDRB than indicated for increased FWDRB; (3) acreage flooded could not be precisely allocated among depths; (4) managerial responses to flooding are ignored.

[3]Six hour storm-duration rainfall amounts were used, but because of the threshold effect of minimum rainfall necessary to cause runoff and subsequent flooding, the sensitivity analysis changes may not precisely apply for storms of shorter or longer duration. As explained in chapter 3, the SCS hydrologist may adjust the storm rainfall depth so as to equate storm duration and watershed time of concentration, as required by the unit hydrograph theory to provide the proper peak floodwater discharge rates. FWDRB sensitivity would be greater than shown in the table for rainfall amounts for storms of shorter duration, and less for storms of longer duration, because of the threshold effect. However, the error is probably not too great in the 3-9 hour storm duration range. Weather Bureau references provide data for 1, 3, 6, 12, 24 hour and longer duration storms, and SCS would use the closest set.

Table 5.1. Alternative Runoff Curve Numbers (CN's) and Relative FWDRB.

Antecedent (pre-flood) soil moisture level (AMC)		Plant cover development level (at flood time)		
		peak growth	mid-season growth	fallow (or 2/3 barren soil)
	Runoff potential	low	"average"	high
AMC-I	low	CN 36 FWDRB 0.00	CN 52 (54) FWDRB 0.06	CN 72 FWDRB 1.10
AMC-II	"average"	CN 56 (54) FWDRB 0.06	CN 71 FWDRB 1.00	CN 86 FWDRB 2.16
AMC-III	high	CN 75 FWDRB 1.53	CN 86 FWDRB 2.16	CN 94 FWDRB 1.96

Data for the North Branch of Mill Creek watershed, Michigan. Regarding alternative CN's, see NEH-4, the SCS Hydrology Handbook, pp. 10.14-10.15. CN 71 is the SCS estimate. For AMC-II, CN 86 seems reasonable for fallow which is assumed whenever 2/3 or more of the soil is not covered by plant material; see NEH-4, Table 9.1. For AMC-II, peak growth CN = 2 x CN (mid-season) - CN (fallow) = 56. The other CN's were obtained using the conversions among AMC levels, see NEH-4, Table 10.1. CN 54 was used in two cases to reduce the number of computations in place of CN 52 and CN 56, as indicated. FWDRB relative values are based on computer program output; for 1.00, FWDRB = $75,715, for the whole project, an approximation of the original SCS estimate.

The SCS model assumes: (1) monthly probabilities of flood loss occurrence (PM's here) are the same as monthly probabilities of intense rainfall (storm) event occurrence for rainfall sufficient to cause nominal flooding (overbank flow) onto the floodplain;[4] (2) a single level of soil moisture throughout the growing season; (3) a single stage of density of plant growth throughout the growing season. These simplifying assumptions allow loss and storm event frequencies to be equated on an annual basis. Hydrologists have questioned this equating in the

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[4]A nominal flood, meaning a stream rise just sufficient to cause overbank flow, need not be a damaging flood: storm, flood and loss events are not the same in meaning; nor are their probabilities.

engineering design context.[5] There is even more reason to question it in the FWDRB context. This is because the smaller-magnitude rainfall amounts, which are much closer to the critical-minimum (threshold) level necessary to cause nominal flooding, are more affected by hydrological conditions assumed in the SCS model for translating storm into flood data.

The rationale for studying crop damage estimates on a monthly basis becomes apparent from the monthly, unweighted contributions to expected annual FWDRB (FWDRB-M). For the example watershed FWDRB-M range from a low of about $2,100 in November to about $138,000 in July, a range of roughly 70:1.[6] FWDRB-M are obtained by deferring the weighting by the monthly probability of loss (PM): FWDRB = FWDRB-M x PM, summed over all months.[7] The FWDRB-M data are much better indicators of variation between months than the FDM data of chapter 3, because cropping patterns, depth-destruction factors and various manipulations are counted.[8]

Antecedent Soil Moisture

The SCS FWDRB estimates assume that localized, intense (storm) rainfall is the sole cause of flooding during the growing season, if

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[5]See Chester O. Wisler and Ernest F. Brater, Hydrology, 2d ed. (New York: John Wiley and Sons, Inc., 1959), pp. 108 and 332-335.

[6]FWDRB-M data are shown in Table 5.3.

[7]SCS use of a single set of composite acre values (CAV) to represent both with and without project conditions simplified the computations. The FWDC deduction from enhancement benefits is ignored.

[8]Alternatively, the PM (monthly probability of loss) could be adjusted, leaving the FWDRB-M unchanged. The approach selected here seems preferable for illustration purposes.

flood data are synthesized from storm data. Given some watershed and storm measurements and assumptions, rainfall depths can be translated eventually into acreage-flooded sets. One of the simplifying assumptions is that antecedent soil moisture level (AMC) is constant during the growing season.[9] After presenting the sensitivity analysis results, this key assumption will be evaluated using some Michigan data and the concept of joint probability of occurrence (for the requisite soil-soaking rain and the proximate, flood-causing storm).

Sensitivity Analysis Results

As shown in Table 5.1, varying only antecedent soil moisture from the SCS assumed level (AMC-II) significantly affects the estimated FWDRB. While the sensitivity analysis is less precise than is suggested by the use of three significant figures, the level (AMC-I) for the lowest runoff potential results in FWDRB of 0.06 ($4,887) of the base level (index of 1.00, FWDRB = $75,715) for the example project. At the opposite extreme (AMC-III), for the highest runoff potential, FWDRB are 2.16 times the base level (or $163,882). In other words, if all storm-caused floods occurred when runoff potential is low, that is when "watershed soils are dry enough for satisfactory plowing or cultivation" (AMC-I), very little if any flood damage would occur. Hence, FWDRB would be virtually zero. Yet, if all flood-causing storms

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[9]According to hydrologists Wisler and Brater (pp. 319 ff.), intense (storm) rainfall, melting snow, and melting snow plus rainfall cause floods in southern Michigan; the latter two, for "larger" basins; and intense, summer, storm rainfall events for "smaller" watersheds. However, PL 566-size watersheds are not necessarily "small" in this sense. "Size" seems to be more related to causes of floods and the differences among considered hydrological variables than to area per se (see Wisler and Brater, pp. 264 ff.).

occurred when "the watershed is practically saturated from antecedent rains" (AMC-III), damage would be much higher. Project FWDRB would be about twice the SCS estimate for "average" runoff potential (AMC-II).[10]

What Does "Average" Soil Moisture Mean?

SCS soil moisture assumption AMC-II does produce the "average" of the two sensitivity-analysis FWDRB estimates for low (AMC-I) and high (AMC-III) runoff potential, but this is not necessarily an indication that SCS hydrologists explicitly considered such pairs of divergent FWDRB estimates.

Rather, it would appear that the SCS Hydrology Handbook, NEH-4, is primarily concerned with the development of engineering design criteria for project structures. While the so-called "average" (AMC-II) runoff potential may be acceptable in this context, the rather extreme FWDRB sensitivity to runoff potential changes suggests that adoption of AMC-II for estimating FWDRB may be questioned. This will be done by considering: (1) joint probabilities of occurrence for soil-soaking rains and proximate, flood-causing storms; (2) Michigan, 5-day, expected rainfall; (3) flood and storm probabilities.

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[10]The three, alternative SCS antecedent (pre-flood or pre-storm) soil moisture conditions (AMC) are defined in terms of accumulative, five-day, pre-storm rainfall (see NEH-4, the SCS Hydrology Handbook, p. 4.12), data in inches:

AMC	Runoff potential	Rainfall limits, 5-day, pre-storm	
		Growing season	Dormant season
AMC-I	low	less than 1.4"	less than 0.5"
AMC-II	"average"	1.4-2.1"	0.5-1.1"
AMC-III	high	more than 2.1"	more than 1.1"

Dormant season rainfall limits apply when the watershed "soils are not frozen and there is no snow on the ground."

Joint, AMC (Soil-Soaking Rain) and Storm Probabilities: Because crop-enterprise values subject to loss and soil moisture level are variable during the growing season, use of an average soil moisture level may be questioned for estimating FWDRB.[11] Even in the design context, hydrologists Wisler and Brater criticize the "average" soil moisture assumption, for record floods (meaning low-probability, rare or great floods, not those used to estimate FWDRB) accompany high intensity storms only if ground storage (pond, swamp, and other) is filled, and if soil infiltration capacity is low. Wisler and Brater illustrate by supposing that a 50-year storm would occur under such circumstances say 5% of the time. They conclude that the resulting hypothetical flood would be a 1000-year event ($P = 1/50 \times 1/20 = 1/1000$, the ex ante probability of occurrence in any one year).[12]

While FWDRB estimation in the SCS model depends on floods with shorter recurrence intervals, the emphasis on joint probabilities is relevant in this context, as well as in the design-criteria context. SCS uses the antecedent precipitation method of estimating soil moisture. In an analysis of historical storm events, the hydrologist would classify soil moisture as AMC-II for cumulative, 5-day, pre-storm rainfall in the 1.4 to 2.1 inch range.[13]

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[11]See Wisler and Brater, pp. 37 and 108.

[12]See Wisler and Brater, pp. 332 ff.

[13]For SCS cumulative, 5-day rainfall criteria for the three AMC levels, see note 10. Chow indicates that antecedent moisture conditions "cannot be determined directly and used reliably." Thus, an index is used. Chow discusses three, of which the SCS is related to one. See Ven Te Chow, "Runoff," sec. 14 in Ven Te Chow, ed., Handbook of Applied Hydrology (New York: McGraw-Hill Book Co., 1964), specifically sec. 14, p. 6.

If this pre-storm, soil-soaking rain and the proximate, flood-causing storm are independent events,[14] we can at least approximate the effect of their joint probability of occurrence. The result is a leftward shift in the SCS damage-frequency curve. This would effectively reduce FWDRB for the example project to the near-zero range.[15]

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[14]Mead regards the division of hydrological events as being quite arbitrary at times; thus, the soil-soaking rain and the proximate flood-causing storm could be part of the same event; see Daniel W. Mead, Hydrology, 2d ed. (New York: McGraw-Hill Book Co., 1950), p. 237.

[15]FWDRB were not actually computed.

If FWDRB were computed, the damage-frequency curves would be plotted using base-estimate damage amounts, which would be paired with their respective, joint probabilities (for the cumulative, 5-day rainfall requisite for AMC-II, and the proximate, flood-causing storms), whereas SCS uses plotting-point probabilities for storms only.

Based on data given in Weather Bureau reference TP-49 (for 4-day and 7-day duration events, and 2-year recurrence intervals at the minimum), it would seem that the SCS-defined, requisite rainfall for soil moisture level AMC-II (5-day, cumulative rainfall of 1.4 to 2.1 inches) could be that for a 5-day duration, 1-year or 1/2-year recurrence-interval event. However, the recurrence interval relates to the cumulative-frequency-distribution probability of occurrence for sometime, anytime during the year. Assuming that a 1-year event rainfall amount would satisfy the requirement for AMC-II, and that it would be equally likely to occur in any 5-day period, its 5-day probability of occurrence is P = 0.137 (P = 1/1 x 5/365).

Resulting, joint probabilities = $P_{storm} \times P_{AMC\text{-}II\ rainfall}$:

Storm-data plotting-point probabilities		Joint, storm-AMC-II plotting-point probabilities (approximate)	
Recurrence interval	P_{storm}	Recurrence interval	$P_{storm,\ AMC\text{-}II}$
1-yr.	1.00	7-yr.	0.137
2-yr.	0.50	15-yr.	0.0685
5-yr.	0.20	36-yr.	0.0274
10-yr.	0.10	73-yr.	0.0137
25-yr.	0.04	182-yr.	0.00548
50-yr.	0.02	365-yr.	0.00274
100-yr.	0.01	730-yr.	0.00137

AMC-Requisite and Michigan, 5-day Rainfall: Rather than computing the joint probabilities for the required, cumulative, 5-day rainfall for soil moisture level AMC-II and the proximate, flood-causing storms, it is possible to compute Michigan 5-day, expected rainfall, and to choose one of the three SCS soil moisture levels. The plotting-point probabilities would be the same as those used by SCS. However, since Michigan, expected, 5-day rainfall is clearly in the AMC-I soil moisture level's rainfall-criterion range, the damage frequency curves would be shifted downward from the SCS-assumed, AMC-II position, thereby reducing FWDRB to virtually zero (actually $4,887, or 0.06 of the base estimate of $75,715, as shown in Table 5.1).[16]

Flood and Storm Frequencies Compared: Short-period hydrological data for a small (about 10 square mile) agricultural watershed in Michigan suggest that:

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[15]TP-49: U.S. Weather Bureau, Two to Ten Day Precipitation for Return Periods of 2 to 100 years in the Contiguous United States (Washington, D.C.: USGPO, 1964), directed by John F. Miller.

Other Weather Bureau references include: TP-29: U.S. Weather Bureau, Rainfall Intensity-Frequency Regime, Part 5 (of 5)--Great Lakes Region (Washington, D.C.: USGPO, 1960), by David M. Hershfield. TP-40: U.S. Weather Bureau, Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years (Washington, D.C.: USGPO, 1961), by David M. Hershfield.

[16]Michigan annual rainfall is about 31 inches; the 5-day, expected equivalent is 0.4 inch (31 inches x 5/365), which is within the requisite range (1.4 inches or less) for AMC-I (see note 10). Summer precipitation is higher, but not much; mean precipitation, 1905-61, at Lansing Airport, Michigan, is about 3 inches per month, April-November, or about 0.5 inch for a 5-day period (3 inches x 5/30). See Michigan Weather Service and U.S. Weather Bureau, cooperating, Climate of Michigan by Stations, revised ed. (no place listed for publication, the cited agencies, February 1966).

(1) Storms occurring in combination with AMC-I requisite rainfall may produce no stream rise or produce a stream rise lower in frequency than the storm.

(2) Storms occuring in combination with AMC-II requisite rainfall have about the same recurrence interval (frequency) as the stream-flow rise.

(3) Storms occurring in combination with AMC-III requisite rainfall produce flow rises of shorter recurrence intervals (higher probability of occurrence) than for the storms.[17]

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[17]It is the author's contention that storm, flood and loss event probabilities of occurrence differ for purposes of estimating FWDRB. Following citation of an opposite view for the engineering design context, the author will document the main text small watershed data. Bell presents several conclusions, one of which is: "For small watersheds in western U.S.A. the same return period may be assigned to the design flood and the corresponding extreme [low probability] rainfall." See Frederick C. Bell, Estimating Design Floods from Extreme Rainfall, Hydrology Papers, No. 29 (Fort Collins, Colorado: Colorado State University, July 1968), p. 18.

For the results presented in the main text, the following procedures were used. Daily rainfall amounts were assigned frequencies on the basis of TP-40 data for 24-hour duration storms, resulting in possible bias because 24-hour and daily rainfall data may differ. Also, 24-hour data would be inappropriate hydrologically, for in the SCS procedure (see ch. 3), storm duration is set approximately equal to the watershed's time of concentration, and this is about 3 to 6 hours, judging by work by Myers and Kidder. However, only daily rainfall data were available. In any event, the results given in the main text should at least be approximations.

In order to estimate the soil moisture level associated with storms and stream rises, the SCS criteria were used (5-day, cumulative rainfall, see note 10), except for 3 early and late season events (in April, early May and October, exceptions that are consistent with Myers and Kidder's classification procedure).

The studied data are for the Sloan Creek and watershed, near Williamston, Michigan, for a surface drainage area of about 10 square miles. Data sources: (1) U.S. Geological Survey, Magnitude and Frequency of Floods in the United States, Part 4, St. Lawrence River Basin, Geological Survey Water Supply Paper 1677 (Washington, D.C.:

Because the seasonal distribution of floods differ between hydrologically "large" and "small" watersheds (see note 9), data for the geographically larger Red Cedar River basin were obtained for comparison with data for two small watersheds and for 1, 6 and 24 hour storms, as shown in Table 5.2. Significantly, the modal month for floods is March, regardless of drainage area, and August for storms, as will be discussed in more detail in the section on monthly loss probabilities (see Table 5.3). The point to be emphasized now is that the proportion of storm events occurring in the SCS-defined growing season (April-November) is far above that for flood events. This biases the estimated FWDRB upward, for SCS assumes that the probabilities for storms represent flood-loss events (which are not necessarily the same as floods).

With reference to watershed size, SCS would use data for longer duration storms in estimating FWDRB for larger watersheds. However, the proportion of storms occurring in the SCS-defined growing season is reduced only from 1.0 to 0.9, roughly, comparing 1-hour and 24-hour storm data in Table 5.2. The proportion is much lower for the smaller (10-15 square mile) watershed flood data, at 0.5-0.6, and the reduction is more substantial for increases in watershed size, with the proportion being 0.3 for the Red Cedar (at both the 250 and 355 square mile drainage areas). SCS used 6-hour storm data for the example watershed (see note

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[17]USGPO, 1965), by S. W. Wiitala; (2) Michigan, Water Resources Commission, Hydrological Studies of Small Watersheds in Agricultural Areas in Southern Michigan, Reports 1, 2 and 3 (Lansing, Michigan: The Commission, 1958, 1960 and 1968).

Also, see Earl A. Myers and E. H. Kidder, "Practical Hydrological Concepts Concerning a Small, Michigan, Agricultural Watershed," Quarterly Bulletin (East Lansing, Michigan: Michigan Agricultural Experiment Station, Michigan State University), vol. 43, no. 4, pp. 743-750, May 1960.

55, p. 172), which has a drainage area of 70 square miles; 24-hour data would probably be used for the largest of PL 566-project watersheds (up to 400 square miles maximum).

Perhaps even more significant is a comparison of May-September storm and flood cumulative probabilities, for it is during these months

Table 5.2. Growing Season Flood and Storm Probabilities Compared, Michigan Data.

Item	Proportion of all annual events for				Annual
	Apr-Nov	May-Nov	Jun-Nov	May-Sept	sum
Storms, 1-hr., 1-yr.	0.99	0.97	0.88	0.94	1.00
Storms, 6-hr., 1-yr.	0.96	0.92	0.83	0.85	1.00
Storms, 24-hr., 1-yr.	0.91	0.86	0.75	0.74	1.00
Floods, Sloan Creek,					
for 9.34 sq. mi.	0.54	0.54	0.45	0.45	1.00
Event numbers	6	6	5	5	11
Floods, Deer Creek,					
for 16.3 sq. mi.	0.58	0.42	0.33	0.33	1.00
Event numbers	7	5	4	4	12
Floods, Red Cedar,					
for 250 sq. mi.	0.33	0.11	-0-	0.11	1.00
Event numbers	3	1	0	1	9
Floods, Red Cedar,					
for 355 sq. mi.	0.35	0.14	0.04	0.12	1.00
Event numbers	18	7	2	6	52

Sources: TP-29, data summed over months shown, for storms. Flood data are for water years, in order presented, annual maximum events (except as noted, for Red Cedar at 355 sq. mi. only): 1955-65; 1954-65; 1954-61; 1903-30, omitting 1905-10, 22 events, and 1931-62, 30 events with water-surface elevation at or above the defined "flood stage." The flood data sources are as follows: (1) U.S. Geological Survey, Magnitude and Frequency of Floods . . ., Paper 1677 (Washington, D.C.: USGPO, 1965); (2) Michigan, Water Resources Commission, Hydrological Studies of Small Watersheds in Southern Michigan, Report No. 3 (Lansing, Michigan: The Commission, July 1968).

that the damageable values for crops are highest (see FWDRB-M, Table 5.3). For these months, the proportion of storm events ranges from 0.7 to 0.9, roughly, and for floods, from 0.1 to 0.5, as shown in Table 5.2. To reiterate, use of storm instead of flood data overstates the estimated damages and FWDRB, which might be even lower if flood-loss (not just flood) probabilities were used.

Soil Moisture and Plant-Growth Density

Despite the SCS simplifying assumptions of constancy, both soil moisture and plant-growth density (or development) vary during the growing season, affecting runoff potential for any given depth of storm rainfall. Monthly variations in these two variables will be considered later. The present emphasis is on the related runoff-potential levels assumed by SCS for the growing season as a whole. FWDRB for both low and high runoff-potential ranges for both variables are the same, since the same runoff curves were used, as shown in Table 5.1, that is, 0.06 and 2.16 times the base estimate of $75,715.

For the growing season as a whole, it would seem as if the SCS-assumed soil moisture level is high for Michigan conditions, resulting in an overstatement of FWDRB. Low-runoff-potential FWDRB, $4,887, is closer to a "ball-park" figure than the SCS estimate of $75,715. Both estimates are for the mid-growing season plant density level (of runoff potential).

In terms of the "reasonableness" of the SCS-assumed plant growth density level, no evidence has been gathered by the author in order to make some independent assessments.

Yet, changes in crops and/or the use of different degrees of conservation practices (e.g., straight-row versus contoured or contoured and terraced cropping practices) could affect the hydrological runoff potential for a watershed. Such changes relate to the whole growing season and may be expressed in terms of SCS rainfall-runoff relationship curve numbers (CN's). There is room for personal judgment in selecting CN's, and furthermore the CN at the time of project planning may differ slightly, but significantly in terms of FWDRB, from the CN at the time of proposed project construction (5-10 years in the future from planning time), as well as from the time of project operations, for which the SCS evaluation is supposed to be representative.[18]

FWDRB Sensitivity to Slight CN Changes

The example project base estimate for FWDRB, $75,715, relates to CN 71. For CN 72, FWDRB are 10% above the base estimate, and perhaps 40-50% above for CN 75.[19] These FWDRB changes are quite significant when compared to the slight CN changes of only 1 and 3, although the imprecision of the sensitivity analysis estimates must be kept in mind

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[18]The SCS Economics Guide (ch. 3, p. 34) alludes to the use of projected, rather than present conditions for evaluation of project investments, but it offers no procedural advice. The SCS Hydrology Handbook, NEH-4, ch. 12, discusses project effects on runoff potential; the implication is that if field personnel judged these effects to be significant, a different CN could be used to represent with-project runoff potential (thereby affecting FWD_2). Even so, very little in the way of significant projections is involved, for the CN without-project conditions most affects the estimated FWDRB, owing to the dominance of FWD_1 (where $FWDRB = FWD_1 - FWD_2$). Only CN 71 was used for the example project evaluation.

[19]The FWDRB index for CN 75 is 1.53 of the base FWDRB estimate, $75,715, but examination of the underlying plotting-point damage data suggests an upward bias; therefore, the author reduced the FWDRB estimate to 1.40-1.50 of the base estimate for CN 75.

when forming any conclusions. Assuming that these 10% and 40-50% increases are at least approximations, and that comparable CN reductions would similarly decrease FWDRB,[20] it may be argued that SCS field-estimation errors for CN's and/or lack of CN corrections for projected rather than present watershed conditions could lead to FWDRB errors, such that a ±10% or ±40-50% or higher confidence interval should be attached, for this reason alone, disregarding other questions raised in this chapter.

Annual and Partial-Duration Series FWDRB

Terms Defined: Consider an illustrative application of these hydrological-statistical concepts to flood discharge data. All discharge rates above the base level constitute a complete duration series of 150 events. Supposing 50 years of record, the 50 annual maxima constitute an annual-maximum series, a sub-type of extreme value series. The 50 largest events constitute a partial-duration series; or more specifically, an annual exceedance series, since there is an average of one event per year. The events may be selected from a consistent part of all years in the record. The partial-duration series approach is most frequently used for an average of more than one event per year, but the extreme-value series can be, if the time interval is less than one year.[21]

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[20]The comment on reductions is based on examination of the data for several sensitivity analysis runs.

[21]See Chow, "Frequency Analysis," in Chow, ed., sec. 8, pp. 1-42, specifically pp. 19-23.

Sensitivity Analysis Results

It will be assumed that, as available evidence indicates, SCS used plotting-point rainfall data directly from Weather Bureau reference TP-40 to estimate FWDRB for the example project.[22] These data represent a partial-duration series. Had they been converted to represent an annual-maximum series, sensitivity analysis results indicate that FWDRB would have been 37% lower; conversely, the partial-duration series FWDRB are 58% higher than annual-maximum series FWDRB. Only 10-year and more frequent plotting-point rainfall amounts are affected (i.e., the 10, 5, 2 and 1 year amounts), but they represent far more events in the simulated sample than the 25, 50 and 100 year amounts. Also, these 10-year and shorter recurrence-interval rainfall amounts are much closer to the critical or threshold level necessary to cause runoff.[23]

For rainfall amounts closer and closer to the critical minimum or threshold amount necessary to cause runoff, constant percentage reductions in rainfall produce larger and larger relative reductions in runoff. Therefore, application of the partial-duration to annual-maximum series conversions to rainfall data is a critical assumption of the sensitivity analysis, for application to any other variables in the chain of computations leading from rainfall to flood damage would

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[22] The hydrologist who worked on the example project evaluation (in 1961) was not with the SCS Planning Party in Michigan when the author examined the evaluation documentation. The author's assumption seems reasonable based on discussion with other members of the Party. No conversion is shown in the documentation.

[23] Conversion factors are from TP-40 for 10, 5 and 2 year data, and based on TP-40 and Chow, sec. 8, p. 22, for 1 year data. The factors are: 0.99, 0.96, 0.88 and 0.70, respectively. The annual-maximum series FWDRB estimate is $47,845.

produce less significant FWDRB reductions. Application of the same conversion factors to the plotting-point damage amounts for the SCS damage-frequency curves reduced FWDRB only 6%, compared to 37%.[24]

Statistical Concepts and FWDRB

This section considers the following: approximating population frequency distributions; possible conflicting SCS Handbook advice; flood recurrence in the growing season; and the SCS adjustment for the "largest versus most-damaging storms or floods."

Approximating Population Frequency Distributions

The six or seven plotting-point damage values computed by SCS to locate the SCS damage-frequency curve represent but do not constitute an implied sample (of 50 or 100 events), which in turn represents the population of all damage values. These representations assume static economic and hydrologic conditions, and a random, probabilistic process, in which the sequence of occurrence of events is ignored; that is, time-dependence (as in a stochastic process) is not assumed.[25] These assumptions may be acceptable in the study of storm data or flood data for design purposes, and possibly even in the study of non-crop flood damages; but in the case of crop damages, the assumption of a stochastic, non-pure-random and possibly non-static (non-stationary) process may be more relevant. The reason for the difference is that

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[24]The conversion factors are given in note 23; resulting FWDRB are $71,307, or 94% of the base estimate ($75,715); this compares with a reduction of 37% (FWDRB = $47,845) for application to the rainfall amounts.

[25]Regarding hydrological processes, see Chow, sec. 8, pp. 9-10.

storm and flood events are hydrologic in nature, whereas losses add an economic dimension, notably management reaction to perceived losses, and their magnitude, timing and sequence.

Hydrologists use both annual-maximum and partial-duration series approaches in the analysis of flood damages, the former usually for an average of one event per year, and the latter for an average of several events per year. In the analysis of crop damages, flood recurrence during the growing season almost certainly means loss-event dependence, even though the floods or storms are assumed to be independent. This estimation problem is the crux of several SCS procedures and the author's criticism of these procedures, as used by SCS in evaluating the example project investment.[26]

The SCS Damage Frequency Curve Defined: The SCS damage-frequency curve is a cumulative frequency distribution curve, for which the variate magnitude is measured in dollars of damage. The probability axis is scaled from 0 to 1.0. For any given damage value on the curve, this axis indicates the cumulative probability; that is, the probability that damage will equal or exceed the value in question.

Hydrologists seldom plot the damage variable. They are more interested in discharge or other variables, usually in the engineering design context, in which design criteria (such as low-probability

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[26]See USDA, SCS, "Frequency Methods," SCS National Engineering Handbook, Section 4, Supplement A (Washington, D.C.; SCS, 1956), ch. 18. Since the ch. 18 for the 1964 edition was not available, ch. 18 of the 1956 edition is being used as a reference; judging by other chapters, the two should be the same, or similar. Also, see U.S. Army, Corps of Engineers, District Engineer (of Sacramento, California), Statistical Methods in Hydrology, revised ed. (Sacramento, California: Corps, January 1962).

discharge rates) are estimated from short-period and multiple-location data (transferred via regional analysis, which is similar to economists' cross-sectional analysis). The cumulative frequency distribution curve is plotted on either semi-log or logarithmic normal (probability distribution) paper (also called log-normal paper or Hazen paper). If the sample data represent a normal distribution, when plotted they form a reasonably straight line on log-normal graph paper, the equivalent of the cumulative normal distribution's "S" shape on arithmetic-scale graph paper. One problem in all of this is that rainfall values cannot be negative; hence, the distribution is assymetrical and not actually normal. Estimation of low-probability design criteria usually requires extrapolation beyond the range of the data; this is questioned within the engineering profession. However, extrapolation is a simple matter, if one uses a visually-fit line or curve for the sample data and log-normal graph paper, because the line is simply extended to the desired probability.[27]

For purposes of estimating crop damages and FWDRB, low-probability events in the engineering design-criteria range are seldom of interest. Damages and FWDRB are computed on an annual average or an expected annual basis, in which relatively high-probability (or low-damage) events play the dominant role by force of their numbers. In a typical, short-period sample of hydrological data there is usually an abundance of low-value, high-probability observations. These observations are

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[27]See NEH-4, the SCS Hydrology Handbook, ch. 18 (1956 ed.); Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis, second ed. (New York: McGraw-Hill Book Company, Inc., 1957), pp. 55-57; Chow, sec. 8, pp. 8 and 27-28.

seldom satisfactory for use in estimating low-probability design criteria, because of sampling error, small-sample, extrapolation and other problems. However, the approaches of hydrologists to these problems affect estimated damages and FWDRB. The impact will be considered in the next sub-section on plotting points and curves.

Because hydrological samples are usually problematic, SCS has chosen to synthesize flood data from storm data, for which the Weather Bureau's longer records are useful in estimating population parameters. The underlying nature of the storm data is thereby imparted to damage and FWDRB data, except as modified by the SCS model.[28]

Plotting-Points and Curves: If engineering design criteria and FWDRB are to be based on historical (time) series flood data, this data will be ranked and plotted by the hydrologist. The so-called plotting-point problem is not confined to graphical analysis, but extends to more sophisticated techniques, although it may be visualized as a shift in the position of a curve. With reference to the SCS damage frequency curve (Figure 3.1), a shift in the curve affects the area under it, that is, expected annual floodwater damages (FWD), and eventually FWDRB (where FWDRB = $FWD_1 - FWD_2$, the difference in area between the with and without project curves).

Edward Kuiper and M. A. Benson appear to differ on whether the Hazen or Weibull methods of assigning plotting-point probabilities would result in the highest FWDRB. Benson indicates that the Weibull method

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[28]See chapter 3, and the SCS Hydrology Handbook, NEH-4, chs. 4-12; also, the SCS Economics Guide, ch. 3.

provides a statistically unbiased estimate. SCS recommends the Hazen method. Judging by Benson's data, differences in estimated FWDRB would not be great. Ray Linsley reports that three approaches gave the following results:

Curve A, FWDRB = $300,000, project B/C ratio = 1.04 (used by agency)
Curve B, FWDRB = $214,000, project B/C ratio = 0.74 (using an approach suggested by Benson in an earlier work than cited here)
Curve C, FWDRB = $147,000, project B/C ratio = 0.51

Linsley further discusses related problems of engineering design criteria standards. George E. Merva indicates that perhaps a ±50% confidence range should be attached to some runoff predictions; similar confidence limits would then apply to related damage and FWDRB estimates.[29]

Possible Conflicting SCS Handbook Advice

Should the TP-40 rainfall data be used directly to form a partial-duration-series estimate, or adjusted to form an annual-maximum-series estimate of FWDRB? For the example project, the FWDRB estimate was based on the direct use of the TP-40 rainfall data (partial-duration series data), without adjustment to the annual series, as the evidence

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[29]Ray K. Linsley, "Engineering and Economics in Project Planning," in Stephen C. Smith and Emery N. Castle, editors, Economics and Public Policy in Water Resource Development (Ames, Iowa: Iowa State University Press, 1964), pp. 93-103, esp. pp. 99-100. M. A. Benson, "Plotting Positions and Economics of Engineering Planning," Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division, vol. 88, no. HY6, part 1, November 1962, pp. 57-61. Edward Kuiper, Water Resource Development--Planning, Engineering and Economics (London: Butterworth and Company, Ltd., 1965), pp. 34-36. Chow, sec. 8, NEH-4, the SCS Hydrology Handbook (1956 ed.), ch. 18, p. 2. Comments by George E. Merva, Associate Professor, Department of Agricultural Engineering, Michigan State University, in reviewing this chapter.

seems to indicate. However, the FWDRB estimate is supposed to be an annual average, and:

> When a partial-duration series is used to get average annual damages, it is necessary to have some method of avoiding double-counting of damages. The historical series also requires such a method when more than one flood per damage season occurs.[30] (Underlines added)

Recall that the example project analysis by SCS was based on a partial-duration series, assuming initially one event per year on the average.[31] The SCS Handbook procedural advice is unclear in this case. In fact, the combined implications of the item just cited, and two others, are that an adjustment is necessary only when the analysis considers more than one event per year on the average:

> The distinction between the two series can be made for many other kinds of data, but with yearly data--such as total annual runoff--the annual and partial duration series are identical.[32]
>
> In general, the annual series should be used, since the partial duration series can be easily computed from it, and there is less total labor involved.[33]

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[30]NEH-4, ch. 18 (1956 ed.), p. 22. This advice would probably be considered only when dealing with historical flood data, because TP-40 provides both variate magnitudes (rainfall depths) and plotting point probabilities.

[31]Initial SCS assumption; the subsequent recurrence adjustment is discussed in the next section, but it does not affect the comments here.

[32]NEH-4, ch. 18 (1956 ed.), p. 1. The comment is misleading in the FWDRB context, for by definition the annual series and partial duration series must be the same for total annual runoff; i.e., the "event" constitutes runoff for the entire year, and the partial duration series (in the largest events for n years of record) must include an event for each year. For the annual series, the annual maximum event is a year's only event. The same is not true for flood events, if "yearly data" means an average of one event per year for a partial duration series, for the largest n events in n years may exclude events for some years, if those in other years are larger (see Chow, sec. 8, pp. 19-23).

[33]NEH-4, ch. 18 (1956 ed.), p. 1.

> The annual-series frequency line is converted to a partial-duration line . . . , if the economist wants to use more than one flood per time period. The remaining steps apply to both the annual- and partial-duration series.[34]

The full context of the last-cited item suggests that the SCS Handbook is in error, judging by Chow and TP-40,[35] because both annual series (one event per year by definition) and partial-duration series (for the one-event-per-year choice) probabilities are shown as being the same in the SCS Handbook for all recurrence intervals.[36] The problem is that the partial-duration series probabilities for one event per year should be less than those for the annual series, for 10-year and shorter recurrence intervals. Therefore, this additional adjustment should apply to all partial-duration series probabilities in this recurrence range, for both one and more than one events per year on the average.[37]

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[34] NEH-4, ch. 18 (1956 ed.), p. 20.

[35] The TP-40 variate-size adjustments are shown in note 23; applications, in notes 23 and 24. Chow (sec. 8, pp. 21-23) graphs and presents a conversion formula for plotting-point probability adjustments, rather than for variate-size adjustments (as in TP-40). The effect of the two types of adjustments appears to be similar, but perhaps not equal. Chow's graph shows that the 2-year annual-series recurrence interval becomes a 1.5-year partial-duration-series recurrence interval (for one event per year on the average); the 5-year, a 4.5-year; and the 10-year, about a 9.6-year.

[36] NEH-4, ch. 18 (1956 ed.), pp. 17-22.

[37] The comment on comparing annual and partial-duration frequency lines (NEH-4, ch. 18 (1956 ed.), p. 17) is misleading, for it suggests that SCS recognizes a difference between the two when the latter refers to one event per year, average. Actually, the comment should indicate that annual series and partial duration series (for an average of one event per year) probabilities differ from partial duration series probabilities (for an average of more than one event per year); then, it would be consistent with Table 3.18-8 (NEH-4, ch. 18 (1956 ed.), p. 19).

Summary-Conclusions: Should a partial-duration series or annual-maximum series estimate of FWDRB be used in the case of one flood event per year on the average? The SCS Hydrology Handbook (1956 ed.) advice seems to be inconsistent at best. TP-40 is mute. Even the eminent hydrologist Ven Te Chow suggests that the difference between partial and annual-maximum series plotting points is unimportant in "ordinary hydrologic analysis."[38] In the author's judgment, the annual-maximum series estimate, 37% lower for the example project, is preferable, because by definition it represents an average of n annual-maximum events in n years, that is, with one event from each year. For the same n number of years the partial-duration series will provide an average for the n largest events, that is, with more than one event taken from some years and none from others. The problem of loss recurrence during the year will be taken up next.

Flood Recurrence in the Growing Season

Storms, Floods and Losses: A crucial assumption of the SCS model is that storm, flood and loss variates are readily convertible, and that all three express the same underlying relationships. Of course, the SCS model's translation process does not involve linear (constant factor) conversions, such that, for example, the damage for a 10-year flood can be obtained by multiplying the rainfall for a 10-year storm by some factor. Yet, a 10-year loss event is assumed to result from a 10-year storm.

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[38]Chow, sec. 8, p. 23, presumably refers to the hydrologists' usual domain, design criteria which are based on large-magnitude, low-probability events, whereas FWDRB are computed on the basis of mathematical expectation and depend on more frequent events.

Loss Event Recurrence Intervals: Two or more storm or flood events sufficiently separated in time to be classified as hydrological independent events need not produce independent loss events. An analysis of peak (highest-stage) flood events would include successive events, even though the river had not subsided from the floodplain to its channel. Annual average damages and FWDRB based on such a sample of peak (highest-stage) flood events would not represent the population average for separate, independent loss events. Thus, the long-term average recurrence interval between loss events need not be the same as the recurrence interval between storm or flood events.

The long-term average recurrence interval between loss events for the Mill Creek project was explicitly assumed to be 0.87 of a year (that is, SCS assumed an upward adjustment of 1.15 in FWDRB to account for recurrence, and 1/1.15 = 0.87 years).[39] SCS applied this explicit recurrence interval correction to FWDRB based on partial-duration series hydrological data, but FWDRB based on annual-maximum series hydrological data are 37% lower (or conversely, 63% of the former). Hence, disregarding other adjustments, SCS computed FWDRB are 1.83 times the annual-maximum series FWDRB (1.83 = 1.15/0.63), and the implied, overall recurrence interval is 0.55 of a year (1/1.83 = 0.55).

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[39]Table 3.18-8, NEH-4, ch. 18 (1956 ed.), p. 19, shows plotting point probabilities for use when the economist wants to consider the effect of more than one flood per year, presumably with reduced damageable values for multiple floods, as implied in the comment on double counting and reference to the SCS Economics Guide (pp. 11 and 14 of ch. 3, 1964 ed.), on p. 22 (of NEH-4). Probabilities for plotting points are shown for 1.2, 1.4, 1.6, 2.0, 2.5, 3.0, 3.5, 4.0, 6.0, 10.0 and 20.0 events per year on the average for a partial duration series, along with a formula for others not shown in the table.

Damageable Value Recovery Between Loss Events: The actual or assumed recurrence interval should be taken into account when assessing the SCS assumptions about recovery of damageable values between loss events. The foregoing comments on recurrence interval might be taken to mean that loss events are on the average 4 months apart during the growing season,[40] but this ignores the by-month probabilities of loss used by SCS. In the storm-to-loss synthesizing model, storm monthly probabilities of occurrence serve as proxies for their loss event analogs; the modal month for storms is August (22.5%), with July (21.2%), June (19.7%) and September (16.6%) not far behind for the Lake states.[41] Thus, events are most likely to occur within the time span of 3 or 4 months (June-August or June-September), when damageable values subject to loss are highest. According to the example project analysis, which initially assumes but one loss event per year, the 4 mid-growing season months rank as follows: July (damageable value index, 1.4), August (1.2), June (0.8) and September (0.6), with May fairly close (0.5).[42]

Yet, a damageable value index by month for an entire benefited area for a watershed probably does not adequately reflect the forces

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[40]Recurrence intervals: 4 months = 8 month growing season x 1/(1.83 events per time interval on the average) = 8 x 0.55.

[41]TP-29 or TP-40 data, 6-hour storm, 1-year return period; monthly values sum to 1.0 for the 12-month year. As previously discussed, flood events probably have a much different pattern, the modal month being March (see Table 5.2).

[42]Actually, an index of FWDRB-M (see Table 5.3), where FWDRB-M = index x \$100,000. This understates the damageable values in absolute terms, but the effect on the index is probably unimportant. Expected annual FWDRB = $FWD_1 - FWD_2$; FWDRB = \$75,715; FWD_2 = \$6,570.

acting on a farm manager who would more likely be faced with the decision of whether or not to crop a certain field or portion thereof in light of repeated flooding. For example, on a per-acre basis, inundation of 0-2 feet in the month of August would produce losses exceeding the without-project, SCS-defined net returns for most high-value crops grown in the example watershed.[43]

One management reaction to repeated flooding would be to use the land for woods, as may have been the case for the example watershed, judging by the possible and approximate location of sampled farms and their cropping patterns.

Another would be to select crops that are little affected by short and shallow floods. This management reaction is the agricultural equivalent of industrial-urban-residential flood proofing.

Management reaction would depend on the actual time of occurrence of typical, or "subjectively certain" floods and their extent with respect to cropping practice timing and field locations. While the SCS evaluation for the example project postulates a different monthly probabilities-of-loss pattern than is now used (the storm pattern, cited previously in this section), both are essentially storm patterns, whereas the author argued earlier in this chapter that a spring flood pattern is more likely in Michigan than a summer pattern. This spring pattern is consistent with the SCS farm survey for the example watershed, because spring floods would <u>delay</u> planting; whereas summer floods

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[43]Based on a comparison of (FDM x D) for depth 1 and NR_1 on a by-crop basis; see ch. 3. (FDM x D) exceeds NR_1 for navy beans, sugar beets, potatoes, onions, carrots, celery, cabbage, and cucumbers; it is less for corn, corn silage, hay, pasture and lawn grass sod, but still significant; it is zero for wheat and oats, due to harvesting prior to August.

would discourage planting, at least near the river, if the net losses per acre exceed the net returns, as SCS data indicates. The SCS farm survey suggests at least some cropping along the river, although the SCS model of the watershed assumes homogeneous cropping patterns in economic reaches, regardless of distance from the river for the example watershed.

The conclusion of these comments on recovery of damageable values between loss events is conditional. If the losses are too high relative to net returns on a per acre basis, there is little reason to believe that the land would be cropped, despite the SCS model's cropping-pattern homogeneity assumption for the watershed's project-benefited area.

How much recovery occurs before the next flood or floods (up to 20 or more)?[44] The assumptions of the example project evaluation would seem to mean that full damageable value is subject to loss in the adjustments for multiple floods. By contrast, the SCS Economics Guide suggests that less and less damageable value will be subject to loss in successive floods.[45] The difficulty in comparing the two is that the Guide is proposing explicit recognition of recurrence in the initial computations that lead to the plotting of the SCS damage frequency curve, but the example project evaluation involves an implicit adjustment for recurrence (the partial-duration versus annual series effect) in plotting the curve, plus an explicit, subsequent recurrence adjustment, following SCS procedures for Corn Belt states.

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[44]See note 39.

[45]SCS Economics Guide (1964 ed.), pp. 11 and 14, ch. 3.

Since about 1968 evaluations by the SCS Planning Party in Michigan have involved downward, rather than upward explicit adjustments for recurrence, but these may only serve to partially offset the implicit upward adjustment associated with possible use of partial-duration series as opposed to annual-maximum series data.

SCS Adjustments for the "Largest versus Most-Damaging Floods or Storms"

Relevant comments have been made in the preceding section on flood recurrence during the growing season with respect to the "largest versus most-damaging floods or storms" adjustment. Like the explicit recurrence adjustment used in the example project evaluation (in 1961), this adjustment factor also has a numerical value of 15%; they were entered together as a multiplicative, last-step, upward adjustment (factor 1.3225, not 1.30).[46] Their use was apparently a matter of established SCS procedure for the Corn Belt region for some years prior to 1958.[47] Neither is currently (1968-70) used by the SCS Planning Party in Michigan, for SCS personnel in Michigan have been developing new approaches to the underlying problems. Therefore, one might expect to see possibly several different attacks as new watershed evaluations are made, discussed and reviewed.

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[46]The two factors were entered multiplicatively (1.15 x 1.15 = 1.3225) and then applied to the estimated damage as determined from the SCS damage frequency curve. If added, then applied, a 30% (15% + 15%), rather than 32.25% adjustment would have resulted.

[47]Intra-SCS correspondence, from Frank F. Erickson, hydraulic engineer, Engineering and Watershed Planning Unit, SCS, Milwaukee, Wisconsin, to Kermit R. Irwin, Watershed Work Plan Party, SCS, Columbia, Missouri, June 1, 1958.

The SCS "largest versus most-damaging flood or storm" adjustment is described as relating to the "one largest storm during the growing season for a 50-year period."[48] This is an imprecise definition. What is meant is the 50 (n) largest storms or floods during the growing season for a period of 50 (n) years, with an average of one per year, presumably for an annual-maximum series and not a partial-duration series. The "one"largest storm's variate magnitude (storm rainfall depth) would have a recurrence interval of 50 years on the average, or a 2% chance of being equaled or exceeded in any one year.

Paraphrasing the cited correspondence, the SCS adjustment factor has to do with the average annual damage computed from the n annual-maximum flood events or storm events for n years versus that computed for "selected," most-damaging (annual-maximum) loss events, n in n years.[49] For storms, magnitude of the frequency-distribution variate is in inches of rainfall depth. For floods, the variate is the peak floodwater discharge, either in a rate of flow (cubic feet per second, cfs) or water-surface elevation or stage at the point of measurement. For loss events, the variate is measured in dollars. As previously stated, the SCS model simplifies by assuming that storms, floods and losses follow frequency distributions that readily translate via the model, although this does not mean that translation is merely a matter of discovering and applying numerical constants (e.g., 2 and 10 year loss amounts can not be obtained from 2 and 10 year storm rainfall

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[48] Ibid., underline added.

[49] The word "selected," taken from the cited correspondence, Ibid., may be problematic as to meaning.

depths via one numerical constant, such as "X dollars of damage per Y inches of rainfall").[50]

An Example Factor: While the cited intra-SCS correspondence does not provide data with which to critique the once-routine, Corn Belt region, 15% upward adjustment to obtain average annual damages (and FWDRB) for the n most-damaging storms or floods from the average for the n largest storms or floods, it does provide data for one project for which a 30% factor was being requested. Data for four variables for a Missouri watershed are contained in the correspondence, that is, for the two damage variables and the two acreage variables. Concentrating on the damage variables, the samples have skewed distributions (arithmetic mean larger than the median), and a high degree of dispersion. Frequency polygons suggest the possibility of bimodal distributions. In any event, there is some question about assuming that the underlying distributions are statistically normal. Statistical assessments and inferences about underlying populations depend on the normality assumption. In accord with the central limit theorem, the sampling distribution of sample means may be assumed to be normal, even if the underlying populations are not, providing that the sample size is large enough. The question is whether or not a sample size of 51 is "large enough."

Two approaches were taken to evaluate the working hypothesis (SCS assumption) that the mean damage for the most-damaging floods is larger

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[50]Cumulative frequency distribution functions for all three variables, for storms, floods and losses, could be plotted on log-normal (Hazen) paper. If statistically normal, the data would plot as a roughly straight line, but the lines would not likely be parallel in an overlay of the plottings, or in a re-scaling of the vertical, variate-magnitude axis to take account of the differences in units of measurement.

than that for the largest floods. The statistical null hypothesis is as follows: the mean for the most-damaging floods is less than or equal to that for the largest floods. Two approaches were taken. Comparing separate means, using a pooled variance, gave t = 1.60. On the other hand, if the observations are paired, their covariance is taken into account, but the test is more subject to non-normality problems than the first test, and t = 3.60. Thus, if the first approach is accepted (t = 1.60), the null hypothesis would be rejected at the 10% level of significance, but accepted at the 5% level; in the second approach (t = 3.60), the null hypothesis would be rejected even at the .5% level of significance.[51] Because of the problem of non-normality of the underlying populations and the problem of whether the sample is large enough to assume normality of the sampling distribution of sample means, caution should be exercised in the interpretation of these statistical assessments. In other words, one would have some question about accepting the SCS assumption that most-damaging flood average damage exceeds that for the largest floods. There may be even more question about the assumption that there is a 15% or 30% difference, for the statistical "t" values would be reduced from those preceding.

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[51]The source is cited in note 47. The data are for the East Fork of Big Creek project, economic reach 1, Missouri, for the 51 years 1907-1957 (sample size, n = 51). Abbreviations: m.d., most-damaging annual-maximum series storm or flood damage; l.s., the same for the largest storms or floods.

Item	Median	Mean	Standard deviation
$X_{l.s.}$	$390	$665	$647
$X_{m.d.}$	$770	$870	$652
$X_{m.d.} - X_{l.s.}$	-0-	$205	$406

Point-Area Rainfall Adjustments

As indicated in chapter 3, if SCS synthesizes flood-loss from storm data, point-estimate, intense-rainfall (storm) depths are obtained from maps in TP-40 (or other similar references) for the watershed location, hydrologically appropriate storm duration, and for 6 or 7 storm recurrence intervals (1, 2, 5, 10, 25, 50 and sometimes 100 years). Via the SCS model, these data are translated into damage amounts, which are paired with their respective plotting-point probabilities (or recurrence intervals), and used to locate the SCS damage-frequency curve. The area under this curve represents average annual damage (FWD), and the difference in areas between the with and without project curves represents FWDRB ($FWDRB = FWD_1 - FWD_2$).

Rainfall intensity is related to storm area and duration. Area-estimate rainfall is less than point-estimate rainfall, but the reduction in estimated damages and FWDRB is greater than the rainfall reduction. To obtain area-estimate from point-estimate rainfall, the adjustment factor is 0.93 for a 24-hour storm covering 100 square miles, and 0.91 for 400 square miles (the maximum for PL 566 project watersheds). For an area of 100 square miles, it is 0.88 for a 6-hour storm, 0.84 for a 3-hour storm, 0.72 for a 1-hour storm, and 0.61 for a 30-minute storm.[52]

Sensitivity Analysis Results

Suppose that the point-area rainfall correction should be applied for a storm covering the entire watershed, 70 square miles for the

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[52]Factors from graph in TP-40, or TP-29 (part 1), or SCS Hydrology Handbook (1956 ed.), ch. 3, Fig. 3.4-1.

example watershed. Evidence indicates that the SCS hydrologist working on the example project evaluation did not use the correction; this will be assumed, although it may be incorrect. Since 6-hour storm data were used by SCS, the correction factor is about 0.9.

FWDRB for area-estimate storm data are 42% below ($43,850) the FWDRB for point-estimate storm data (base estimate FWDRB = $75,715).

If both the area-point and the annual-maximum versus partial-duration series adjustments are made, FWDRB are 48% below ($39,609) the base estimate FWDRB ($75,715) for the example watershed.[53]

Monthly Loss Probabilities (PM's)

Previous sensitivity analysis in this chapter related largely to the acreage-flooded (AF) variable, and the typical acre loss values for the floodplain (CAV, composite acre values) were assumed fixed. The emphasis in this section is on the monthly probabilities of loss, PM's (see chapter 3, FWDRB step 2 and the methodology section of this chapter). As employed in chapter 3, PM's are an integral computational part of the composite acre values (CAV's). Alternatively, the acreage flooded (AF) data may be treated as an annual average, and the PM's as the monthly probabilities of occurrence for this extent of flooding. As indicated in the methodology section of this chapter, annual FWDRB can be obtained by weighting the unweighted, monthly contributions to FWDRB (FWDRB-M), and summing; $FWDRB = \sum_m PM_m \times FWDRB\text{-}M_m$. The FWDRB-M data will be used extensively in this section.

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[53]The partial-duration versus annual-maximum series adjustments for 10-year and shorter recurrence intervals are shown in note 23. To obtain the combined adjustment, the point-area factor (0.9) was applied first to the rainfall data, then the other factors.

Flood versus Storm PM's

Table 5.3 shows the effect of using flood in place of storm PM's for the example project.

Table 5.3. Monthly FWDRB-M, PM and Related Data, Example Project.

Month	FWDRB-M, dollars	PM	FWDRB-M x PM, dollars	PM, 6-hr., 1-yr. recurrence, storms	PM, Red Cedar River, floods	PM, Deer & Sloan Creek, combined, floods
April	$ 9,275	.05	$ 464	.025	.212	.087
May	52,939	.26	13,764	.087	.096	.087
June	82,813	.21	17,391	.197	-0-	.130
July	137,578	.16	22,012	.212	.019	.130
August	120,418	.11	13,246	.225	-0-	.043
September	58,674	.05	2,934	.166	-0-	-0-
October	11,808	.16	1,889	.047	.019	.087
November	2,055	-0-	-0-	.012	-0-	-0-
Non-growing season months:						
December				.002	.019	.043
January				.003	.019	.043
February				.005	.154	.043
March				.019	.462	.307
Sum		1.00	$71,700	1.000	1.000	1.000
FWDRB			$75,715	$87,704	$10,441	$42,524

Sources: Example project data are approximations of original SCS estimates. Storm data, TP-29. Red Cedar River data, for 355 square mile drainage area, see Table 5.2 for event data and sources. Deer and Sloan Creek data in Table 5.2 were combined; for an area of about 10-15 square miles of surface drainage; sources in Table 5.2. The sum of monthly data (FWDRB-M x PM) are increased by the factor 1.056 to account for indirect damages.

Varying the PM set has a considerable impact on FWDRB, with other variables in the model remaining unchanged from those used for the base estimate (FWDRB = $75,715). The use of a PM set for 6-hour, 1-year recurrence interval storms increased FWDRB to 1.16 of the base estimate, if the PM's are developed from the storm data in accord with their implied statistical nature, and if the PM's are not adjusted to sum to 1.00 for an 8-month growing season rather than a 12-month year, as will be discussed shortly. In the author's view, these conditions for forming a PM set from storm data (in TP-29 or TP-40) are procedurally correct only if a 1-year storm is sufficient to cause not just nominal flooding (overbank flow), but actual losses. If a larger rainfall amount is required, such as for a 2-year storm, the references provide the storm-data PM's. However, judging from recent use of storm data to form PM sets by the SCS Planning Party in Michigan, it would appear that these conditions are not interpreted in this way. Therefore, other things being equal, if the example project evaluation had been done in the mid or late 1960's, the SCS base estimate would be 1.26 of the one being used here; that is, $95,678, as opposed to $75,715, and in contrast with the $87,704 shown in Table 5.3.

If the PM set based on annual maximum floods for the Red Cedar River (as measured at East Lansing, Michigan, where the drainage area is 355 square miles, near the 400-square-mile maximum for PL 566 projects) is used, FWDRB are reduced to $10,441, or 14% of the base estimate. Owing to the shorter sample period length, the combined data for the Deer and Sloan Creeks, for drainage areas of about 10-15 square miles, have wider confidence intervals than the Red Cedar data. Nevertheless, they seem to support the hydrologists' contention that smaller watersheds are more likely to have summer, rather than primarily spring floods. Yet, the modal month is still clearly March for both sets of flood PM's, whereas August is the modal month for all storm PM's for storms longer than 6 hours in duration, of the 1-year recurrence interval. Mid-summer modality also holds for other storm PM's. Using the Deer-Sloan Creek

PM's reduces FWDRB to 56% of the base estimate, as compared to a reduction to 14% for the Red Cedar PM's.

Assuming a linear, area-proportional adjustment, FWDRB would be about 50% of the base estimate, other things being equal, because of shifting from a storm-data PM set to a flood-data PM set, for an area of 70 square miles, based on the Deer-Sloan and Red Cedar flood data.[54]

Monthly Runoff-Potential Adjustments

Consider the effects of varying runoff potential on a monthly rather than an annual basis. As explained in the methodology section, the adjustments were applied to the FWDRB-M data, rather than to the PM data (where average annual FWDRB = FWDRB-M x PM, summed for all months), so that the effect could be more readily observed. However, the effect on annual average FWDRB is the same, regardless of whether the adjustment is applied to the PM or FWDRB-M variables.

The runoff-potential variations in Table 5.4 seem reasonable to the author as an approximation for Michigan conditions, but their empirical validity is not at issue here; rather, the purpose is to show the FWDRB sensitivity to such changes. The by-month soil moisture variations from the routinely, SCS-assumed level (AMC-II) reduced FWDRB to $21,299, compared to the base estimate of $75,715, and to the estimate of $4,887 for the low-runoff potential (AMC-I) on an annual (or all-months) basis, and $163,882 for the high-runoff potential (AMC-III) on an

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[54]A linear area-proportional adjustment may be inappropriate. Suppose that it is acceptable and could be done as follows: [70 sq. mi./(355 - 15 sq. mi.)] x (56% - 14%) = 0.206 x 42% = 9%. And, 56% - 9% = 47%, or about 50% of the base estimate.

Table 5.4. Monthly Runoff-Potential Variations.

Item	Monthly, unweighted FWDRB (FWDRB-M) in $1,000's								Annual
	April	May	June	July	Aug	Sept	Oct	Nov	FWDRB
Base estimate									
CN	71	71	71	71	71	71	71	71	71
	$9.3	$52.9	$82.8	$137.6	$120.4	$58.7	$11.8	$2.1	$75,715
Soil moisture variations only									
AMC	III	II	I	I	I	I	II	III	
CN	86	71	54	54	54	54	71	86	
	$20.0	$52.9	$5.3	$8.7	$7.6	$3.7	$11.8	$4.5	$21,299
Plant cover variations only									
Level	f	f	ms	ms	pg	pg	f	f	
CN	86	86	71	71	54	54	86	86	
	$20.0	$114.0	$82.8	$137.6	$7.6	$3.7	$26.9	$4.5	$79,596
Combined variations									
CN	94	86	54	54	36	36	72	94	
	$17.8	$114.0	$5.3	$8.7	-0-	-0-	$13.1	$4.0	$37,088
PM	5%	26%	21%	16%	11%	5%	16%	0%	100%

Source: approximation of SCS estimate for the Mill Creek project and sensitivity analysis variations. Abbreviations: f, fallow (2/3 or more of the ground is not covered by plant material, SCS definition); ms, mid season; pg, peak growth. Annual FWDRB = FWDRB-M x PM x 1.056, summed over all months.

annual basis. These changes assume that plant growth development or density remains at the routinely, SCS-assumed mid-season level.

If the plant-growth-development assumption is changed on a monthly basis, as shown in Table 5.4, while holding the soil moisture level constant (at AMC-II), the resulting variation in runoff potential causes FWDRB to increase to $79,596, compared to the base value of $75,715, and to $4,887 and $163,882 for the high and low runoff-potential assumptions on an annual (or all-months) basis. (Coincidentally, the last two estimates are the same as for the soil moisture variations on an annual basis, owing to the use of the same CN's for the extreme changes of both variables, as explained in Table 5.1).

The author would judge the $37,088 FWDRB estimate as the most reasonable of the three shown in Table 5.4 for comparison with the base estimate of $75,715; it is 49% of the base estimate, meaning a reduction of 51%. Disregarding other criticisms of SCS estimates for the moment, this $37,088 FWDRB value relates to acreage-flooded data for use on a monthly rather than annual basis. Thus, the PM's remain as those for storm data, and the conversion to flood data is achieved by adjusting the runoff potential on a monthly basis, and shown in Table 5.4 as an adjustment of FWDRB-M values. Since the translation from storm to flood data is done in this way, use of storm, not flood PM's seems tenable. However, other corrections are necessary to achieve comparability with previous estimates. For example, the point-area rainfall correction, the explicit (SCS factor 1.15) and implicit recurrence adjustments, and the SCS "most damaging versus largest floods" (SCS factor 1.15) adjustments have not been taken into account here.

FWDRB Sensitivity to Storm-Data PM Changes

Storm-data PM's may be used as proxies for flood-data PM's, providing the adjustments in monthly runoff potential are sufficient to justify the substitution, as postulated in the preceding section. Still, flood and loss-event monthly probabilities of occurrence (PM's) are not necessarily the same. Since SCS does use unadjusted storm-data PM's as direct proxies for loss-event PM's, assuming a single, annual (meaning all growing season months') runoff potential, the effect of 12 possible PM sets will be considered. Of course, the SCS Planning Party hydrologist would select only one. A most likely choice is indicated in Table 5.5 for the example project if it had been evaluated using the PM data from TP-29 or TP-40.[55]

The effects of three choices are shown in Table 5.5, and they will be discussed in the following order: (1) the storm duration choice, (2) the choice of return period or periods to use in forming the PM set, and (3) the choice of whether the monthly probabilities of flood loss occurrence composing the PM set will sum to 1.0 for the 8-month growing season or the 12-month year.

Table 5.5. Index of FWDRB for 12 PM-Set Assumptions.

Storm duration, hours	PM set for all return periods, 1 to 100 yrs.		PM set for 1-year return period	
	8-month	12-month	8-month	12-month
1-hr.	1.38	1.37	1.34	1.23
6-hr.	1.26[a]	1.22	1.22	1.16
24-hr.	1.14	1.07	1.09	0.99

Source: Computer program approximation of SCS estimate for the North Branch of Mill Creek watershed, Michigan, and sensitivity analysis variations. FWDRB index of 1.00 for $75,715, crops-only FWDRB.

[a]Judging by an explanation of current practices by the hydrologists of the SCS Planning Party in Michigan, the PM set yielding an FWDRB index value of 1.26 would be used.

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[55]For the example watershed the monthly probabilities were based on a by-month tally of daily rainfall data for a nearby Weather Bureau station (at Bad Axe, Michigan). Each of the tallied events, for a period of 20 years or more, produced enough rainfall to cause nominal flooding (i.e., overbank flow, but not necessarily damaging flooding), given the assumptions and procedures of the SCS model. Currently, SCS uses monthly probability data in Weather Bureau references TP-40 and TP-29; this data is for a whole region, rather than for one station near the watershed. Hydrologists of the SCS Planning Party in Michigan have been studying monthly flood occurrences for Michigan streams; resulting PM's would be for flood events, rather than storm events, a distinct improvement.

The storm duration choice: The SCS hydrologist's choice of storm duration to determine the PM set would likely be the same as that used for determining the intense rainfall event set, as explained in chapter 3.[56] As shown in Table 5.5, FWDRB decline as storm duration increases, because longer duration storms have relatively lower probabilities of occurrence during mid-growing-season months when the crop values subject to loss are highest.

Return period choice: The choice of what return period (recurrence interval) data to use in formulating PM sets (monthly probability of flood loss sets) relates to the underlying statistical nature of the intense storm rainfall data in Weather Bureau references TP-40 and TP-29, and to the critical minimum (threshold) level of rainfall necessary to cause a flood loss (not just nominal flooding, meaning overbank flow).

Intense rainfall is a continuous variable, and the related probabilities of occurrence found in Weather Bureau references are for a cumulative frequency distribution. Annual cumulative probability of occurrence (P) is related to return period length, which is the same thing as recurrence interval length: P = 1/(return period or recurrence interval length in years). For example, the probability is P = 0.04 (25-year) that 6-hour duration rainfall will equal or exceed

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[56]Weather Bureau reference TP-40 provides intense rainfall (storm) event data sets for selected storm durations, such as 1, 3, 6, 12 and 24 hours, and selected return periods (1, 2, 5, 10, 25, 50 and 100 year return periods). Data for the storm duration nearest to the watershed's time of concentration is usually chosen; rainfall amounts are then adjusted to achieve equivalence between the two times. However, the PM set is not adjusted by the hydrologist for this reason.

2.90 inches some time during the year for the location of the Mill Creek watershed, Michigan, according to the maps in Weather Bureau reference TP-40. This probability statement includes the occurrence of all events with larger rainfall amounts, such as 50 or 100 year events. Furthermore, one cannot specify the probability that rainfall will exactly equal 2.90 inches, for such a statement can only be made about mutually exclusive events (such as the number of 6's expected in several tosses of a die).

For any one return period (recurrence interval or annual cumulative probability of occurrence) the sum of monthly probabilities equals the annual probability. That is, the Weather Bureau has estimated the chance of occurrence by month for several regions of the continental United States, and this information is contained in references TP-29 and TP-40. Thus, with respect to time of occurrence during the year, the data take on a mutually exclusive character. But with respect to magnitude, the storm event rainfall variable is still continuous. For example, the statement that 6-hour, 1-year storm event rainfall has the probability P = 19.7% of occurring in June relates to a cumulative frequency distribution in terms of rainfall depth; it includes all less-frequent events (for 2, 5, 10, 25, 50 and 100 year return periods as shown in TP-29).

Assume that a 1-year storm is sufficient to cause flood losses, as SCS assumed for the example watershed, then the monthly probabilities for a 1-year storm form the proper PM set. Such a PM set is shown in Table 5.3, as taken directly from TP-29. Again, the PM's sum to 1.00 for the year, because the Weather Bureau has divided the annual probability P = 1.00 among all 12 months.

Suppose that a 2-year, rather than a 1-year storm, is required to cause flood losses, then the monthly probabilities for a 2-year storm form the proper PM set. In this case, the sum of PM's is P = 0.50, the annual cumulative probability for rainfall of 2-year and larger magnitude. Similarly, if the rainfall for a 5-year storm is the threshold amount necessary to cause flood losses, then the 5-year storm monthly probabilities form the proper PM set, and the PM's sum to P = 0.20. The effect of shifting from a 1-year to a 2-year or longer recurrence interval PM set would be to reduce the estimated damages and FWDRB.

However, SCS hydrologists have apparently interpreted the probabilities shown in TP-29 as referring to discrete data with respect to storm rainfall depth; that is, the probabilities of occurrence of possible events shown in TP-29 (1, 2, 5, 10, 25, 50 and 100 year events) were summed on a monthly basis.[57] Suppose that 1-year storm event data is sufficient to cause nominal flooding in the watershed according to the assumptions used for the SCS model. Then the 1-year probabilities alone would provide the proper PM set.

Forming the PM set from probabilities for all return periods boosts the PM's for mid-growing-season months, when the crop values subject to loss are higher, at the expense of PM's for other months when crop values subject to loss are lower. In either case the PM set sums to 1.0, and the effect of this alternative interpretation is to redistribute the PM's among months.

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[57]The sum for all months is 1.87, and the PM for each month must be adjusted downward by the factor 1.00/1.87 so that the sum for all months is 1.00.

The effect of this alternative method of obtaining PM sets would depend on the monthly crop values subject to loss. As shown in Table 5.5, the effect of this alternative alone is relatively minor (compare data in columns 2 and 3 with that in columns 4 and 5, respectively). Conceivably, the effect for other watersheds would differ.

The 8-month versus 12-month sum choice: The choice of letting the PM set of monthly probabilities of flood loss occurrence sum to 1.00 for the 8-month growing season increases resulting FWDRB over the FWDRB estimated when the PM's sum to 1.00 for the 12-month year, as shown in Table 5.5. The monthly data shown in TP-29 sum to 1.0 for the 12-month year, and the adjustment is made to increase the weight (PM) for growing-season-month crop losses, because non-growing-season-month crop losses are not estimated, according to members of the SCS Planning Party in Michigan.

The effects of using an 8-month PM sum of 1.0 would appear to be relatively minor, judging by the roughly 1% to 10% expected annual FWDRB differences for the example watershed. Yet, the differences could be greater for other watersheds.

The implications about non-growing-season-month values subject to loss are rather interesting, and suggest a high degree of compensation for the PM set adjustment used by SCS, at least for Michigan.[58]

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[58]In Michigan the four non-growing-season months, December through March, are generally characterized by frozen ground; crop values subject to loss (such as fall planting of wheat or fall plowing for other crops) would probably be quite low, and not affected very much by a flood.

Specifically, the 1-year, 6-hour PM set indexes shown in Table 5.5 relate to a FWDRB difference of only $4,303. This is the difference in estimated FWDRB between using a PM set that sums to 1.0 for 8 as opposed to 12 months. On a 12-month basis, the 4 winter months have a cumulative PM sum of 4.4%, implying an average, unweighted monthly FWDRB of $97,795, approaching that for mid-summer months.[59] This is quite high. Recall that the SCS model accounts for non-crop and indirect FWDRB separately; thus, the concern here is with crop FWDRB only.

Summary

This chapter shows the effect of changing several hydrological assumptions on estimated FWDRB. FWDRB are quite responsive. It is important to keep in mind that SCS used the storm-to-flood synthesizing model for the example project and that many of the changed assumptions have to do with the translation process. Damages and FWDRB based on historical floods were not studied. However, for PL 566 evaluations SCS apparently depends mostly on the storm-to-flood synthesizing model, because of the lack of observed flood data.

While SCS assumes an eight month growing season in Michigan and the Midwest, a single runoff potential is used as a simplification. If either soil moisture level or plant growth density is changed to the

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[59]The precise division among the four months is not important. The FWDRB-M value, $97,795 ($4,303/0.0404 = $97,795), is assumed to be the same for all four months. Reversing the arithmetic, the cumulative PM's for all four months, 4.4%, yields the annual difference in FWDRB (where annual FWDRB = FWDRB-M x PM, summed over all months, in this case only the four winter months). For summer month FWDRB-M values, see Table 5.3.

low runoff potential level, FWDRB fall to 0.06 of the base estimate of $75,715. If either is changed to the high runoff potential level, FWDRB are 2.16 of the base estimate. Other combinations of these two three-range assumptions are possible. They indicate that FWDRB are quite responsive to slight runoff potential changes. Runoff curve number (CN) changes in the 1-4 range from the SCS-assumed CN 71 could change FWDRB by perhaps ±10-50% from the base level. Conceivably, a field estimation error could include a range of CN ±1-4. The FWDRB range of 0.06-2.16 of the base estimate is for CN 54 and CN 86 compared to the SCS-assumed CN 71 (see Table 5.1).

The author changed soil moisture and plant-growth density assumptions on a monthly basis. A tenable combined-effect assumption set reduced FWDRB to roughly 50% of the base estimate (see Table 5.4).

Holding runoff potential constant at the SCS-assumed level (CN 71), the author studied the effect of certain procedural and conceptual changes, affecting the rainfall depths, as obtained from Weather Bureau reference TP-40. TP-40 provides rainfall amounts and plotting-point probabilities (cumulative frequency distribution probabilities). For areas larger than 10 square miles, TP-40 and the SCS Hydrology Handbook suggest that the point-estimate rainfall amounts be reduced to provide an area estimate, such as for the 70 square mile example watershed, for which the reduction factor is 0.9 (a 10% reduction). Applying this factor (0.9) to the TP-40 rainfall data reduced FWDRB to 58% of the base level (a 42% reduction).

Rainfall data in TP-40 are based on the concept of a partial-duration series, that is, the n largest events in n years, meaning that some years contribute more than one event and other years, none. By contrast, an annual-maximum series is based on the n annual-maxima in n years, that is, each year contributes one event. It would seem that the annual-maximum series provides an average closer to the ordinary concept of an arithmetic mean. FWDRB for annual-maximum series rainfall data are 37% below the FWDRB for partial-duration series rainfall data (unadjusted TP-40 rainfall data).

Combining the point-area and annual-maximum-series (from partial duration series) adjustments, FWDRB are reduced 48% below the base level, to \$39,609 from \$75,715. Based upon available evidence the author assumed that the SCS hydrologist made neither of these adjustments. The high degree of benefit sensitivity is due to the threshold effect, for the rainfall amounts used to estimate FWDRB are quite close to the critical minimum necessary to cause flooding.

Up until about the mid 1960's SCS adjusted FWDRB upward from the value obtained from the damage frequency curves. A combined factor for flood recurrence (1.15) and the "most damaging versus largest floods" (1.15) was applied (1.3225), boosting FWDRB over 30%. If this factor is deleted from the estimate of the previous paragraph, FWDRB are \$29,950 (\$39,609/1.3225), or about 40% of the base estimate. The "most damaging versus largest floods" adjustment has to do with problems in the translation of storm into flood and flood into damage data. The explicit recurrence adjustment (1.15) complements the implicit recurrence adjustment associated with using a partial-duration series estimate in place of an annual-maximum series estimate, and the two combined provide not a 15%, but an 83% boost (1.15/0.63 = 1.83).

Conceivably, this is the equivalent of assuming almost two floods (1.83 floods) per year, but the SCS evaluation of the example project was based on the assumption of but one flood per year in the computation of typical acre loss values for the floodplain (the composite acre values, CAV). It would seem tenable to argue that successive floods would produce less damage, especially if they are of the storm-caused variety. That is, composite acre values (CAV) should be reduced when evaluating an average of more than one flood per season, if the CAV's were computed assuming one flood per season.

March is the modal month for floods in Michigan and probably elsewhere in the Midwest, judging by data for the Deer and Sloan Creek watersheds (about 10-15 square miles) and the Red Cedar River basin (both at 250 and 355 square miles of drainage area). Substituting flood for storm data to represent the monthly probabilities of flood loss (PM) reduced FWDRB to $10,441, using the Red Cedar data, and to $42,524, using the Deer-Sloan data, compared to base estimate FWDRB of $75,715. Even these reduced estimates may be high because the acreage flooded data are based on the SCS runoff potential assumptions. Furthermore, flood-event probabilities need not be the same as loss-event probabilities, although they seem to represent a significantly different phenomena than storm-event probabilities. Incidentally, if the example project were re-evaluated by SCS using the TP-29 storm PM's, other things being equal, FWDRB would be 26% above the base estimate (see Table 5.5).

The last section of this chapter shows the effects of using different PM sets, formulated from intense (storm) rainfall event data in Weather Bureau reference TP-29 (or less conveniently from TP-40). The

SCS hydrologist would select a PM set so as to approximately equate the storm duration and the watershed time of concentration. Given this, there are at least four alternative PM sets that could be developed. Assuming that a 1-year storm rainfall amount would be sufficient to cause losses (not just nominal, overbank flow), these four alternatives could produce perhaps a 10% variation in estimated FWDRB (see Table 5.5). However, perhaps it should be emphasized that the sum of PM's for any one recurrence interval equals the annual, ex ante probability of occurrence [P = 1/(recurrence interval in years)]. If a 2-year storm is required to cause losses, the sum of PM's for the year is 0.50, not 1.00; thus, using a 2-year PM set would reduce FWDRB considerably. Still, mid-summer month modality prevails for storm PM's, but March modality holds for flood PM's, neither of which are loss PM's.

In closing this chapter, perhaps a few words of judgment are in order. The example project may reasonably well represent or at least suggest the FWDRB responsiveness of other PL 566-size watersheds in the Midwest. The methodology only simulates the effect of changes in rainfall and runoff; it appears to be capable of producing good approximations.[60] The monthly probability of loss changes are entirely independent, as is the computation of joint requisite-rainfall and proximate-storm probabilities. Therefore, there are some independent routes to the conclusion that, in the author's judgment, FWDRB may be

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[60]Watersheds vary in hydrological character. Responsiveness of acreage flooded data to changes in storm-rainfall runoff and related flood discharge rates depends upon the stream-channel and valley cross-sectional profiles in the floodplain area. A floodplain with steep slopes will be less affected by increases in flood discharge rate than a floodplain with flatter slopes. Also, see note 56, chapter 2, and note 6, chapter 3.

far closer to zero than to $75,715 for the example project. Disregarding all other questions raised in this chapter, perhaps the key question is: Do flood losses--not storms and not floods--actually occur in the mid-growing season when values subject to loss (FWDRB-M) are highest? (See Table 5.3.)

CHAPTER VI

CROP ENTERPRISE ASSUMPTIONS

This chapter is concerned with the sensitivity of small watershed, PL 566 project benefits to changes in selected crop enterprise variables. Basically, all crop-related benefits are the equivalent of the aggregate difference in net returns, less associated costs, for the project-benefited portion of the watershed, with returns to land and management not counted in the enterprise cost data. However, because of their importance in a policy sense and because of computational and sensitivity differences among them, the analysis will be concerned with the three crop-related categories of project benefits, which are, in order of descending PL 566 program importance:

FWDRB: floodwater damage reduction benefits; computed on an expected annual basis for floodplain land which is included in, but usually smaller than the project-benefited portion of the watershed.

MILUB: more intensive land use benefits, for already cropped farm land in the project-benefited part of the watershed.

LUCB; land use change benefits, for previously uncropped farm land in the project-benefited part of the watershed.

These three categories of benefits will be given primary focus, but other classifications may be used by SCS for policy reasons.

Methodology

The analysis of this chapter involves substituting alternative crop prices, costs, yields and planting patterns into the SCS model of chapter 3, and comparing the model output, usually benefits, to a base level which is an approximation of the original SCS estimate for the example watershed. Two approaches are used. In the first part of the chapter, the specified variable is changed for all crops by the same percentage; for example, all crop prices are increased by 10%. Later, specified variable changes differ by crop, but they apply to all crops; for example, 1959-63 crop prices are substituted for those assumed by SCS.

In studying the effect of yield changes, two approaches are used with respect to the effect on production costs. In terms of background, recall from chapter 3 that SCS computes by-crop production costs in two different parts. Total cost per acre = AVC (average variable cost per unit of output) x Y (yield per acre) + AFC (non-AVC cost, per acre). It must be kept in mind that AVC does not represent all production cost per unit of output, and that AFC does not represent all production costs figured on a per-acre basis.

SCS computes two sets of per-acre AFC costs, AFC_1 for the without project output level, yield level Y_1 and AFC_2 for the with-project yield level Y_2. In the first part of this chapter yield data are changed, and this affects only the AVC portion of total per acre costs, not the AFC portion. In the second part of this chapter per-acre AFC costs are changed when a new crop yield set is introduced. Proportional adjustments are used to compute the new per-acre AFC costs,

$AFC^*_{k,j}$, as follows;

$$AFC^*_{k,j} = AFC_{k,1} + (AFC_{k,2} - AFC_{k,1}) \times (Y^*_{k,j} - Y_{k,1})/(Y_{k,2} - Y_{k,1})$$

These adjustments to obtain paired AFC and Y sets for each crop are made only in the LUCB and MILUB computations, and not in the FWDRB computations. Of course, that portion of by-crop, per-acre total production costs associated with AVC changes whenever yields are changed in all computations (see chapter 3 for procedures).

Two Michigan projects are studied in this chapter. The North Branch of Mill Creek project, in the Thumb area's vegetable crop belt near Imlay City, is also the example in chapters 3 and 5. It has only 3 reaches (subdivisions of the project-benefited area with reasonably homogeneous cropping patterns), but 17 crops, including most of the standard field crops for Michigan, as well as fresh market vegetables and lawn grass sod. All three categories of benefits, FWDRB, MILUB and LUCB, were included in the early-1962 project analysis by SCS. PLT (projected long term) crop prices were used. AN (adjusted normalized) crop prices were used in the Tebo Erickson project analysis, completed by SCS in March 1968. This project is located in Bay County, north of Bay City and slightly inland from the shore of Saginaw Bay. The benefited area is divided into seven economic reaches, and 11 crops are grown, with somewhat less emphasis on vegetable crops than in the Mill Creek project. However, FWDRB are rather unimportant, and LUCB were not computed, meaning that justification of the project depended heavily on MILUB.

Base values to be used in the sensitivity analysis for the two projects are given in Table 6.1.

Table 6.1. Base Values for the Example Projects

Project	FWDRB, crops only	MILUB	LUCB	Annual benefits (all)	Annual costs	Benefit cost ratio
Mill	$75,715	$130,362	$74,604	$282,065	$40,520	6.96
Tebo	$ 1,821	$ 43,578	-0-	$ 45,596	$20,990	2.17

Source: Computed approximations of SCS estimates for the North Branch of Mill Creek and Tebo Erickson watershed projects, Michigan; secondary benefits excluded; FWDRB are for crops only, but annual benefits include minor, non-crop FWDRB.

All-Crop, Percentage Change Sensitivity Analysis

In this section the sensitivity of MILUB, LUCB, FWDRB and overall benefits to selected percentage changes in crop prices, yields or costs is considered. The specified variable for all crops is changed by the same percentage; for example, all crop prices are increased 10%. Later in this chapter variables are changed for crops on an individual basis; for example, in place of the PLT crop price set, 1959-63 Michigan state average prices are used. Regardless of the approach used, FWDRB respond only to yield set 1 (without project yield) variations; LUCB, only to yield set 2 (with project yield) variations, except for the effect of FWDC.[1] Otherwise, all benefit categories respond to all variable changes.

Overall benefit response depends on the importance of various categories of benefits. FWDRB are least sensitive, because they are essentially the equivalent of farm income only, whereas enhancement

[1]Regarding FWDC, see footnote 4.

benefits (EB), that is, MILUB and LUCB, are partially net benefits, with associated costs deducted.

Benefit Response Coefficients

Results for this section are summarized in Table 6.2, which shows the benefit response coefficients for changes in crop prices, costs and yields over the range ±50% from the SCS-assumed levels. These benefit response coefficients are defined as follows:

$$\frac{\text{(\% change in benefits, from the base level)}}{\text{(\% change in independent variable, from the base level)}}$$

A positive coefficient means both changes are in the same direction, and a negative coefficient means the two changes are in opposite directions. The coefficients are approximately constant and symmetrical over the range of variation, ±50% from the SCS-assumed (base) levels of the independent variables, as may be seen more clearly in Tables 6.3 and 6.4, from which Table 6.2 is derived.[2]

Table 6.2. Approximate Benefit Response Coefficients

Variable	Project	FWDRB	MILUB	LUCB	Annual benefits
Crop prices	Mill	+2.0	+3.2	+4.5	+3.2
	Tebo	+1.6	+2.5	----	+2.4
Crop costs	Mill	-1.3	-2.2	-3.8	-2.3
	Tebo	-0.7	-1.2	----	-1.1
Yield set 1 (without project)	Mill	+0.8	-5.6	-0-	-2.3
	Tebo	+1.1	-4.6	----	-4.3
Yield set 2 (with project)	Mill	-0-	+7.6	+2.1	+4.1
	Tebo	-0-	+6.5	----	+6.2

Source; Tables 6.3 and 6.4. Yield changes do not affect per-acre AFC costs.

[2]Not all of the supporting data are shown in Tables 6.3 and 6.4.

The significance of these benefit response coefficients is in their size and variation among benefit categories and independent variables. Except for variables that do not affect the benefit category in question (indicated by a benefit response coefficient of zero), the coefficients range from 0.7 to 7.6. Again, the FWDRB responses to changes in crop enterprise variables are lowest, because FWDRB are project-credited farm income only, whereas MILUB and LUCB incorporate relatively large deductions for associated costs.

Keeping in mind the approximate constancy and symmetry of benefit response, consider for example the largest coefficient, for MILUB yield set 2 and the Mill Creek project. As shown in Table 6.3, an increase in yield set 2 of 10% from the base level increases MILUB 76% (index value of 1.76 times the base level). Similarly, the second 10% (yields at +20%) adds roughly another 76% to benefits (MILUB at 2.51), relative to the base level. The same MILUB response of 76% holds for the third, fourth and fifth yield set 2 increments of 10% from the base level, and for all five decrements of 10%.

Indexes of Benefit Response

Tables 6.3 and 6.4 show benefit responses directly in terms of indexes for various benefit categories and in terms of benefit cost ratios for the two example projects.[3] A few words of caution are in order. The extreme range of SCS model input data, from -50% to +50% of the base level, upsets in many cases the normal relationship of

[3]Index values are obtained by dividing the benefits for the change in question by the base value shown at the tops of the columns in Tables 6.3 and 6.4.

variables in the crop enterprise equations. Notably, net returns for some crops may become negative long before these ±50% extremes are reached. Surprisingly, this does not seem to upset the symmetrical and approximately constant benefit responses, except for quirk LUCB responses to yield set 1 decreases, due to use of the SCS computational procedure for FWDC.[4]

A partial solution to the negative net returns problem did not prove to be satisfactory. As adverse SCS model data input changes become more extreme, crop net returns become negative. Furthermore, in some cases, with-project net returns may actually be lower than without-project net returns. If NR_1, NR_2 or the difference (NR_2 - NR_1) becomes negative, the crop in question can be deleted from the planting pattern, and the vacated acreage can be apportioned among the remaining crops. However, the benefit response coefficients lose their virtual symmetry and constancy. It is even possible to improve a project's

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[4]As explained in chapter 3, FWDC are deducted from enhancement benefit net farm income, along with associated costs. Yield set 1 does not affect the computation of LUCB net farm income, but it does affect the FWDC deductions for LUCB and MILUB. For the Mill Creek project, SCS computed FWDC as follows:

$$FWDC = FWD_2 \times FA_2 \times (PR_4 - PR_1) \, / \, (PR_1 \times FA_1)$$

FWDC are the increase in with-project floodwater damages (FWD_2) over what was estimated using CAV_1. FA is the acreage inundated by a 50-year flood, without, FA_1, or with the project, FA_2. PR are typical acre profits, without, PR_1, or with the project, PR_4.

In the SCS formulation for FWDC, very low PR_1 boosted FWDC to $1,393,089, when yield set 1 was reduced 50%, compared to base level FWDC of $1,738. Alternative computation of FWDC as FWD_2 (at CAV_2) less FWD_2 (at CAV_1) resulted in FWDC of only $5,165 at this extreme, and $2,542 at the base level (compared to the $1,738 FWDC estimate using the SCS computational routine).

Table 6.3. Benefit Sensitivity Indexes, Mill Creek Project, Michigan.

Variable change		Benefit sensitivity indexes FWDRB	MILUB	LUCB	Overall	B/C ratio
Base, value		$75,715	$130,362	$74,604	$282,065	6.96
Base, index		1.00	1.00	1.00	1.00	- -
Prices	-10%	0.80	0.68	0.55	0.68	4.74
	-20%	0.59	0.35	0.10	0.35	2.45
	-30%	0.39	0.06	-0.34	0.05	0.34
	-40%	0.19	-0.26	-0.78	0.27	-1.89
	-50%	0.02	-0.57	-1.23	-0.59	-4.11
Costs	+10%	0.87	0.78	0.61	0.76	5.29
	+20%	0.73	0.55	0.22	0.51	3.58
	+30%	0.60	0.37	-0.16	0.29	2.04
	+40%	0.47	0.14	-0.55	0.05	0.35
	+50%	0.33	-0.08	-0.94	-0.19	-1.32
Yield set 1	+10%	1.08	0.42	1.00	0.75	5.25
	+20%	1.17	-0.16	1.00	0.51	3.54
	+30%	1.25	-0.74	1.00	0.26	1.83
	+40%	1.34	-1.33	1.00	0.02	0.11
	+50%	1.42	-1.91	1.00	-0.23	-1.60
Yield set 1	-10%	0.92	1.58	1.00	1.25	8.67
	-20%	0.83	2.16	1.00	1.49	10.36
	-30%	0.75	2.73[a]	0.99[a]	1.73	12.04
	-40%	0.66	3.28[a]	1.08[a]	1.96	13.65
	-50%	0.58	10.44[a]	3.06[a]	5.79[a]	40.33[a]
Yield set 2	+10%	1.00	1.76	1.21	1.41	9.79
	+20%	1.00	2.51	1.43	1.81	12.62
	+30%	1.00	3.27	1.64	2.22	15.45
	+40%	1.00	4.03	1.86	2.63	18.28
	+50%	1.00	4.78	2.07	3.03	21.11
Yield set 2	-10%	1.00	0.24	0.79	0.59	4.13
	-20%	1.00	-0.51	0.57	0.19	1.30
	-30%	1.00	-1.27	0.36	-0.22	-1.53
	-40%	1.00	-2.03	0.14	-0.63	-4.36
	-50%	1.00	-2.78	-0.07	-1.03	-7.19

Source; Computed approximation of SCS estimate and sensitivity analysis variations thereof. FWDRB for crops only; overall benefits include minor non-crop FWDRB. Yield changes do not affect per-acre AFC costs.

[a]LUCB index variation from 1.00 is due to FWDC dominance which is avoided if an alternative computational routine is used. This FWDC problem affects MILUB, as well as LUCB, in the -30%, -40% and -50% computations. See the main text, note 4.

Table 6.4. Benefit Sensitivity Indexes, Tebo Erickson Project, Michigan.

Variable change		Benefit sensitivity indexes FWDRB	MILUB	Overall	B/C ratio
Base value, dollars		$1,821	$43,578	$45,596	2.17
Base value, index		1.00	1.00	1.00	- -
Prices	-10%	0.84	0.75	0.75	1.64
	-20%	0.69	0.50	0.51	1.11
	-30%	0.54	0.25	0.27	0.58
	-40%	0.30	0.00	0.02	0.05
	-50%	0.23	-0.25	-0.22	-0.48
Costs	+10%	0.94	0.89	0.89	1.93
	+20%	0.87	0.77	0.78	1.78
	+30%	0.81	0.66	0.66	1.44
	+40%	0.74	0.54	0.55	1.20
	+50%	0.68	0.43	0.44	0.95
Yield set 1	+10%	1.11	0.54	0.57	1.23
	+20%	1.21	0.09	0.14	0.29
	+30%	1.32	-0.37	-0.30	-0.64
	+40%	1.42	-0.83	-0.73	-1.58
	+50%	1.53	-1.28	-1.16	-2.52
Yield set 2	-10%	1.00	0.35	0.38	0.82
	-20%	1.00	-0.30	-0.24	-0.53
	-30%	1.00	-0.95	-0.87	-1.88
	-40%	1.00	-1.60	-1.49	-3.23
	-50%	1.00	-2.26	-2.11	-4.59

Source: Computed approximation of SCS estimate and sensitivity analysis variations thereof. FWDRB are for crops only, but overall benefits include minor non-crop FWDRB. Yield changes do not affect per-acre AFC costs.

benefit cost ratio by deleting certain crops, even though the sensitivity analysis changes appear worse otherwise.[5]

The effects of adverse data input changes for the SCS model can be summarized from Tables 6.2-6.4 by comparing the degree of change necessary to reduce project benefit cost ratios below unity:

	Base B/C	Prices	Costs	Yield 1	Yield 2
Mill Creek	6.96/1	-25%	35%	35%	-25%
Tebo	2.17/1	-25%	45%	12%	-5%

To account for the differences between the two projects, one must consider the initial benefit cost ratio (lower for the Tebo), benefit response coefficients (generally higher for the Mill Creek), and benefit composition (no LUCB and unimportant FWDRB for the Tebo).

On the basis of its lower initial benefit cost ratio, one would expect the Tebo's ratio to fall below unity before that of the Mill Creek when increasingly adverse data input changes are introduced into the SCS model. However, the Mill Creek's benefit cost ratio falls below unity at about the same price reduction level as the Tebo's ratio. Also, the Mill Creek's benefit cost ratio falls below unity at a lesser cost reduction than the Tebo's ratio. In both cases this is because of the Mill Creek's higher benefit response coefficients. Yet, despite higher MILUB response coefficients for yields for the Mill Creek project, adverse yield changes cause the Tebo's benefit cost ratio to fall below unity before that of the Mill Creek. This is due to the

[5]For the Tebo Erickson project, with crop costs increased 50% above the base level, only fresh market bell peppers remained. MILUB jumped to 1.71 times the base level (versus 0.43 of the base level with all crops left in). The benefit cost ratio rose to 3.56/1 (versus 0.95/1 with all crops left in), as compared to a base level ratio of 2.17/1.

high proportion of MILUB for the Tebo (MILUB have high yield response coefficients) and the unimportance of FWDRB for the Tebo (FWDRB have low yield response coefficients compared to MILUB).

Other Changes

Two additional changes will be considered here: simultaneous yield set 1 and 2 changes, and alternative yield set 1 (yield set 1-A) changes.

Simultaneous yield set 1 and 2 changes: The Mill Creek model was studied for positive and negative, simultaneous yield set 1 and 2 changes of 10%, 20% and 30% from the base yield levels.[6] As expected, FWDRB responded as if only yield set 1 was varied, and LUCB responded as if only yield set 2 was varied. Overall project benefits and MILUB responded symmetrically with coefficients of about 1.6-1.7. For overall project benefits, response coefficients in the 1.6-1.7 range rank with the lowest for single variable changes, because both net return sets are moving together. The coefficients of benefit response for simultaneous yield set 1 and yield set 2 changes are positive, meaning that benefits change in the same direction as yields.

Alternative yield set 1 (yield set 1-A) data: SCS separates FWDRB from enhancement benefits using flood-free and poorly-drained yields (yield set 1) to represent without-project conditions. Unseparated benefits can be computed using with-flooding and poorly-drained yields

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[6]In this range, FWDC computational-quirk effects on LUCB for yield set 1 reductions are just on the threshold of becoming apparent. They are ignored here. See note 4.

(yield set 1-A, Appendix, Table 6) to represent without-project conditions. As described in the methodology section, a special AFC per-acre cost set (AFC_{1-A}) was computed for use with yield set 1-A. Only the AFC per-acre costs for the LUCB and MILUB subroutines are changed, even though the FWDRB subroutine employs per-acre costs that represent a portion of the AFC costs. However, AVC costs change with yields in all subroutines. Recall that total crop cost per acre = AVC (average variable cost per unit of output) x Y (yield per acre) + AFC (non-AVC cost, per acre costs).

In effect, project benefits are computed in the LUCB and MILUB subroutines, but it proved simpler to compute benefits with FWDRB included, and then to deduct FWDRB.

Substitution of yield-cost set 1-A for set 1, with FWDRB deducted, resulted in a benefit cost ratio of 8.0/1, exceeding the base ratio of 6.96/1 for the Mill Creek project. Decreasing yield-cost set 1-A only reduces the FWDRB deduction modestly and increases remaining benefits, owing to the coefficients of benefit response (Table 6.2). Increasing yield-cost set 1-A by 10% brought the benefit cost ratio down to 6.48/1, with FWDRB deducted. Alternately, a 10% yield-cost set 1 reduction brought the benefit cost ratio down to 6.96/1, with FWDRB deducted, coincidentally equal to the base ratio.[7]

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[7]For yield and cost set 1-A, with FWDRB deducted, B/C = 8.0/1 = ($387,230 - $63,563) / $40,520 = $323,662 / $40,520. The yield set 1 decrement resulted in a benefit cost ratio of 8.67/1 (see Table 6.3), or 6.96/1, with FWDRB deducted; 6.96/1 = ($351,191 - $69,317) / $40,520 = $281,874 / $40,520. See Table 6.1 for base estimate data. In both cases the FWDRB deductions exclude non-crop FWDRB ($1,383).

Alternative Crop Prices

The effects of selected sets of alternative crop prices and comparable crop cost adjustments are shown in Table 6.5 (for price sets shown in Appendix, Table 7). Price sets can be introduced independently of the cost adjustments.[8] Restoring costs to their 1960 level (an increase of 12.36%) reduced benefits to 70% of the base level. Combined usage of 1959-63 prices and costs (an increase in costs of 13.63% from the base level) improved overall benefits slightly (1.02 of the base level). Introduction of 1964-66 prices alone substantially increased the benefits (to 1.87 times the base level). The benefits fell when crop costs were raised to the 1964-66 level (an increase of 15.33%). None of these prices and cost sets reflect the complete removal of government farm programs, although the AN (adjusted normalized) set reflects partial removal. Yet, benefits fell to only

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[8]SCS based its estimates of production costs on 1960 Michigan data, decreased by 0.89, the PLT adjustment factor for 1960, obtained by dividing the PLT value of the index of farm prices paid, all items, by the 1960 value of the index (0.89 = 265/299, with a base of 100 for 1910-14). Costs for 1960 were restored with the factor 1.1236 (1.00/0.89).

Other cost levels were developed using the index of prices paid by farmers, production items only, 1910-14 base of 100, as is used in the newer adjusted normalized (AN) factors by SCS: AN index value, 272; 1960, 265; 1959-63, 268; and 1964-66, 277. The factors were obtained as follows:

1959-63, 1.1363 (268/265 x 1.1236);
1964-66, 1.1745 (277/265 x 1.1236);
AN, 1.1533 (272/265 x 1.1236).

In practice SCS uses these adjustment factors on operations and maintenance costs for structural (mainstream) and associated-cost (on-farm and inter-farm) works, as well as on crop production costs, but the factors computed here were applied to production costs only for purposes of the sensitivity analysis.

Table 6.5. Effects of Alternative Price and Cost Sets.

Assumptions		Benefit component index FWDRB	MILUB	LUCB	Overall	B/C ratio
Base, value		$75,715	$130,362	$74,604	$282,065	6.961
Base, index		1.00	1.00	1.00	1.00	
Price	Cost					
PLT	1960	0.84	0.73	0.52	0.70	4.898[a]
1959-63	PLT	1.26	1.37	1.44	1.36	9.458[a]
1959-63	1959-63	1.07	1.07	0.90	1.02	7.127[a]
1964-66	PLT	1.49	2.02	2.03	1.87	13.051
1964-66	1964-66	1.25	1.62	1.33	1.44	10.007
AN	AN	1.01	1.05	0.80	0.97	6.775[a]

Source: Approximation of SCS estimate for the North Branch of Mill Creek watershed and sensitivity analysis variations thereof.

[a]Reach 3, base B/C ratio of 1.22/1, has a B/C ratio less than unity.

0.97 of the base level (for PLT, projected long-term prices and costs), with the introduction of the AN prices and AN cost adjustment factor.

However, the use of a price set based on projections (for 1965 by George Brandow) to remove the effect of government programs, reduced benefits to 0.37 of the base level, as shown in Table 6.7. Clearly, the policy decision of what price and cost set to use in evaluations could affect project justification.

Crop Price Data

Without government programs, U.S. net farm income would have been 25-50% lower since 1955; prices received, 10-20% lower; and gross receipts, 5-15% lower, according to Tweeten's summary and critique of several economists' studies.[9] Deflations of this magnitude could significantly affect Federal investment in PL 566 and other agricultural water resource projects, as was just shown by the use of Brandow's prices-received data, and as will be further considered in chapter 7 by use of farm income reductions in the study of 12 Michigan PL 566 projects.

While the discussion of agricultural prices and government programs can become quite involved, the purpose of this section is just to consider the relationship of PLT, AN, USDA average and George Brandow's projected prices.

The selected crop price data in Table 6.6 will serve to illustrate the discussion. The PLT (projected long term) prices[10] were used in SCS evaluations of PL 566 projects over the period 1957-66, until the adoption of the newer AN (adjusted normalized) prices by all agencies

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[9]Luther G. Tweeten, "Commodity Programs for Agriculture," in National Advisory Commission on Food and Fiber, Agricultural Policy: A Review of Programs and Needs (Washington, D.C.: USGPO, 1967), vol. 5 of the Technical Papers, pp. 107-130.

[10]See USDA, ARS and AMS, Agricultural Price and Cost Projections . . . (Washington, D.C.: USDA, September 1957). The PLT prices:

> are not forecasts of future prices. They are based on rigid assumptions of rapid population growth, national prosperity, and a trend toward world peace. Under such conditions, the general level of prices received by farmers and cost-price relationships are not expected to be much different than those prevailing in the period 1953-55. The projections imply some improvement in agricultural cost-price relationships from 1955 levels, reflecting the existence of large surpluses of some commodities and the possibility for some easing in industrial prices which could come from an enlarged industrial capacity and increasing competition. The projections also take account of recent changes that have occurred in supply and requirement expectations of particular crops. In general, the projections reflect the long-term levels that might reasonably be expected with production and requirements in balance under competitive conditions.

Table 6.6. Selected Crop Price Data.

Crop	Unit	PLT, Mich.	1960-64 U.S. avg.	Normalized prices: Current U.S.	Normalized prices: Adjusted AN, U.S.	Brandow projections, 1965, U.S.
Wheat	bu.	$ 1.60	$ 1.77	$ 1.82	$ 1.30	$0.87
Corn	bu.	1.40	1.08	1.09	1.05	0.77
Oats	bu.	0.76	0.62	0.62	0.60	0.41
Barley	bu.	1.12	0.92	0.91	0.85	0.62
Sorghums (56 lb. bu.)	bu.	----	0.98	1.03	0.95	0.68
Hay, all	ton	18.20	22.40	22.00	22.00	
Dry beans, edible	cwt.	6.00	7.14	6.97	7.00	
Sugar beets	ton	15.30	11.90	11.70	11.70	
Soybeans	bu.	2.28	2.38	2.45	2.45	1.35
Cotton	lb.	----	0.314	0.315	0.250	0.21
Tobacco	lb.	----	0.60	0.60	0.60	
Cabbage, fresh mkt.	cwt.	1.95	2.28	2.29	2.29	
Carrots, fresh mkt.	cwt.	1.81	3.32	3.34	3.34	
Celery, fresh mkt.	cwt.	3.30	3.85	3.87	3.87	
Potatoes	cwt.	1.75	2.01	1.70	1.70	
Farm price indexes, USDA, 1910-14 base of 100						
Prices received, all		235	240	243	233	190 (21% < 1959)
Prices received, crops		---	231	236	217	175 (21% < 1959)
Prices paid, all		265	---	---	---	
Prices paid, production items only		---	269	272	272	

Sources: For PLT: USDA, ARS and AMS, Agricultural Price and Cost Projections . . . (Washington, D.C.: USDA, 1957). For AN and related: U.S. Water Resources Council, Interim Price Standards . . . (Washington, D.C.: The Council, April 1966); supplemented by (for vegetable crops) USDA, SCS, Economics Guide Notice 7 (Washington, D.C.: SCS, March 26, 1968). Brandow's projections: Walter Wilcox, "Agriculture's Income and Adjustment Problems," U.S. Congress, Joint Economics Committee, Economic Policies for Agriculture in the 1960's (Washington, D.C.: USGPO, 1960), pp. 14-17.

in the Water Resources Council in 1966. The shift from PLT to AN prices would adversely affect projects with benefits dominated by grains, sugar beets and cotton, because all of these crops suffered price reductions. These crops are directly affected by government programs. Therefore, to obtain their AN prices from their current normalized prices, a slight downward reduction was applied.[11] The current normalized prices are approximately the same as the USDA average for the United States for 1960-64. The PLT sugar beet price includes Sugar Act payments, whereas the AN sugar beet price does not (see Appendix, Table 7). Further adjustments are necessary to obtain prices for particular states from the PLT and AN prices for the United States.

The Water Resource Couuncil's alteration of 1960-64 prices to obtain the AN prices did not remove the full effect of government programs, as suggested by George Brandow's projections for 1965. For grains the AN prices are roughly halfway between the PLT prices and Brandow's. For the sensitivity analysis the author reduced 1959-63

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[11]United States, Water Resources Council, Interdepartmental Staff Committee, Interim Price Standards for Planning and Evaluating Water and Land Resources (Washington, D.C.: The Council, April 1966), p. 2:

> The adjustments in normalized prices to reduce the influence of Government programs are intended to reduce or remove most direct price support effects or payments under such programs rather than the full effects of all production adjustment programs. For crops seriously in surplus, further constraints in the form of additional price adjustments or acreage limitations may need to be applied.

Restrictions on surplus crop production as a primary, dominant source of project benefits are discussed in chapter 2.

prices by 20% to complete the Brandow series (see data in Appendix, Table 7).[12]

Crop Cost Data Adjustments

As explained in chapter 3, costs for various practices and inputs are obtained by the SCS in-state Planning Party from USDA, state agricultural colleges and experiment stations, local suppliers and other sources. SCS uses a crop enterprise rather than farm budget approach. Essentially, a list of inputs and practices is priced for each enterprise for a base year. Then the costs are adjusted downward using a factor that is intended to put crop costs on the same projected basis as the crop prices used in evaluating the watershed investment. The factor is obtained by dividing the proper projected value of the USDA index of prices paid by farmers by the value in the base year. For the PLT factors the all-items index is used, but for the AN factors the production-items index is used.[13]

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[12]Walter Wilcox, "Agriculture's Income and Adjustment Problems," in U.S. Congress, Joint Economics Committee, Economic Policies for Agriculture in the 1960's, 86th Congress, 2d Session (Washington, D.C.: USGPO, 1960). The prices were developed by George Brandow using a demand model for 1965, assuming discontinuance of Federal surplus disposal and storage programs; plus international stability; and upward trends in population, productivity and real income per capita. The USDA's index of prices received by farmers was projected to decline 21% from 1959 using these assumptions.

[13]As shown in Table 6.6, the PLT value for the USDA all-items, prices paid by farmers index is 265, and the AN value, for the production-items index is 272. Using the respective index values from USDA, ERS, Demand and Price Situation, DPS-115 (Washington, D.C.: USDA, February 1968), the author computed the following factors, which may differ from those used by SCS for some years, apparently because preliminary data were used. PLT factors are first: 1960, .88, 1.09; 1961, .88, 1.02; 1962, .86, 1.01; 1963, .85, 1.00; 1964, .85, 1.01; 1965, .83, .99; 1966, .79, .95; 1967, .77, .95. PLT factors and prices were last used

Depending on what happens through time, the cost adjustment factors may either compensate for rising production costs (if the costs and the index actually move together), or decrease the costs used in the evaluation (if costs remain relatively constant, while the index rises).

SCS also applies these cost adjustment factors to project operation-maintenance costs for both associated works (cost item ACOM) and structural works (cost item SCOM). However, the author did not adjust these costs.

Alternative Crop Yields

While many variables affect the project-credited farm income, it is relevant to emphasize the effect of crop yields, because of the comparatively high degree of benefit responsiveness to slight changes in yield assumptions, as shown previously in Tables 6.2-6.4. Yield assumption changes on a by-crop basis are more problematic than those for prices, because yields vary with soil type, climate, water problems, and other factors peculiar to the watershed. While state average yields probably do not represent watershed conditions sufficiently well for SCS usage in project evaluations, 1959-63 state average yields for Michigan correspond surprisingly well with the without-project (Y_1) yields used by SCS for the Mill Creek project, with the exception of vegetable crops, as shown in Appendix, Table 6. USDA's 1959-63 state average yields for Michigan were adjusted to form the necessary without (Y_1) and with project (Y_2) yield sets to use in the SCS benefit computation model of chapter 3.

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[13]by SCS in 1966. See Appendix, Table 1, for factors used by SCS for 12 Michigan PL 566 projects. Also, see footnote 8 on conversions used by the author.

Table 6.7. Effects of Alternative Crop Prices, Costs and Yields.

Assumption change	Benefit component index FWDRB	MILUB	LUCB	Overall	B/C ratio
Base, value	$75,715	$130,362	$74,604	$282,065	6.96
Base, index	1.00	1.00	1.00	1.00	- -
(A) Brandow (no government support) prices, costs for 1960[a,c]					
	0.61	0.47	-0.05	0.37	2.60
(B) State yields (Y_1, -25%; Y_2, +25%), costs for 1960[b,c]					
	0.58	2.05	0.44	1.22	8.53
(C) Prices, costs and yields[a,b,c]					
	0.44	1.07	-0.11	0.59	4.07

Source: Approximations of SCS estimate for the North Branch of Mill Creek watershed and sensitivity analysis variations thereof. FWDRB are for crops only, but overall benefits include minor non-crop FWDRB.

[a]Prices based on projections by George Brandow for 1965, without government programs; see data in Appendix, Table 7.

[b]Yields, based on Michigan state average for 1959-63 (shown in Appendix, Table 6), plus 25% for Y_2 and minus 25% for Y_1, with proportional per-acre AFC cost adjustments for MILUB and LUCB only.

[c]1960 production costs: SCS PLT costs x 1.1236, see main text, footnote 8.

Tables 6.7 and 6.8 can be used to show yield change effects. Alternative B in Table 6.7 shows the effect of using adjusted state average yields for 1959-63, 1960 costs and the original SCS PLT prices, while alternatives A-E, Table 6.8, are similar except that 1959-63 state average prices are used. These 1959-63 prices provide benefit index values quite close to the base value when used in combination with 1960 costs (compare the base index and altnerative A in Table 6.8); therefore, for present purposes this assumption combination will be regarded as an approximate equivalent of the original SCS assumptions.

While it becomes something of a guessing game, a little discussion of which alternative assumptions would approximate the SCS results may be useful. In terms of overall benefits, adjusting 1959-63 state average yields to -25% (for Y_1) and +25% (for Y_2) overshoots the original SCS estimate (see alternative B, Table 6.7). Adjustments of -25% (Y_1) and 100% (no adjustment for Y_2) are about right (see alternative B, Table 6.8). However, yield set 1 would have to be raised above the state average yields to approximate the SCS estimate for FWDRB, and yield set 2 should be raised to bring overall benefits up to the level of the SCS estimate. State yields adjusted to -10% (Y_1) and +10% (Y_2) better approximate the original SCS estimate of MILUB, only slightly improve the FWDRB approximation, and leave overall benefits lower (see alternative C, Table 6.8). Clearly, it is possible to effect a considerable range of overall benefits. Any of a number of alternative yield assumptions would leave the NMBC project with a benefit cost ratio well above 1:1.

Because of the policy constraint on MILUB and LUCB, effects of different yield assumption alternatives are interesting. For example, alternative D, Table 6.8, reduces MILUB (to 54% of the base level) and LUCB (to 43% of the base level), but does not greatly affect FWDRB (84% of the base level), and still provides a benefit cost ratio of 4.14/1.

SCS Yield Assumptions

SCS employs yields for the mid-evaluation-period (some 25 or 30 years in the future from the date of planning), judging by SCS practice in Michigan, 1968-70. The yields themselves are the result of joint agricultural college and USDA efforts. The yields are for various soil management groups, under wet and well-drained conditions, with no specific reference to flood problems in the assumptions of projection. For the example project (evaluated by SCS in 1961 and early 1962), the yields were based on what was believed to be possible at planning time. Thus, as indicated in chapter 3 and further discussed in chapter 8, SCS yield assumptions represent a shift from what is technologically and otherwise possible in the near future to what is possible in the more distant future, that is, for both with and without project conditions. With respect to inputs and input-output ratios, SCS adjusts fertilizer, seed, chemical spray and possibly other input rates for the higher yield levels to obtain the per-acre cost data (AFC data).

The effect of using higher yields (in both with and without project yield sets) would be to increase overall benefits and to emphasize FWDRB, judging by the yield sensitivity analysis for the example projects. Thus, increasing yield set 1 boosts FWDRB; yield set 2 similarly affects LUCB. Simultaneously raising both yield sets 1 and 2 increases MILUB. The overall percentage increase in benefits would at least equal that in yields, and could be two or three times as much.

Conceptualizing the effect of using higher yields to evaluate PL 566 projects requires some appreciation of the SCS-assumed growth patterns for project-credited farm income. FWDRB accrue at their full 100% rate (based on without-project yields and per-acre costs) at time zero in the evaluation period (usually 50 years). However, enhancement benefits (EB) are based on gradual and delayed achievement of the move from without to with project farm income. Despite the use of 15-20 year development periods for the achievement of with-project income levels, the simplifying SCS assumption of instant installation means that 1/2 to 3/4 of the average annual benefit rate accrues at time zero of the evaluation period, taking into account both EB and FWDRB.[14] Because this proportion is so high, and because project benefits are increased by yield increases, it is relevant to question the use of mid-evaluation period yields.

The use of mid-evaluation period yields may be viewed as a proxy for computing yield and farm income data on a year by year basis. Assuming that yields would increase over time, early-year yields are overstated and later-year yields understated by the use of mid-evaluation period yields. The net effect is an overstatement of project-credited farm income in terms of present values. This will be reconsidered in chapter 8.

Multiple Assumption Changes

While previously considered assumption changes were for one variable at a time, Tables 6.7 and 6.8 show the effects of combined price-cost, yield and cropping pattern changes for the Mill Creek project. For all alternatives shown, crop costs are restored to their 1960 level, as estimated by SCS; that is, the SCS reduction to PLT cost levels has been removed. The USDA state average prices for

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[14] SCS-assumed growth patterns for project-credited farm income are discussed in more detail in chapter 7. The proportions cited are from Appendix, Table 3, last column; they are computed as follows: (benefits, time zero) / (average annual benefits), using the SCS definition of benefits in which associated costs are deducted. This is a proxy for the proportion: (project-credited farm income, year zero) / (eventually-achieved farm income). The definition of benefits includes OTHERB (see chapter 7), but excludes secondary benefits; it is not the equivalent of net cash flow, for SCK and SCOM are omitted (see chapter 7).

Michigan, 1959-63, include the effects of government farm programs, but the prices based on George Brandow's projections for 1965 specifically exclude the effects of government farm programs. The 1959-63 state average yields for Michigan are used with several adjustment factors, constant for all crops, and differing for the with and without project yield sets. There are four pairs of yield adjustment factors (I, II, III and IV, as defined in Table 6.8) and their use is repeated in Table 6.8 for alternatives B-E, G-J and M-P. Finally, cropping patterns for economic reach 3 are applied to the other two reaches, thereby transferring benefit dependence from vegetable to field crops, which are perhaps more typical of Michigan agriculture. In Table 6.8 each new assumption change is shown alone (alternatives A, F, K and L) and then combined.

The shift from PLT prices and costs (base index) to 1959-63 state average prices and 1960 costs (alternative A, Table 6.8) did not greatly affect any category of benefits. Both sets of prices include the effects of government programs. To exclude the effects of government programs, prices based on George Brandow's projections were introduced, and all categories of benefits declined significantly (Table 6.8, alternative F). Introducing adjusted 1959-63 state average yields produced varying effects. Progressing through yield-adjustment assumptions I-IV, FWDRB improve, because yield set 1 increases; MILUB and LUCB decrease, because yield set 1 increases and yield set 2 decreases (alternatives B-E and G-J, Table 6.8).

If the negative LUCB benefits were deleted for the most severe of these alternatives (J in Table 6.8), the project would have a benefit cost ratio far below the base level of 6.96/1. Nevertheless, FWDRB would represent about 78% of average annual benefits compared to 27% for the base estimate data. Therefore, altering yield and price assumptions can be viewed as a means of changing the apparent emphasis on various kinds of benefits (see chapter 2).

Flood prevention benefits (FPB)		
FWDRB	$39,817	(+$1,383, non-crop)
FPB-MILUB	5,750	
Sub-total, FPB	$46,950	
Agricultural water management benefits (AWMB)	5,750	
Total benefits, costs, B/C	$52,700	/ $40,520 = 1.30

Introducing economic reach 3 cropping patterns reduces the benefit cost ratio to 1.24/1 (alternative K, Table 6.8), quite close to the base estimate for reach 3 (B/C = 1.22/1), and this demonstrates the importance of vegetable crops (including potatoes) in producing the base level benefit cost ratio (6.96/1) for the Mill Creek project. Even modest price reductions or cost increases would be sufficient to reduce the benefit cost ratio below unity for a project with cropping patterns like those of reach 3, as shown in Table 6.5 (alternatives with superscript a after B/C ratio). For example, restoration of crop costs to the 1960 level, or the use of 1959-63 state average prices with PLT costs, or 1959-63 prices and costs, or the more recent SCS AN prices nd costs.

Assuming reach 3 cropping patterns, 1960 crop costs, and crop prices at remove the effect of government programs reduces the benefit cost tio to -0.50/1. Beyond this, progressing through yield adjustment ctors I-IV for 1959-63 state average yields merely worsens the ratio lternatives M-P, Table 6.8).

Table 6.8. Effects of Alternative Prices, Costs, Yields, and Cropping Patterns.

Assumption changes	Benefit sensitivity indexes FWDRB	MILUB	LUCB	Overall	B/C ratio
Base, value	$75,715	$130,362	$74,604	$282,065	6.96
Base, index	1.00	1.00	1.00	1.00	- -
1959-63 Michigan State average prices (P), 1960 costs (C), and yield (Y) variations[a,b]					
(A) P & C only	1.07	1.07	0.90	1.02	7.13
(B) Y-I	0.70	1.40	0.47	0.96	6.71
(C) Y-II	0.81	0.98	0.49	0.80	5.59
(D) Y-III	0.84	0.54	0.43	0.59	4.14
(E) Y-IV	0.88	0.09	0.37	0.38	2.63
Projected 1965 prices (P), 1960 costs (C), and yield (Y) variations[b,c]					
(F) P & C only	0.61	0.47	-0.05	0.37	2.60
(G) Y-I	0.44	0.85	-0.15	0.48	3.32
(H) Y-II	0.49	0.53	-0.18	0.33	2.23
(I) Y-III	0.51	0.32	-0.22	0.23	1.60
(J) Y-IV	0.53	0.09	-0.25	0.12	0.84
Projected 1965 prices (P), 1960 costs (C), economic reach 3 cropping patterns (R_3), and yield (Y) variations[b,c]					
(K) R_3 only	0.18	0.10	0.30	0.18	1.24
(L) R_3,P&C only	0.11	-0.15	-0.14	-0.07	-0.50
(M) Y-I	0.09	-0.44	-0.30	-0.26	-1.78
(N) Y-II	0.10	-0.50	-0.30	-0.28	-1.94
(O) Y-III	0.11	-0.53	-0.30	-0.29	-2.04
(P) Y-IV	0.11	-0.58	-0.31	-0.32	-2.22

Source: Approximations of SCS estimates for the North Branch of Mill Creek watershed and sensitivity analysis variations thereof. FWDRB are for crops only, but overall benefits include some minor non-crop FWDRB.

[a]Alternative A only uses 1959-63 costs (SCS PLT costs x 1.1363) rather than 1960 costs as stated (SCS PLT costs x 1.1236). See prices, Appendix, Table 7.

[b]Alternative yield sets are based on 1959-63 Michigan State average ields (Y-M), as shown in the Appendix, Table 6, adjusted as follows to btain without-project (Y_1) and with-project (Y_2) yields;

(I) Y_1 = Y-M x 0.75 and Y_2 = Y-M x 1.00;
(II) Y_1 = Y-M x 0.90 and Y_2 = Y-M x 1.10;
(III) Y_1 = Y-M x 0.95 and Y_2 = Y-M x 1.05; and
(IV) Y_1 = Y-M x 1.00 and Y_2 = Y-M x 1.00.

r-acre AFC costs adjusted proportionately for MILUB and LUCB only.

[c]Prices based on projections by George Brandow for 1965, without vernment programs; see data, Appendix, Table 7.

Alternative Cropping Patterns

Cropping pattern data are critical in determining project benefits. The use of reach 3 cropping patterns for all reaches of the Mill Creek project would reduce the benefit cost ratio from the base level of 6.96/1 to 1.24/1, as shown in Table 6.8 (alternative K). The effect of altering cropping patterns may be suggested by the data in Table 6.9. When cropping patterns and by-crop loss values are multiplied and summed for all crops they provide the composite acre values (CAV, typical acre loss values for the floodplain), which are used in conjunction with acreage flooded data to determine floodwater damages (FWD) and reduction benefits (FWDRB), as explained in chapter 3.

The differences between composite acre values for reaches 1, 2, and 3 are due to cropping pattern differences (Table 6.9). Depth of inundation effects are by comparison insignificant.[15] Cropping intensification to the with-project economic level[16] is less important than broader

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[15]Tolley and Freund similarly conclude that the type of agriculture represented here by cropping patterns is quite important. However, the author is more inclined to reviewer Cohee's comment that probabilities of error associated with hydrological data should not be lightly dismissed; Tolley and Freund assign probabilities to different variables, and indicate that those associated with the type of agriculture require the most judgment, whereas those dealing with hydrology are more objective. This may be, but FWDRB are extremely sensitive to changes in hydrological assumptions, as shown in chapter 5.

See George S. Tolley and Ralph Freund, Jr., "Does the State of the Data Suggest a Program for Modifying Planning and Evaluation Procedures?" with comment by Melville H. Cohee, in G. S. Tolley and F. E. Riggs, Economics of Watershed Planning (Ames, Iowa; The Iowa State University Press, 1961), pp. 127-147.

[16]CAV for the intensified cropping situation assume Y_2, per acre costs based on AFC_2, and with-project cropping patterns based on 100% completion and achievement of the MILUB and LUCB initial net return levels.

Table 6.9. Cropping Patterns and Crop Contributions to FWDRB.

Crop	Per-acre, level 1, depth 1, loss, $	Percentage of the floodplain planted to the crop			Percentage of FWDRB contributed by the crop		
		reach 1	reach 2	reach 3	reach 1	reach 2	reach 3
Corn, grain	$ 22.59	8.2%	17.9%	11.3%	2.9%	13.4%	29.0%
Corn, silage	23.00	1.6	3.0	5.0	0.6	2.3	13.1
Oats, grain	5.65	1.4	5.0	8.1	0.1	0.9	5.2
Wheat, winter	11.78	6.5	6.1	8.1	1.2	2.4	10.8
Navy beans	18.81	-0-	3.1	16.3	-0-	1.8	34.9
Sugar beets	110.72	11.9	5.5	-0-	17.7	16.6	-0-
Clover hay	3.18	-0-	6.0	16.3	-0-	0.6	5.9
Alfalfa hay	7.39	11.5	7.5	-0-	1.3	1.8	-0-
Permanent pasture	1.66	-0-	9.7	8.3	-0-	0.4	1.1
Lawn grass sod	0.99	4.4	-0-	-0-	0.1	-0-	-0-
Potatoes	94.11	23.8	11.7	-0-	35.1	34.5	-0-
Onions, fresh mkt.	120.07	2.4	-0-	-0-	4.5	-0-	-0-
Carrots, fresh mkt.	109.38	12.8	4.9	-0-	22.0	16.8	-0-
Celery, fresh mkt.	218.46	2.9	-0-	-0-	9.9	-0-	-0-
Cabbage, fresh mkt.	86.18	1.4	2.4	-0-	1.9	6.5	-0-
Lettuce, fresh mkt.	90.74	1.0	-0-	-0-	1.4	-0-	-0-
Cucumbers, fresh mkt.	44.46	1.6	1.5	-0-	1.1	2.1	-0-
Total		91.4%	84.3%	73.4%	100.0%	100.0%	100.0%
Composite acre values, by reach, output level and depth of inundation, dollars							
Level 1, depth 1		$63.67	$31.49	$ 8.80			
Level 1, depth 2		68.27	36.01	11.74			
Level 2, depth 1		86.66	49.05	16.74			
Level 2, depth 2		93.38	56.17	22.02			

Source: Approximation of SCS estimates for the Mill Creek project; data in columns for FWDRB may not add to total because of rounding.

changes in the type of agriculture, represented by the shift from predominantly vegetable crop and sugar beet farming (reach 1 data, Table 6.9) to field crop farming (reach 3 data).

Cropping patterns are expressed in Table 6.9 as percentages of the floodplain acreage devoted to each crop, but differ from those indicating the proportion of FWDRB associated with each crop. For reach 1, 3/4 of the FWDRB, but only 1/2 of the acreage is represented by sugar beets, potatoes and carrots. These crops account for 1/2 of the FWDRB and 1/4 of the area for reach 2. Going to reach 3, navy beans and clover hay occupy the same acreage, but navy beans account for over 1/3 of the FWDRB, and clover hay, about 6%. Winter wheat is grown in all 3 reaches, occupying 6.5%, 6.1% and 8.1% of the respective areas, and it accounts for 1.2%, 2.4% and 10.8% of the FWDRB for reaches 1, 2 and 3.[17]

Summary

The three categories of crop benefits for PL 566 projects in agricultural watersheds, FWDRB, MILUB and LUCB, differ in sensitivity to changes in crop price, cost and yield data. Increments or decrements for each of these variables were introduced into the SCS model as constants for all crops, for the range 10% to 50%, by units of 10%. Benefit responses remained constant over the considered range, with coefficients of response varying from one to about eight. FWDRB are

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[17]The cropping pattern and benefit percentages differ for FWDRB, MILUB, LUCB and overall benefits. Regarding the several cropping pattern sets, see John Vondruska, Estimating Small Watershed Project Benefits: A Computer Systematization of SCS Procedures (East Lansing, Michigan: Department of Agricultural Economics, Michigan State University, February 1969), pp. 58-59 (discussion of R).

generally least sensitive, whereas MILUB and LUCB are extremely sensitive to yield changes. The response of MILUB to simultaneous yield set 1 and 2 changes is far less, ranking with those for prices and costs.

Judging by the Mill Creek project, PLT (projected long term), AN (adjusted normalized) and Michigan state-average (1959-63) prices and the respective crop-cost adjustments provide about the same level of benefits. Using 1964-66 state-average prices and the PLT crop-cost level virtually doubled benefits, but benefits were considerably reduced when the comparable 1964-66 cost adjustment factor was applied. On the other hand, using a price set based on projections (by George Brandow, for 1965) to remove the effect of government programs and 1960 crop costs reduced the benefit cost ratio to 2.60/1 (about 1/3 of the base ratio of 6.96/1).

Because project benefits are quite sensitive to crop yield changes, it is relevant to consider the assumptions underlying the yield data. As will be explained in chapter 7, the with-project level of farm income is achieved quite rapidly in the evaluation period (see Figures 7.3 and 7.4). According to SCS practice in Michigan (in the late 1960's), mid-evaluation-period yields are used, but they would appear to result in overstated benefits, as will be discussed in chapter 8.

Project benefits are also sensitive to cropping-pattern assumption changes.

The combined effects of adverse assumption changes of the type considered in this chapter are sufficient to reduce even a rather high benefit cost ratio to unity or below. The assumptions studied in this chapter affect the level of project-credited net farm income and they

will be taken up again at the close of chapter 7, as part of a study of 12 Michigan PL 566 projects.

CHAPTER VII

INVESTMENT CRITERIA: BENEFIT AND COST TIMING, PATTERN AND LEVEL ASSUMPTIONS

Twelve Michigan PL 566 project evaluations are studied in this chapter, with emphasis on benefit and cost timing and pattern changes. The sections include the following: methodology and investment criteria, ranking projects, interest rates, enhancement benefits analysis, cash flow timing and instant installation, FWDRB (floodwater damage reduction benefits) redefined, adverse farm income and capital cost changes, and summary.

The twelve projects have work plans dating from 1959 to 1968, and are primarily oriented toward assisting farmers to improve their income or asset situations via flood control, drainage and irrigation (Sturgeon only). However, the Sturgeon emphasizes natural resource investments for recreation, as does the more recent Maple River project group, which is not studied here. Detailed data were not available for some projects; hence, they are not studied here. As in chapters 5 and 6, project base estimate data are developed for comparison with sensitivity analysis results.

Data for the twelve PL 566 projects were obtained from SCS files, and supplemented by other data from work plans. However, for some projects, SCS prepared subsequent, supplementary work plans and

supporting documentation (in SCS files). The projects' data are shown in the Appendix, Tables 1-5.

Methodology and Investment Criteria

In this section consideration will be given to the mathematical formulation of investment criteria used in chapter 7. While some other criteria are studied, only three will be employed throughout the chapter: the SCS B/C (the SCS annual benefit cost ratio), the IRR (the internal rate of return), and the NPV sum (net present value sum) for all 12 Michigan projects. In all cases secondary benefits are excluded.[1]

The SCS Benefit Cost Ratio (SCS B/C)

The SCS B/C computational routine provides numerical benefit cost ratios that are the equivalent of those that would result from use of actual SCS procedures described in chapter 3.[2] The SCS annual benefit cost ratio may be simply formulated as

$$\text{SCS B/C} = (\text{FWDRB} + \text{EB} + \text{OTHERB}) \, / \, (\text{SCK} \times A_4 + \text{SCOM})$$

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[1]Based on discussions with John Okay, economist with the SCS Planning Party in Michigan, in late 1969, secondary benefits may not be used to justify a project, i.e., to bring its benefit cost ratio above unity, but they may be used to supplement a ratio already above unity. Their use seems ambiguous to the author and subject more to agency directives or non-written understandings than to long-standing policy. The agency's policy-procedural guide condones use of non-national, regional or local secondary benefits, in compliance with Senate Document 97 (of 1962); see USDA, SCS, Watershed Protection Handbook (Washington, D.C., SCS, 1967), secs. 102.02213 and 102.02214.

[2]Regarding reconciliation of the author's base estimates for chapters 5-7 and the SCS agency estimates, see chapter 1 and also footnote 19 in chapter 3. The two sets of B/C ratios are shown in Appendix, Table 3 and differ usually by less than 5 percent.

In words, it is the comparison of annual benefits to annual costs, with mainstream project costs amortized in the denominator of the ratio (SCK x A_4). Rather than compute EB (enhancement benefits) as in chapter 3 (following SCS procedures), the author has chosen to compute EB cash flows for all years in the evaluation period (years t = 1, ..., T, where T = 50 or 100). These cash flows differ from those computed for alternative, non-SCS investment criteria in that amortization factors are used. SCS B/C is computed as follows:

$$\text{SCS B/C} = (\text{FWDRB} + \text{OTHERB} + \text{EB}) \,/\, (\text{SCK} \times A_4 + \text{SCOM}), \text{ and}$$

$$\text{EB} = A_3 \times \{\sum_t^T \sum_{if}^3 [\text{DNR}_{if} - (\text{ACK}_{if,1} \times A_1) - (\text{ACK}_{if,2} \times A_2) - \text{ACOM}_{if} - \text{FWDC}_{if}] \times P_{1,if,t} / (1 + r_3)^{t-1}\}$$

Variables are defined as follows:

A: an amortization factor; generally used to determine equal annual loan repayments over a period of years including both principal and interest; used by SCS to convert capital or present values into annual equivalents. Interest rates and amortization periods differ by project (see Appendix, Table 2, including footnote b).

The use of amortization factors is discussed later in this section.

Factor	Interest	Period	Use
A_1	r_1	15-50 yrs.	$\text{ACK}_{if,1}$ amortization
A_2	r_2	25-50 yrs.	$\text{ACK}_{if,2}$ amortization
A_3	r_3	50-100 yrs.	EB amortization
A_4	r_4	50-100 yrs.	SCK amortization

ACK: associated capital costs for on-farm ($\text{ACK}_{if,1}$) and inter-farm ($\text{ACK}_{if,2}$) works of improvement; excludes SCK.

ACOM; annual operations-maintenance cost for ACK; excludes SCOM.

DNR; difference between with and without project net returns (net farm income, annual, see chapter 3, including Tables 3.5 and 3.7); exclude FWDRB.

EB; enhancement benefits (annual).

FWDC: change in with-project floodwater damages (annual) resulting from computing damages at the without-project level of economic activity and the increase in damages due to intensification of economic activity (see chapter 3, Table 3.7, footnotes 15 and 16, and chapter 6, footnote 4).

FWDRB: floodwater damage reduction benefits (annual), the difference between with and without project damages; $FWDRB = FWD_1 - FWD_2$. Crop FWDRB are one form of project-credited farm income, exluding DNR.

OTHERB: annual, non-FWDRB and non-EB benefits; exclude secondary benefits.

P: the proportion of the initially-estimated EB cash flows achieved in any one year; maximum P ranges from 75% to 100%, depending on the project (see Appendix, Table 2, including footnote c).

r: an interest rate (see A, amortization factor, preceding, and Appendix, Table 2, for rates used by SCS); as many as four rates may have been used by SCS in evaluating each of the 12 studied projects.

SCK: structural capital costs for major mainstream works; exclude ACK.

SCOM: annual operations-maintenance costs for SCK; see ACOM.

Values used for these variables are shown in Appendix, Tables 1-3.

Subscripts are defined as follows:

if: EB cash flows (DNR, ACOM, FWDC and amortized ACK) are usually divided into components by SCS, and separate EB achievement rates ($P_{1,if,t}$) are applied to compute annual cash flows for any year t.

For the EB sub-category more intensive land use benefits (MILUB), if = 1.

For the EB sub-category land use change benefits (LUCB) associated with land formerly in permanent pasture or idle uses, if = 2.

For LUCB associated with land formerly in farm woods, if = 3.

To obtain the sum of all cash flows for any one year (t), it is necessary to sum over the range if = 1-3. For some projects, SCS used only one or two categories of EB (see Appendix, Table 2, including footnotes c-g), and in this case the additional variable values were set to equal to zero for purposes of computer programming.

t: refers to a year, t = 1, ..., T, where T = 50 or 100 years, the evaluation period length.

The computation of EB (enhancement benefits) is the most complicated operation in obtaining SCS B/C, an annual benefit cost ratio. Prior to discounting, summation over t, and application of the amortization factor A_3 in the formulation of EB, annual combined EB cash flows during the evaluation period may be visualized as a polygon as in Figures 7.3 and 7.4. Time is measured along the horizontal axis, and the height of the polygon for any year t is determined by the proportion $P_{1,if,t}$. SCS procedures involve slicing the polygon into horizontal segments (see chapter 3, Table 3.8), while the approach used in this chapter involves slicing the polygon into vertical segments, with one vertical segment for each year t (where t = 1, ..., T, and where T = 50 or 100 years). In either case the segments are discounted and summed to obtain a present value which is then amortized. According to SCS assumptions the combined EB annual cash flows (DNR, ACOM, FWDC and amortized ACK) are a single entity which intially grows after the fashion of a decreasing rate growth curve (as in Figure 7.3), but with linear approximations. Subsequently, the combined EB annual cash flow rate reaches a maximum and becomes constant after the growth period is completed (after 15-30 years, depending on the project). The maximum annual EB cash flow rates are determined by the maximum value of the proportion $P_{1,if,t}$, and this is in the range of 75 to 100%, depending on the project (as shown in Appendix, Table 2, columns 12 and 16).

The SCS instant installation assumption[3] complicates the matter in that all annual cash flows are advanced five years with respect to EB. Thus, the linear approximation of a growth curve in Figure 7.3 and repeated in Figure 7.4a becomes the linear approximation shown in Figure 7.4b, as will be discussed and studied later in this chapter. For Mill Creek the MILUB farm income difference (DNR_1 = \$258,042), 35% is achieved at time zero (beginning of year 1) with instant installation, another 25% is added in equal increments (5% per year) over years 2-6, and still another 20% is added in equal increments over years 7-16 (2% per year), with flows counted as occurring at the beginning of each year. The sum of these percentages is 80% which is the maximum $P_{1,if,t}$, and the farm income difference (DNR) reaches the level of \$206,434 (\$258,042 x .80) in years 16-50 of the evaluation period. The other components of EB grow in similar fashion.

Alternative Investment Criteria

As previously indicated, the SCS B/C is a computational routine that provides numerical benefit cost ratios that are the equivalent of those obtained using SCS procedures, as in chapter 3. Other kinds of investment criteria used in this chapter include the IRR (internal rate of return), sum of NPV's (net present values) for all 12 projects, and the PV B/C (present value benefit cost ratio). One difference between the SCS and these other criteria is that SCS employs amortized capital cost flows, whereas the other criteria employ capital cost flows. Another difference is that SCS uses multiple interest rates in each project

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[3]USDA, SCS, Watershed Protection Handbook (Washington, D.C.: SCS, 1967), sec. 102.0211.

evaluation. This is done only with the SCS NPV among the alternative, non-SCS criteria, as will be described later. Single interest rates are used in other criteria that are alternative to the SCS criterion, but it should be pointed out that multiple rates may be entirely appropriate from a policy standpoint; they can be used with NPV and B/C computations, and even with Robert Marty's modification of the IRR, called the composite internal rate of return, as described briefly in chapter 4.[4] The question of how to develop suitable capital cost flows is more difficult, and this will be taken up following the general introduction of the alternative, non-SCS criteria formulations.

Following McKean and others, the author will define investment to mean a negative net cash flow ($b_t - c_t$). A positive net cash flow is counted as a receipt. In this definition there is no distinction between capital costs (SCK and ACK) and recurring costs (operations maintenance costs, SCOM and ACOM). Capital cost (SCK + ACK) is not the same in meaning as investment.[5]

Thus, $(\text{net cash flow})_t = (b_t - c_t)$, without reference to whether c_t represents a capital cost or recurring cost or both. More formally:

$$(\text{net cash flow})_t = AN + \sum_{if}^{3} [(DNR_{if} - FWDC_{if} - ACOM_{if}) \times P_{1,if,t} - (ACK_{if,1} + ACK_{if,2}) \times (P_{1,if,t} - P_{1,if,t-1})]$$

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[4]On the use of multiple rates to distinguish publicly and privately borne benefits and costs, see Kenneth J. Arrow and Robert C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," American Economic Review vol. 60, no. 3, June 1970, pp. 364-387. Also, see Robert Marty, "The Composite Internal Rate of Return," Forest Science, vol. 16, no. 3, September 1970, pp. 277-279.

[5]Roland McKean, Efficiency in Government Through Systems Analysis (New York: John Wiley and Sons, Inc., 1958), pp. 76-77, 114-116 and 122.

evaluation. This is done [illegible]

non-GIS criteria, as will [illegible]

used in other criteria [illegible]

It should be pointed out [illegible]

from a policy standpoint [illegible]

not read with Robert Gray [illegible]

composite internal rate [illegible]

The question of costs [illegible]

unit, and this will be [illegible]

alternative, non-GIS unit [illegible]

Following McKean and [illegible]

when a negative net cash [illegible]

counted as a receipt. [illegible]

between capital costs ([illegible]

maintenance costs, WCON will [illegible]

the same in meaning as in [illegible]

Thus, (net cash flow)$_t$ [illegible]

R_t represents a capital cost [illegible]

$$(\text{net cash flow})_t = [\text{illegible}]$$

[illegible]

On the use of multiple rates [illegible] and relatively [illegible] some benefits and costs, see [illegible] Uncertainty and the Evaluation of [illegible] American Economic Review vol. [illegible], no. [illegible] also Robert Jerry, "The Composite Internal Rate of Return," Forest Science, vol. 10, no. 3, September 1964, pp. [illegible]

Roland McKean, Efficiency in Government Through Systems Analysis (New York: John Wiley and Sons, Inc., 1958), [illegible]

If $t > 1$, AN = FWDRB + OTHERB - SCOM.

If $t = 1$, AN = FWDRB + OTHERB - SCOM - SCK.

If $t = 1$, $P_{1,if,t-1} = 0$.

An exception occurs if the SCS instant-installation assumption is dropped, in which case an SCK_t is specified for years 1-5. If (net cash flow)$_t$ is negative, it is added to the C (investment) present value sum; if it is positive, it is added to the B (net receipt) present value sum.

$$B = \sum_{t}^{T} [(\text{positive net cash flow})_t \ / \ (1 + r)^{t-1}]$$

$$C = \sum_{t}^{T} [(\text{negative net cash flow})_t \ / \ (1 + r)^{t-1}]$$

For any one year (t) the net cash flow will be either positive or negative. Thus, each year will contribute a net cash flow to either the B (net receipt) sum or the C (investment) sum, but not to both. This is emphasized because other definitions are possible.

Using B (net receipt sum) and C (investment sum) as defined here, the present value benefit cost ratio PV B/C = B/C which is not the same as SCS B/C. The net present value NPV = B - C. The internal rate of return IRR is the rate of discount for which NPV = 0.[6]

As previously mentioned, the author computed data for the SCS NPV which is a net present value, like the NPV just discussed, except that SCS-assumed multiple interest rates were used in place of a single

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[6]The computed IRR's are approximate and are associated with a slightly positive, rather than zero NPV. They are the lowest discount rates with a positive NPV computed to the nearest 0.1 of a percentage point. For example, if the computed IRR = 5.0%, the NPV is slightly positive, and for r = 4.9%, the NPV is negative.

If $t > 1$, ΔS = PVOAS ...

If $t = 1$, ΔS = PVOAS ...

If $t = 1, 7, 11$ ...

An exception occurs if ...

dropped, in which case ...

cash flow), is negative ...

value sum, if it is positive ...

present value sum.

$$B = \sum_{t}^{T} \text{(positive ...)}$$

$$C = \sum_{t}^{T} \text{(negative ...)}$$

For any one year (t) the ...

negative. Thus, each year ...

the B (net receipt) sum or ...

This is maintained because ...

Using B (net receipt) ...

the present value benefit ...

same as SCS B/C. The net present ...

rate of return IRR is the rate ...

As previously mentioned, the ...

NPV which is a net present value ... (net discounted) sum, ...

that SCS-assumed multiple interest ... used in place of a single

---

The computed IRR's are ... not calculated with a slightly positive, rather than zero NPV. This was the lowest discount rate with a positive NPV computed to the nearest 0.1 of a percentage point. For example, if the computed IRR = 5.0%, the NPV is slightly positive, and for r = 4.9%, the NPV is negative.

interest rate. Interest rates r_1, r_2, r_3 and r_4 are employed in a manner that appears to be compatible with SCS usage, although complete compatibility is not possible. Rates r_1 and r_2 are used to discount ACK_1 and ACK_2 capital cost flows respectively. Rate r_3 is used to discount non-ACK components of EB (DNR, ACOM and FWDC). Rate r_4 is used to discount FWDRB, OTHERB and SCOM, all of which are constant for all years in the evaluation period. Complete compatibility with SCS assumptions is not possible, because SCS amortizes ACK's using rates r_1 and r_2, combines these amortized ACK cash flows with other EB annual cash flows (DNR, ACOM and FWDC), discounts the combination at rate r_3 for summation into a present value, and then amortizes this EB present value into an annual equivalent value using rate r_3. Furthermore, there may be some question as to whether rate r_3 or rate r_4 should be used to discount FWDRB, OTHERB and SCOMB to best reflect SCS assumptions, although this question does not arise for the more recently evaluated of the 12 studied projects, since for these projects $r_3 = r_4$.

ACK Investment Rates for Alternative (Non-SCS) Investment Criteria

SCS applies the analogs of EB achievement rates $P_{1,if,t}$ to the combined EB annual cash flows (EB-100% in Table 3.8, chapter 3, i.e., the alebraic sum of DNR, ACOM, FWDC and amortized ACK) in a way that can be readily used in formulating SCS B/C, as described earlier in this section. In effect these combined EB cash flows increase after the fashion of a decreasing-rate growth curve during the EB development period, after which they become constant at a rate determined by the maximum value of the EB achievement rate variable $P_{1,if,t}$ (see

Figure 7.3). For the alternative, non-SCS investment criteria, non-ACK or recurring annual cash flows (DNR, FWDC and ACOM) follow the same pattern during the evaluation period. However, the ACK cash flows follow an investment rate pattern based on the EB achievement rate difference $P_{1,if,t} - P_{1,if,t-1}$ (with $P_{1,if,t-1} = 0$ for $t = 1$) during the EB development period, after which they become constant (at a zero or other rate, as explained later in this chapter). Thus, for the alternative, non-SCS investment criteria the ACK investment-rate cash flows decline gradually during the EB development period.

Disregarding non-ACK cash flow components of EB, undiscounted ACK cash flows for any year t for the SCS B/C are obtained as:

$$ACK_t = \sum_{if}^{3} \{[(ACK_{if,1} \times A_1) + (ACK_{if,2} \times A_2)] \times P_{1,if,t}\}$$

For the non-SCS investment criteria ($P_{1,if,t-1} = 0$ for $t = 1$):

$$ACK_t = \sum_{if}^{3} [(ACK_{if,1} + ACK_{if,2}) \times (P_{1,if,t} - P_{1,if,t-1})]$$ assuming the ACK economic lives equal the evaluation period in years (as discussed later in this chapter). In the SCS B/C the ACK_t is an amortized annual cash flow, reduced by the proportion $P_{1,if,t}$, and in the non-SCS investment criteria the ACK_t is a portion of the total capital cost investment (ACK, ignoring SCK). For example, suppose: ACK = \$1,000,000, one EB component (thereby summation over subscript "if" is superfluous), and amortization at 6% interest over 50 years (amortized ACK cash flows, ACK x A = \$63,440). And $P_{1,if,t}$, .35 at time zero (first part of year 1), increases .25 over years 2-6 (.05 per year beginning one year hence), and increases another .20 over years 7-16 (.02 per year), for a maximum $P_{1,if,t}$ of .80 for years 16-50 of the evaluation period. ACK cash flows are as follows:

Year	$P_{1,if,t}$	ACK_t for SCS B/C (amortized)	ACK_t for non-SCS criteria (investment rate)
1	.35	$22,204	$350,000
2	.40	25,376	50,000
...			
7	.60	39,333	20,000
...			
16-50	.80	50,752	-0-

Amortization, Cash Flows and Discount Factors

For both the SCS and alternative, non-SCS investment criteria, the present values of discounted ACK cash flows are obtained as follows:

$$\text{PV of ACK cash flows} = \sum_{t}^{T} [ACK_t \;/\; (1 + r)^{t-1}]$$

At 6% interest the sums are $702,981 (using amortization) and $670,616 (using investment rate ACK_t data), respectively. Actually, either could be used in computing an SCS annual benefit cost ratio, but the equivalent of the former is used by SCS, and it results in a lower ratio than if the sum $670,616 is used, disregarding other cash flows. The difference has to do with the technical point that the discount-factor power t is more consistent with the definition of amortization than the power t-1. However, any overstatement of ACK deductions (reducing the benefit cost ratio) is outweighed by the effect of using the discount-factor power t-1 rather than t on all EB annual cash flows for years t = 1-T (where T = 50 or 100), thereby increasing the benefit cost ratio.

Recall that SCS used as many as four different amortization factors in evaluating some of the 12 studied PL 566 projects. Two of these, A_3 and A_4, appear to be rather straightforward in effect, since they both are used to convert a present value into an annual equivalent for use in the SCS annual benefit cost ratio. However, A_1 and A_2, even A_4, distract attention from critical variables, the capital cost investment rates. The numerical data given in the preceding paragraph compare the present value of ACK amortized cash flows ($702,981) and ACK investment rate flows ($670,616), but both flows are based on the SCS enhancement benefits achievement rates $P_{1,if,t}$.

Do enhancement benefits achivement rates $P_{1,if,t}$ represent a realistic specification of ACK cash flow rates, that is, ACK investment rates? SCS work plans specify a much faster rate and more complete degree of land treatment investment than do the $P_{1,if,t}$ data for ACK. The difference is significant, as will be shown later in this chapter.[7]

Technically, using the discount-factor power t rather than t-1 is consistent with the definition of amortization. For example, given an amortized flow (at interest rate r, for N years) of $20, this can be obtained as $\$20 = A_{r,N} \times \sum_{t}^{N}[\$20 / (1 + r)^t]$, whereas the discount-factor power t-1 would give a value larger than $20 on the left side of the equation. The amortization factor is computed as follows:

$$A_{r,N} = \frac{r}{[1 - 1 / (1 + r)^N]}$$

[7]The ACK_t cash flows for any year t are based on the EB achievement rates $P_{1,if,t}$ for the SCS B/C and on the achievement rate difference $P_{1,if,t} - P_{1,if,t-1}$ (with $P_{1,if,t-1} = 0$ for t = 1) for alternative, non-SCS criteria, as explained earlier in this chapter. SCS procedures, as incorporated in SCS B/C in this chapter, apply EB achievement rates $P_{1,if,t}$ to amortized ACK cash flows which are a part of the entity of all EB cash flows (DNR, ACOM, FWDC and amortized ACK cash flows). This may be done as a matter of simplification by SCS. When transferred to non-SCS investment criteria the EB achievement rate differences ($P_{1,if,t} - P_{1,if,t-1}$, with $P_{1,if,t-1} = 0$ for t = 1) provide a rather slow and partial completion of ACK investments. Much faster rates of completion (5 year as opposed to 15-30 year) and higher degrees of completion (100% as opposed to about 80% typically) are shown in typical SCS work plans for the land treatment investment in a watershed. These land treatment investment rates are applied to ACK investments in the section of this chapter on cash flow timing and instant installation. Project NPV's, IRR's and B/C's are reduced significantly.

For comparison, using the power t in forming the present value sum of ACK_t cash flows in the preceding example gives the sum \$663,190 and this is less than the sum using the discount-factor power t-1, \$702,981, where ACK_t is an amortized flow ($ACK \times A_{6\%,50\ yrs.} \times P_{1,if,t}$). The lower of these two sums is reasonably close to the sum \$670,616, which is obtained using the power t-1 and investment-rate ACK_t cash flows [$ACK_t = ACK \times (P_{1,if,t} - P_{1,if,t-1})$, where $P_{1,if,t-1} = 0$ for t = 1]. However, for consistency, the author used the discount factor t-1 in both SCS B/C and the alternative, non-SCS investment criteria. The discount-factor power t-1 seems to reflect SCS procedures as used in the 12 studied projects, as discussed for the Mill Creek project in chapter 3 (see Table 3.8 where 35% of \$120,211, the EB-100% value, is counted at full value, the equivalent of counting a cash flow at time zero, the beginning of year 1, meaning the discounting of cash flows with the discount-factor power t-1 and not t).

Again, another point to keep in mind is that using the discount-factor power t-1 increases the present value of any net cash flow $(b - c)_t$. Given the typical cash flow patterns for a PL 566 project, this results in a higher numerical value for the SCS annual benefit cost ratio or any other investment criterion than if the discount-factor power t is used.

Some investment analyses use the discount-factor power t-1 for capital cost cash flows and the power t for project-credited income. The rationale is that capital cost flows occur at the beginning of the year and income later in the year. Implicitly, this means a causal relationship between the two flows for one year. As indicated in chapter 3 and later in this chapter, capital cost cash flows are in themselves insufficient to result in the project-credited farm income, because management choices involving changes in crop input combinations, use rates and practice timing are also necessary. Furthermore, SCS assumes changes in output combinations. One might expect some increase in income due solely to the capital investments, but not as much as SCS credits to a project, based on the assumption that these several complementary changes will occur.

To summarize, SCS uses amortized ACK data and computes an annual benefit cost ratio in such a way that obtaining present value sums by using the discount-factor power t-1 rather than t is implied. While this decreases the benefit cost ratio in terms of the effect of ACK alone and is inconsistent with the definition of amortization, the overall impact is to increase the ratio, since net cash flows for any one year are generally positive. Thus, cash flows for all years in the evaluation period are counted as occurring at one year intervals beginning at time zero (the beginning of year 1), then one year hence (the beginning of year 2), then two years hence (at the beginning of year 3), ..., and finally T-1 years hence (at the beginning of year T). Some economists recommend discounting capital cost flows by the power t-1 and other annual cash flows by the power t, assuming within-year causality. Any one of these differences will affect the apparent worth of a project to some extent, regardless of the investment criteria used. In the author's judgment one of the most significant problems with the use of amortized ACK cash flows is that the combined EB cash flows (the algebraic sum of DNR, FWDC, ACOM and amortized ACK) are treated as a single entity with a single accrual or growth pattern, whereas there is reason to believe ACK investment cash flows are made at a much more rapid rate than is suggested by the EB achievement rate data $P_{1,if,t}$. This is not to deny the relevance or impact of any of these other possible changes.

Post EB Development Period ACK
Investment Rates for Non-SCS Criteria

As previously indicated, ACK cash flow or investment rates for alternative, non-SCS investment criteria are determined by EB achievement rates for any year t as follows (with $P_{1,if,t-1} = 0$ for t = 1):

$$ACK_t = \sum_{if}^{3} [(ACK_{if,1} + ACK_{if,2}) \times (P_{1,if,t} - P_{1,if,t-1})]$$

Recall that the EB achievement rate $P_{1,if,t}$ reaches a maximum after the EB development period, meaning after the first 15-50 years of the 50-100 year evaluation period, depending on the project. In the previously cited example, the maximum $P_{1,if,t} = .80$ occurs in year 16 and remains constant over years 16-50. For these years no ACK investment occurs since the ACK economic lives equal the evaluation period in years.

However, if the ACK investment has an economic life shorter in length than the evaluation period, replacement investment is required. In the SCS B/C this is handled by using an ACK amortization factor based on a shorter period of time. For simplicity the author assumed for non-SCS criteria a constant rate of ACK replacement investment flows for projects in which SCS assumed that the ACK economic life was less than the evaluation period in years. Other patterns of replacement investment could have been assumed. Essentially, the eventually completed amount of ACK investment is re-invested after the initial ACK life has been completed.

Continuing the previous example, suppose that the ACK economic life were 25 years instead of 50 years, then $ACK_{t=26-50}$ = \$32,000. That is, 80% of the initially estimated ACK investment of \$1,000,000 is assumed to be completed eventually, and this along with the ACK economic life determines the amount of the replacement ACK investment for years 26-50 as follows:

\$32,000 = \$1,000,000 x .80 / 25 year ACK economic life

More generally, ACK replacement investment rates for years beyond the initial ACK economic life period are determined as follows:

$$ACK_t = \sum_{if}^{3} [(ACK_{if,1} + ACK_{if,2}) \times (\text{maximum } P_{1,if,t}) / (\text{ACK life})]$$

for t>(ACK economic life) to t = T.

This explanation has been simplified a bit in that the on-farm ($ACK_{if,1}$) and inter-farm ($ACK_{if,2}$) investments require separate treatment in some cases. Actually this computation is required for only 3 of the 12 studied projects to show the effect of SCS assumptions in the base estimates for the non-SCS investment criteria (Table 7.1). However, the computation is required for all 12 projects for certain sensitivity analysis alterations of SCS assumptions, as discussed later in this chapter.

Maximum or eventually-completed EB achievement rates $P_{1,if,t}$ are shown in Appendix, Table 2 (columns 12 and 16), along with the SCS-assumed ACK economic lives (columns 5 and 7) and evaluation period lengths (column 3).

Base-Estimate Investment Criteria Data

Computed data for several investment criteria are shown in Table 7.1. The SCS B/C computational routine provides annual benefit

Table 7.1. Investment Criteria Base Estimate Data, 12 Michigan PL 566 Projects, 1959-68.

Project name	Project date	SCS B/C, ratio[a]	PV B/C at 5%, ratio	IRR	NPV at 5% $1000's	SCS NPV[a] $1000's
Black	1963	2.85	2.08	9.5%	$ 136	$ 275
Cass, M.	1963	3.12	2.07	9.1%	753	1,670
Cass, S.	1961	1.69	1.26	6.2%	658	1,423
Catlin	1966	1.75	1.39	6.7%	52	159
Farm Creek	1965	1.22	0.97	4.8%	-2	27
Jo Drain	1964	1.51	1.22	6.2%	69	246
Little	1962	1.33	1.03	5.1%	6	55
Misteguay	1959	9.17	3.29	14.3%	6,241	8,061
Muskrat	1959	4.97	2.44	12.3%	263	199
Mill Creek	1962	7.35	5.21	22.7%	4,574	5,718
Sturgeon	1966	2.00	2.25	9.3%	371	1,051
Tebo	1968	2.22	1.70	8.4%	384	831
Totals					$13,504	$19,716

Source: computed, program input data, Appendix, Tables 1-3.

[a]As explained in the main text, both the SCS B/C data (which approximate the SCS-computed annual benefit cost ratios) and the SCS NPV data are computed using the SCS-assumed multiple interest rates. These SCS-assumed interest rates may number as many as four per project, and the rate sets differ among projects. The SCS-assumed rates are shown in Appendix, Table 2.

cost ratios that approximate those computed using SCS procedures, although the two routines differ as explained previously in this section. The SCS B/C ratios of Table 7.1 and those computed by SCS are shown in Appendix, Table 3, and there is some discussion of the relatively minor differences between them in chapter 1. The PV B/C and the NPV data shown in Table 7.1 are computed at 5%.[8] They are computationally consistent with the IRR, meaning that the PV B/C = 1 and the NPV = 0 when computed at an interest rate equal to the IRR. The SCS NPV is an NPV, like the NPV just discussed, except that the SCS-assumed interest rates are employed (with as many as four per project and with interest rate sets differing among projects).

Ranking Projects

The 12 Michigan PL 566 projects are ranked in Table 7.2 using different investment criteria as ranking devices. However, the results should be interpreted with caution. Recall that SCS evaluated these 12 projects over the period 1959-68. Crop input and output prices and coefficients differ. Growth patterns for enhancement benefits differ. Capital costs reflect different price levels. The problem of different interest rates is removed for the non-SCS criteria, except the SCS NPV which uses the original SCS-assumed rates. SCS-assumed ACK economic lives differ. With these differences in mind the project rankings may be considered to illustrate the general effect of ranking by various criteria.

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[8]The NPV and PV B/C were obtained for 20 interest rates, but the NPV and PV B/C data are shown here only for a rate of 5%. The 20 rates are as follows: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 25, 30, 35, and 40 percent.

Table 7.2. Twelve Michigan PL 566 Projects Ranked by Selected Investment Criteria[a,b]

Rank	NPV at 5% $1000's		IRR %		Single r, for SCS B/C = 1[b] %		SCS B/C base ratio		SCS B/C 1970 ratio[b]		PV B/C at 5% ratio	
1	Mist	6241	Mill	22.7	Mill	19.8	Mist	9.17	Mill	4.99	Mill	5.21
2	Mill	4574	Mist	14.3	Mist	12.3	Mill	7.35	Mist	4.50	Mist	3.29
3	CasM	753	Musk	12.3	Musk	11.3	Musk	4.97	Musk	3.02	Musk	2.44
4	CasS	658	Blac	9.5	Blac	9.2	CasM	3.12	Blac	1.87	Stur	2.25
5	Tebo	384	Stur	9.3	CasM	8.7	Blac	2.85	CasM	1.80	Blac	2.08
6	Stur	371	CasM	9.1	Tebo	8.3	Tebo	2.22	Stur	1.69	CasM	2.07
7	Musk	263	Tebo	8.4	Stur	8.0	Stur	2.00	Tebo	1.64	Tebo	1.70
8	Blac	136	Catl	6.7	Catl	6.5	Catl	1.75	CasS	1.00	Catl	1.39
9	Jo	69	CasS	6.2	CasS	6.1	CasS	1.69	Farm	0.98	CasS	1.26
10	Catl	52	Jo	6.2	Jo	6.1	Jo	1.51	Catl	0.97	Jo	1.22
11	Litt	6	Litt	5.1	Litt	5.1	Litt	1.33	Jo	0.97	Litt	1.03
12	Farm	-2	Farm	4.8	Farm	4.8	Farm	1.22	Litt	0.83	Farm	0.97

Source: computed, program input data in Appendix, Tables 1-3.

[a]Project names are as follows: Blac, Black; CasM, Cass, M.; CasS, Cass, S.; Catl, Catlin; Farm, Farm Creek; Jo, Jo; Litt, Little; Mist, Misteguay; Musk, Muskrat; Mill, Mill Creek; Stur, Sturgeon; and Tebo, Tebo. Full names and locations are given in Appendix, Table 4.

[b]SCS B/C 1970 ratios and single interest rates, which, if used in place of SCS-assumed multiple rates, would provide the ratio SCS B/C = 1, are explained more fully in Table 7.3, footnotes a-c, as well as in the main text relating to Table 7.3.

The explanation for inconsistent project rankings between the IRR and NPV's computed at various interest rates may be found in Figures 7.1 and 7.2; that is, NPV curves differ in responsiveness to changes in interest rate and they may intersect before reaching the IRR (the interest rate at which NPV = 0). Similarly, the PV B/C curves for different projects differ in responsiveness to changes in interest rate and may intersect before reaching the IRR (the interest rate at which PV B/C = 1). Thus, one should not expect NPV and IRR rankings and NPV and PV B/C rankings to agree. Furthermore, part of the divergence between NPV and PV B/C rankings may be explained by the tendency of PV B/C curves and NPV curves to interesect respectively. However, the PV B/C is a ratio (present value of benefits / present value of costs), and NPV is a difference (present value of benefits - present value of costs). On this basis, one would expect differences in project ranking between the NPV and PV B/C.

Despite some criticisms, the IRR is a useful device. It is an analog to the single interest rate, which, if used in place of the SCS-assumed multiple rates of interest, would make the SCS B/C = 1. Their relationship will be discussed in detail later. Only 3 of the 12 projects change ranking between these two devices (Table 7.2). The NPV and PV B/C data in Table 7.2 both assume an interest rate of 5%, but ranking divergences are clearly apparent. On the other hand, the base SCS B/C and PV B/C (at 5%) data provide somewhat similar rankings. Project rankings with the SCS B/C 1970 data differ from those with the SCS B/C base-estimate data. The SCS B/C 1970 data will be discussed in more detail shortly; briefly, they reflect interest rate and ACK economic life assumptions that might be used if the projects were re-evaluated by SCS in fiscal 1970, other things remaining unchanged. Projects change rank rarely by more than one or two places in Table 7.2 until the NPV ranking is compared to the ranking by any other device (excluding the SCS B/C 1970 which introduces a change in underlying variables).

Interest Rates

Background

The question of what interest rate (or rates) to use in evaluating public investments has received considerable attention by economists, but there are several unresolved issues, as discussed in chapter 4. Social opportunity cost proponents argue for a rate (or rates) usually representing the return on foregone uses of the real resources. Depending on the means of measurement, rates ranging from perhaps 7% to over 15% might be suggested for 1969-70. At the other end of the scale, a social time preference rate, roughly represented by the yield on long-term Federal bonds (6.8% for 1969), with a reduction to remove the market inflation-expectations, could be in the vicinity of 4-5%.

Owing to the problems of market imperfections and uncertainty and a host of other difficulties, it does not appear that the two rate positions can be reconciled. In the selection of a rate three general issues stand out: capital formation (or net investment, having to do with the rate of economic growth), the division of investment between public and private projects, and the division of resources between short and long term projects.

To encourage a higher rate of capital formation, the government could lower all interest rates via monetary, fiscal and debt-management policies.

Capital formation may be accomplished either in the private or public sectors, but to transfer resources from higher to lower earning potentials is inefficient. Although there may be some questions about definitions, the internal rate of return (IRR) on the projects studied in this chapter may serve as a rough yardstick for comparison with earnings in the private sector. Individually, only three of the twelve projects have an IRR above 10%. Taken as an aggregate, the twelve projects have an IRR just under 12%. Rates of return on private investment may be in the 10-20% range, depending on definition and the risk class (variability of outcome class).

Could not the twelve Michigan PL 566 projects have been good investments, allowing for the rise in rates of return since the early 1960's, when most of these projects were planned and approved, and allowing for the lower rates of return on utility-type investments (due to less variability of outcome)? Perhaps, but the project rates of return stated here are base-estimate rates (as shown in Table 7.1) and no corrections have been made for optimism bias. Possible sources of agency optimism bias in stating project returns have been studied in chapters 5 and 6; they will be taken up again later in this chapter. Depending on the assumptions selected to judge the agency estimates, this optimism bias may be slight or considerable. In any event, if returns on the public projects are lower than returns for comparable private sector investments, a misallocation of resources has occurred, and society would have been better off to avoid such public projects.

Concerning the division of investment between short and long term projects, one position is that private market rates of return on investment are high because individual (private) decision makers are short-sighted. It is presumed that society should react differently, paying more attention to the future to offset the defective telescopic faculty of individual decision makers. In other words, the government could use a lower rate of interest in evaluating public investments, thereby emphasizing long-term projects. Lower interest rates have the effect of increasing the relative value of benefits farther in the future than do higher rates. Another way of saying this is that lower rates encourage capital-intensive, long-lived investments. Assuming that the distant-future benefits are in fact "correctly stated" (i.e., assuming no optimism bias), critics of low discount rates argue that an income transfer from the poor to the rich is implied, since real per capita income increases through time. Furthermore, the use of low discount rates is not a means of encouraging public as opposed to private investment, if this is desired to counteract the short-sightedness of private decision makers on the aggregate rate of capital formation. Rather, low discount rates encourage capital-intensive public investments; that is, for example, spending on school buildings rather than education. (Note: capital intensity and economic life may refer to different dimensions of PL 566 project investments, as discussed in chapter 8.)

Agency Practice

As mentioned earlier in this chapter, SCS has evaluated PL 566 project investments using as many as four different interest rates per project, with the rate sets changing with projects through time. Since about 1965 the SCS Planning Party in Michigan has used just two rates per project.[9] The inter-agency authored Greenbook (of 1950) apparently accounts for the two rates used on the earliest planned of the 12 studied Michigan projects (the Misteguay, 1959). For the Misteguay, the SCK-amortization factor (A_4) was based on an interest rate (r_4) of 2.5%. In contrast to the 2.5% rate for SCK amortization, the Greenbook advocated a 4% rate for handling private costs and benefits (meaning $r_1 = r_2 = r_3 = 4\%$), as for the Misteguay project.

Eckstein is critical of the Greenbook's recommendations of a 4% rate, if the reason is the evaluation of "private" costs (meaning associated costs, ACK, which may be public costs in part via Federal ACP payments to farmers). However, if the reason is to distinguish private and public risks, Eckstein is willing to accept use of dual rates. More recently Arrow and Lind advocated the explicit use of dual rates, a lower rate for evaluating publicly borne costs and benefits, and a higher rate for evaluating privately borne costs and benefits.[10]

Since 1962 evaluations have been based on the rather ambiguous policy statement known as Senate Document 97, actually authored by an inter-agency committee and later published by the Senate. It recommends

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[9]As shown in Appendix, Table 2, four of twelve projects were actually evaluated with $r_3 \neq r_4$, although the work plans indicated $r_3 = r_4$. This may mean that enhancement benefits were computed when the rates for one fiscal year were in force, and that SCK's were amortized later when higher rates for the next fiscal year were in force.

[10]The Greenbook: U.S. Congress, Subcommittee on Benefits and Costs of the Federal Inter-Agency River Basin Committee, Proposed Practices for Economic Analysis of River Basin Projects ... (Washington, D.C.: USGPO, 1950). Otto Eckstein, Water Resource Development (Cambridge, Massachusetts: Harvard University Press, 1958), pp. 60, 64, and 88-90. Kenneth J. Arrow and Robert C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," American Economic Review, vol. 60, no. 3, June 1970, pp. 364-378.

a single rate for evaluations. However, SCS practice (1967-70) is based on two rates, with a second, higher rate for ACK amortization, following the concept of local borrowing costs.[11]

Economists have been critical of Senate Document 97's definition of a long-term rate for use in evaluations. Essentially, it is a coupon rate for outstanding, marketable Treasury obligations, which were long-term at the time of original issue, but which may be due or callable in a much shorter period of time. In 1968 the agencies redefined the rate to relate to current yields on such obligations with maturity or call dates 15 or more years in the future. Thus, the definitions differ on two points. However, the new definition rate was established at a base of 4.625%, below the then current yield on long-term bonds, and it is not allowed to advance more than 0.25 of a percentage point per fiscal year. Thus, a rate of 4.875% was in use in fiscal 1970 (July 1, 1969 to June 30, 1970) when the current yield on the bonds was closer to 7%.

Apart from the criticism of the water resources agencies' definition of a long-term interest rate, economists who advocate "risky" or opportunity cost rates may find the rate too low for other reasons. This is because yields on long-term government bonds (with a deduction for inflationary expectations) represent an essentially riskless, lenders' rate, which is perhaps a reasonable approximation of a social time preference rate.

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[11]U.S. Congress, Policies, Standards and Procedures ..., Senate Document 97, 87th Congress, 2d Session (Washington, D.C.: USGPO, 1962), pp. 11-12. USDA, SCS, Economics Guide (Washington, D.C.: SCS, 1964), ch. 6, p. 5 and ch. 7, pp. 6-7. On SCS interest procedures, see USDA, SCS, Watershed Protection Handbook (Washington, D.C.: SCS, 1967), sec. 102.0213.

Single-Rate Proxies for SCS Multiple Interest Rates

Table 7.3 shows several discount rates for the 12 studied PL 566 projects, both single-rate proxies for SCS-assumed multiple interest rates and internal rates of return (IRR). Each is computed under two different sets of assumptions, those used by SCS in the original evaluations and those which might have been used by SCS in fiscal 1970, other things remaining unchanged. For 1970, 25-year ACK economic life is assumed, while the original SCS evaluations used ACK economic lives ranging from 15 to 50 years. SCK are amortized using an interest rate of 4.875%, and ACK are amortized using a rate of 6.5%. These interest rate assumptions do not affect the IRR's and single rates (to make SCS B/C = 1), because the IRR's and these single rates are program outputs and not data inputs.

When the single rate proxy for SCS multiple rates is determined for a project, the computations are iterative, employing one rate at a time until a rate is found to provide the required SCS B/C ratio. That is, the procedure described in the methodology section of this chapter is used to compute the SCS B/C, except that $r_1 = r_2 = r_3 = r_4$, with various rates being tried until the one is found that provides approximately the correct SCS B/C (as shown in columns 2 and 3 of Table 7.3). The same process is used to obtain the rate for which SCS B/C = 1. Computation of the IRR is also iterative, but the procedure finds the rate for which the NPV = 0 and the PV B/C = 1.

The 1970 interest rate and ACK economic life assumptions significantly reduced the benefit cost ratios for all 12 projects. Similarly, the single-interest-rate proxies for the SCS multiple rates rose

Table 7.3. Single Interest Rate Proxies and Internal Rates of Return, 12 Michigan PL 566 Projects[a,b]

Project name and documentation date		SCS B/C base ratio	SCS B/C 1970 ratio	Single interest rate proxies[b] for SCS B/C base		Single interest rate proxies[b] for SCS B/C = 1[c] base		Internal rate of return[c] base	
				base	1970	base	1970	base	1970
1		2	3	4	5	6	7	8	9
Black	1963	2.85	1.87	3.7%	5.3%	9.2%	8.8%	9.5%	8.9%
Cass, M.	1963	3.12	1.80	4.1	5.6	8.7	7.9	9.1	8.1
Cass, S.	1961	1.69	1.00	3.6	5.4	6.1	5.4	6.2	5.4
Catlin	1966	1.75	0.97	4.4	5.7	6.5	5.6	6.7	5.5
Farm Creek	1965	1.22	0.98	3.5	5.1	4.8	5.0	4.8	4.9
Jo Drain	1964	1.51	0.97	4.1	5.5	6.1	5.4	6.2	5.0
Little	1962	1.33	0.83	3.7	5.4	5.1	4.5	5.1	4.2
Misteguay	1959	9.17	4.50	3.0	5.6	12.3	11.7	14.3	13.7
Muskrat	1959	4.97	3.02	3.9	5.7	11.3	10.6	12.3	11.6
Mill Creek	1962	7.35	4.99	3.0	5.1	19.8	19.7	22.7	22.6
Sturgeon	1966	2.00	1.69	3.6	5.1	8.0	8.7	9.3	9.5
Tebo	1968	2.22	1.64	3.9	5.3	8.3	8.1	8.4	8.3

Source: computed, program data inputs, Appendix, Tables 1-3.

[a]Base estimate (original SCS) assumptions are shown in Appendix, Table 2. The 1970 assumptions are intended to suggest what SCS might assume, if the projects were re-evaluated in fiscal 1970, other things remaining the same. The 1970 assumptions are as follows: interest rates for SCK amortization and EB computations (rates r_4 and r_3, respectively) are 4.875%, interest rates for ACK amortization (rates r_1 and r_2) are 6.5%, and ACK economic life is 25 years. These assumptions are the same for all projects, whereas the base estimate (original SCS) assumptions (for the period 1959-68) differ by project.

[b]Single interest rate proxies are rates of interest, which, if used in place of the SCS-assumed (or 1970 implied SCS) multiple rates, would provide the equivalent SCS B/C.

[c]Single rates to make SCS B/C = 1 (columns 6 and 7) and IRR's (columns 8 and 9) differ because the 1970 ACK life for all projects is 25 years, whereas the base estimate (original SCS) ACK economic life varies among projects from 15 to 50 years.

(compare the rates in columns 4 and 5, Table 7.3). Single-interest-rates (to make SCS B/C = 1) and IRR's fell for 10 of the 12 projects because the assumed ACK economic life (25 years) is lower for the 1970 computations. However, these two rates do increase for the Farm Creek and Sturgeon projects, because SCS assumed ACK economic lives shorter than 25 years (see Appendix, Table 2).

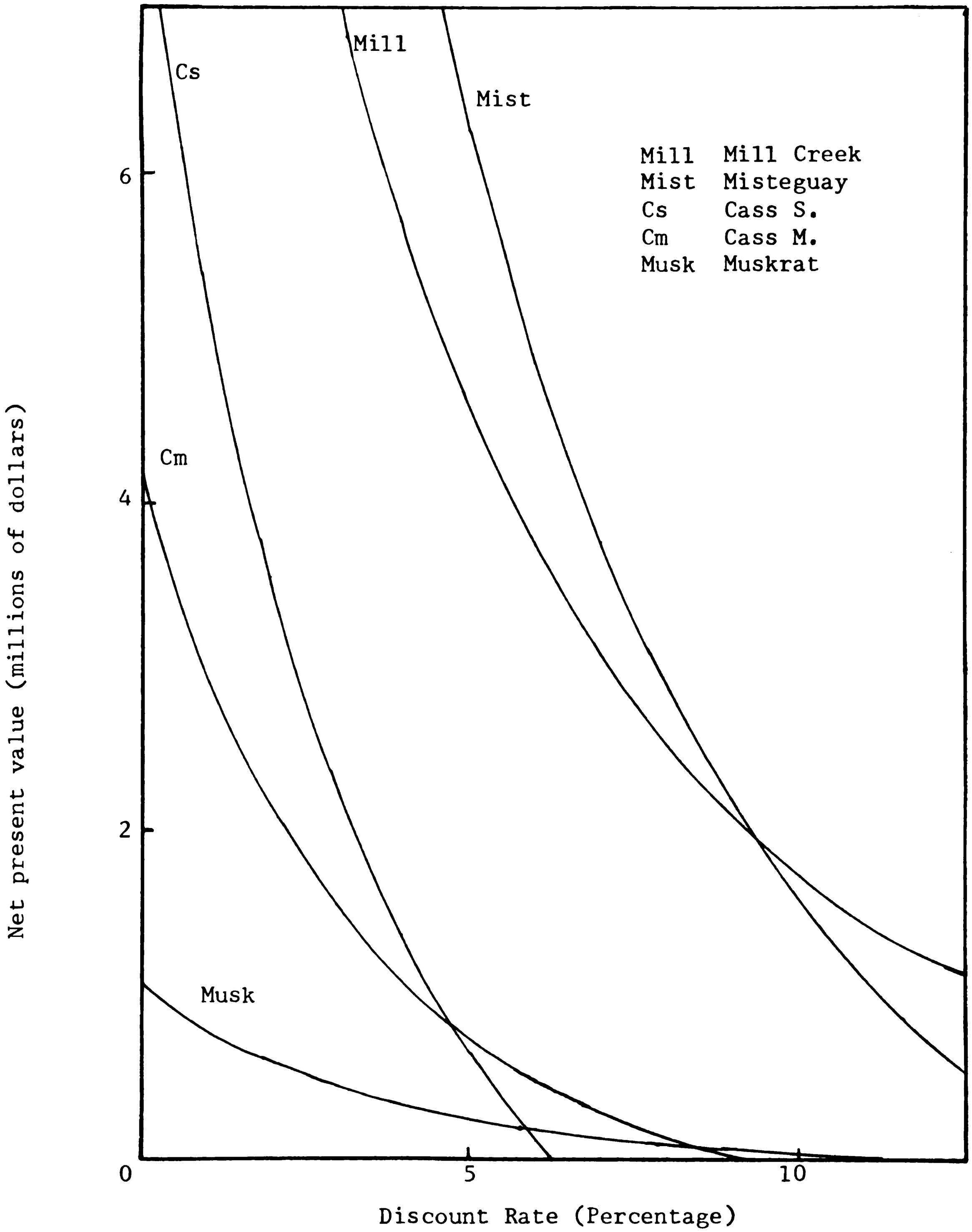
Why do the IRR's and the single interest rates (which, if used in place of the SCS-assumed multiple rates would provide an SCS B/C = 1) differ? First, slight computational discrepancies could account for differences of perhaps 0.1 to 0.3 of a percentage point. Second, IRR's are generally higher than the single interest rates (to make SCS B/C = 1). An explanation has to do with the use of amortized ACK cash flows rather than investment-rate ACK cash flows in the SCS B/C. Recall that in the methodology section it was shown that the sum of amortized ACK cash flows is larger than the sum of investment rate ACK cash flows (assuming $r = 6\%$, EB achievement rates $P_{1,if,t}$ for MILUB for the Mill Creek project and ACK = $1,000,000, the discounted present value sums are $702,981 and $670,616, respectively). This difference would lower the computed SCS B/C at any rate of interest as compared to what the SCS B/C would be if investment rate ACK flows were used as in the non-SCS investment criteria. Thus, in general, if the SCS B/C and PV B/C were computationally consistent, one would expect the SCS B/C to reach a computed value of one at a lower rate of interest than the PV B/C. Third, contrary to this explanation, the single interest rate to make SCS B/C = 1 exceeds the IRR for 4 of the 12 projects under the 1970 assumptions specified in Table 7.3. Apart from computational discrepancies some other factor could account for this. Fourth, the SCS B/C has a different cash flow arrangement than the non-SCS investment criteria. One should not necessarily expect the SCS B/C and the PV B/C to provide a ratio of unity at the same interest rate.

Interest Rate Sensitivity Analysis

Net present value (NPV) curves for the 12 studied PL 566 projects are shown in Figures 7.1 and 7.2. In Figure 7.1 four rates of return over cost (RRC's) may be observed, that is, discount rates at which the NPV curves for two projects intersect (see chapter 4). If NPV curves did not intersect, IRR's (discount rates for which NPV = 0) would be valid ranking devices, regardless of the interest rate selected. For example, at discount rates above about 9.5%, the NPV for the Mill Creek project exceeds the NPV for the Misteguay, but for discount rates below 9.5% the Misteguay has a higher NPV.

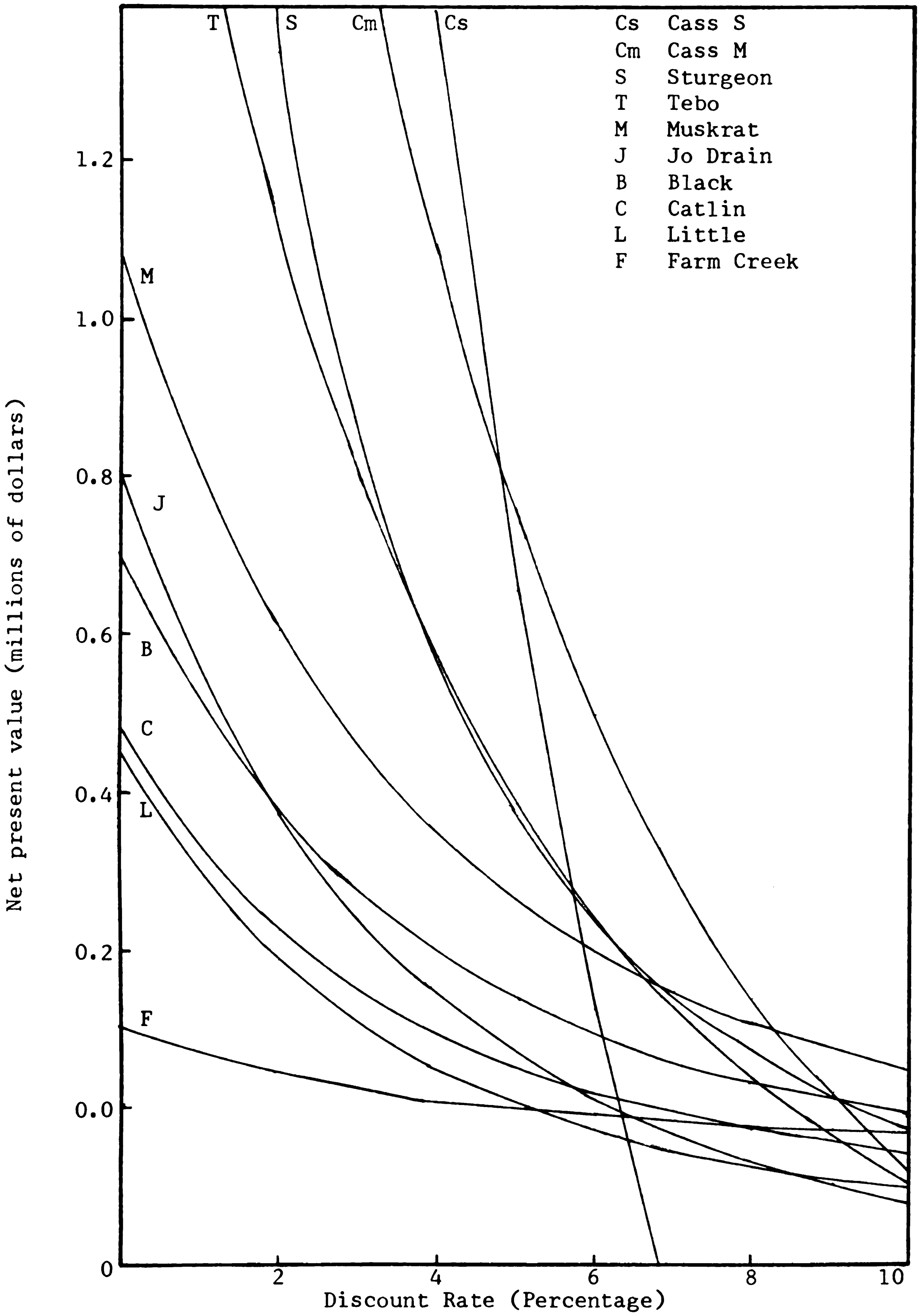
While the NPV variations among the 12 projects are too great to conveniently draw all 12 NPV curves on one set of axes, one can still observe different degrees of interest rate responsiveness among the NPV curves. All NPV curves are more responsive at lower rates of interest (that is, the curves are steeper). However, notice that the NPV curve for the South Branch of Cass River project does not level out quite so well and forms RRC's with the NPV curves for six other projects before reaching its IRR (6.4%, where NPV = 0), as shown in Figure 7.2. The NPV curves for the Sturgeon and Tebo projects intersect twice (RRC = 4% and RRC = 6.4%). Below the lower RRC (4%) and above the higher RRC (6.4%), the NPV and IRR rankings would agree, but not between them.

Figure 7.1. NPV Curves, Michigan PL566 Projects.



Source: Computed, program input data, Appendix, Tables 1-3.

Figure 7.2 NPV Curves, Michigan PL 566 Projects.



Source: Computed, program input data, Appendix, Tables 1-3.

NPV Sums for 12 Projects

Because single-project IRR, NPV and B/C data require more space to present, 12-project NPV sums at 5% will be used as primary quantitative measures of responsiveness to different changes throughout the rest of this chapter. However, the 12-project NPV sums may be used as discount-rate sensitivity indicators in their own right, as shown in Table 7.4, just as single-project NPV's can be used, as in Figures 7.1 and 7.2.

For discount rates with positive NPV's for the 12 projects, notice that the NPV responsiveness to a given change, a 10% reduction in farm income (see Table 7.9), increases with the discount rate. Thus, the relative NPV data in Table 7.4 (column 5) suggests the importance of keeping in mind that NPV sensitivity at 5% is below NPV sensitivity at higher rates of discount, at least for this type of change. The higher 12-project NPV-sum responsiveness at discount rates above 5% is due to the increasingly negative NPV's of some projects, as well as to the decreasing but still positive NPV's for other projects. Projects are not deleted from the sum if their NPV becomes negative.

The use of a 12-project NPV sum at 5% may be defended as being based on a rate that approximates the marginal internal rate of return for the 12 projects. The marginal IRR is the rate of discount for which the lowest ranked project has a zero NPV. For these projects the marginal IRR is actually just over 4.8% (at which the Farm Creek project has a positive NPV of $115, compared to a $-1894 NPV at 5%).

Table 7.4 shows the 12-project NPV sum using the SCS-assumed multiple rates of interest, as applied to their respective cash flow components. This is the sum of SCS NPV's which are mentioned in the methodology section of this chapter under non-SCS criteria. The sum of

$19.7 million approximates the single-rate sum at 4%, $18.2 million.

Recall that the SCS-assumed interest rate sets differ by project.

Table 7.4. Net Present Value Sums, Selected Discount Rates, 12 Michigan PL 566 Projects.

Discount rate (percentage)	NPV sum, $ millions	NPV relative to NPV at 5%	NPV sum, for 10% farm income reduction: $ millions	Relative[b]
1	2	3	4	5
0	61.0	4.52	52.7	.86
1	44.4	3.29	38.1	.86
2	32.8	2.42	27.7	.85
3	24.4	1.81	20.3	.83
SCS-assumed[a]	19.7	1.46	16.2	.82
4	18.2	1.34	14.8	.81
5	13.5	1.00	10.6	.79
6	9.9	.73	7.5	.75
7	7.2	.53	5.0	.70
8	5.0	.37	3.1	.62
9	3.2	.24	1.5	.47
10	1.8	.13	0.2	.13
12	-0.4	-1.03	-1.7	4.29
14	-1.9	-1.14	-3.0	1.57
16	-3.0	-1.22	-4.0	1.32
18	-3.9	-1.29	-4.8	1.22
20	-4.6	-1.34	-5.3	1.17
25	-5.7	-1.42	-6.3	1.11
30	-6.4	-1.47	-6.9	1.08
35	-6.9	-1.51	-7.4	1.07
40	-7.2	-1.53	-7.6	1.06

Source: computed, program input data, Appendix, Tables 1-3.

[a]SCS-assumed multiple rates differ by project, as shown in Appendix, Table 2. The NPV sum is the sum of individual project SCS NPV's as described in the methodology section of this chapter and shown in Table 7.1.

[b]Ratio = (NPV in column 4) / (NPV in column 2).

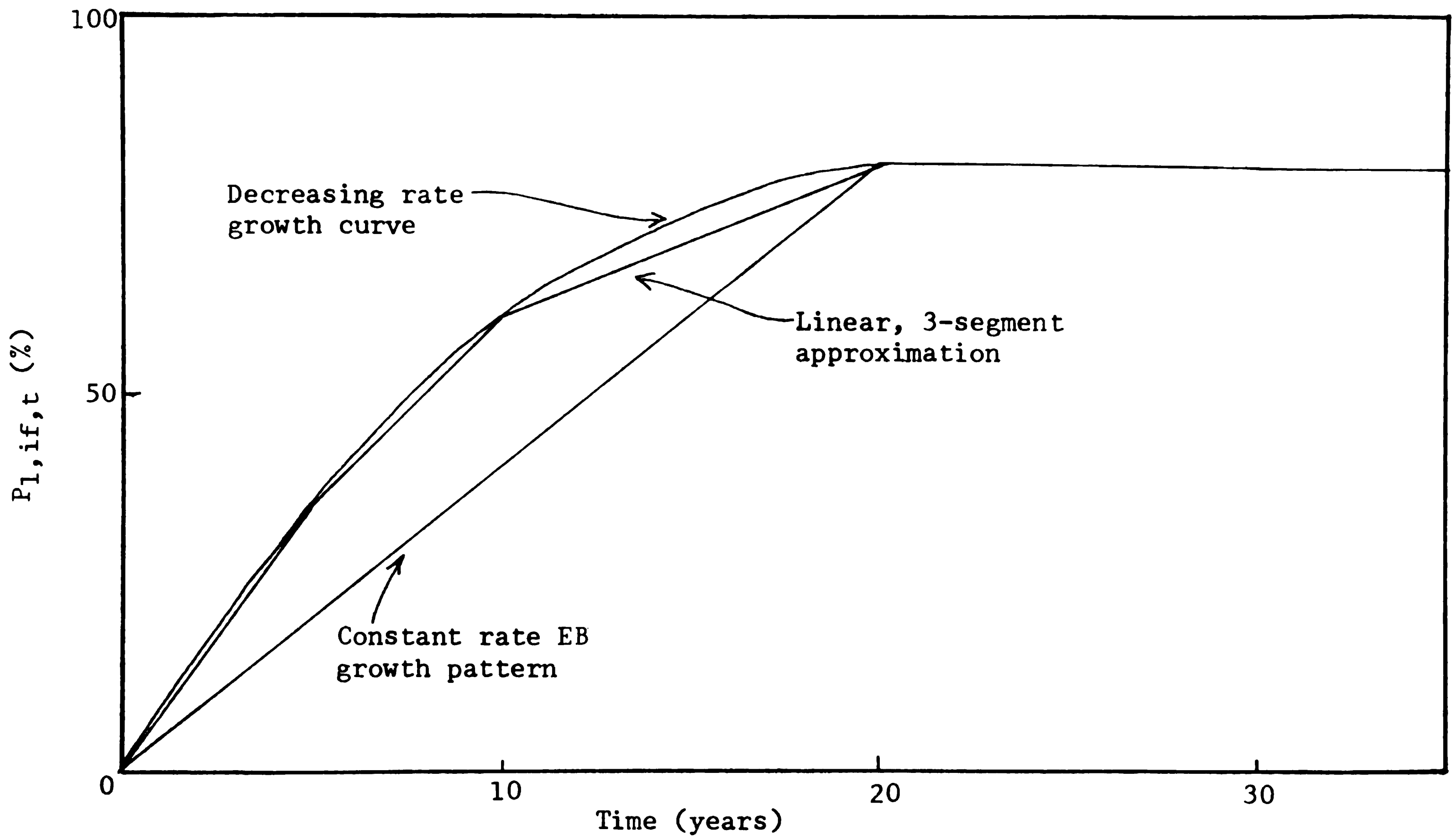
Enhancement Benefits Analysis

Suppose that the SCS instant installation assumption is dropped. Then the EB (enhancement benefits) annual undiscounted cash flows may be visualized as growing after the fashion of a decreasing rate growth curve for the first few years of the evaluation period, after which they assume a constant annual cash flow rate, as shown in Figure 7.3. Actually, SCS assumed a three-segment linear approximation of the growth curve for several of the 12 studied PL 566 projects. As explained in the methodology section of this chapter, the SCS benefit cost ratio and the SCS B/C treat the algebraic sum of EB cash flows (DNR, ACOM, FWDC and amortized ACK cash flows) as an entity. This entity grows as shown in Figures 7.3 and 7.4 during the evaluation period.

One significant difference between the SCS B/C and alternative, non-SCS investment criteria is the treatment of ACK cash flows. Recall from the methodology section of this chapter that the SCS B/C employs amortized ACK cash flows, with the flow for any year t based on the EB achievement rate $P_{1,if,t}$. The alternative, non-SCS criteria employ ACK investment rate cash flows based on the EB achievement rate difference $P_{1,if,t} - P_{1,if,t-1}$. For both kinds of criteria the EB annual achievement rate $P_{1,if,t}$ determines the cash flow for EB non-ACK recurring items (DNR, FWDC and ACOM). These effects of the EB achievement rate variable $P_{1,if,t}$ should be kept in mind.

If the time axis were extended to include all years in the evaluation period (50 or 100 years, depending on the project), then the area under the EB growth curves in Figures 7.3 and 7.4 could be interpreted as representing the undiscounted present value of the EB

Figure 7.3. Alternative EB Growth Patterns.



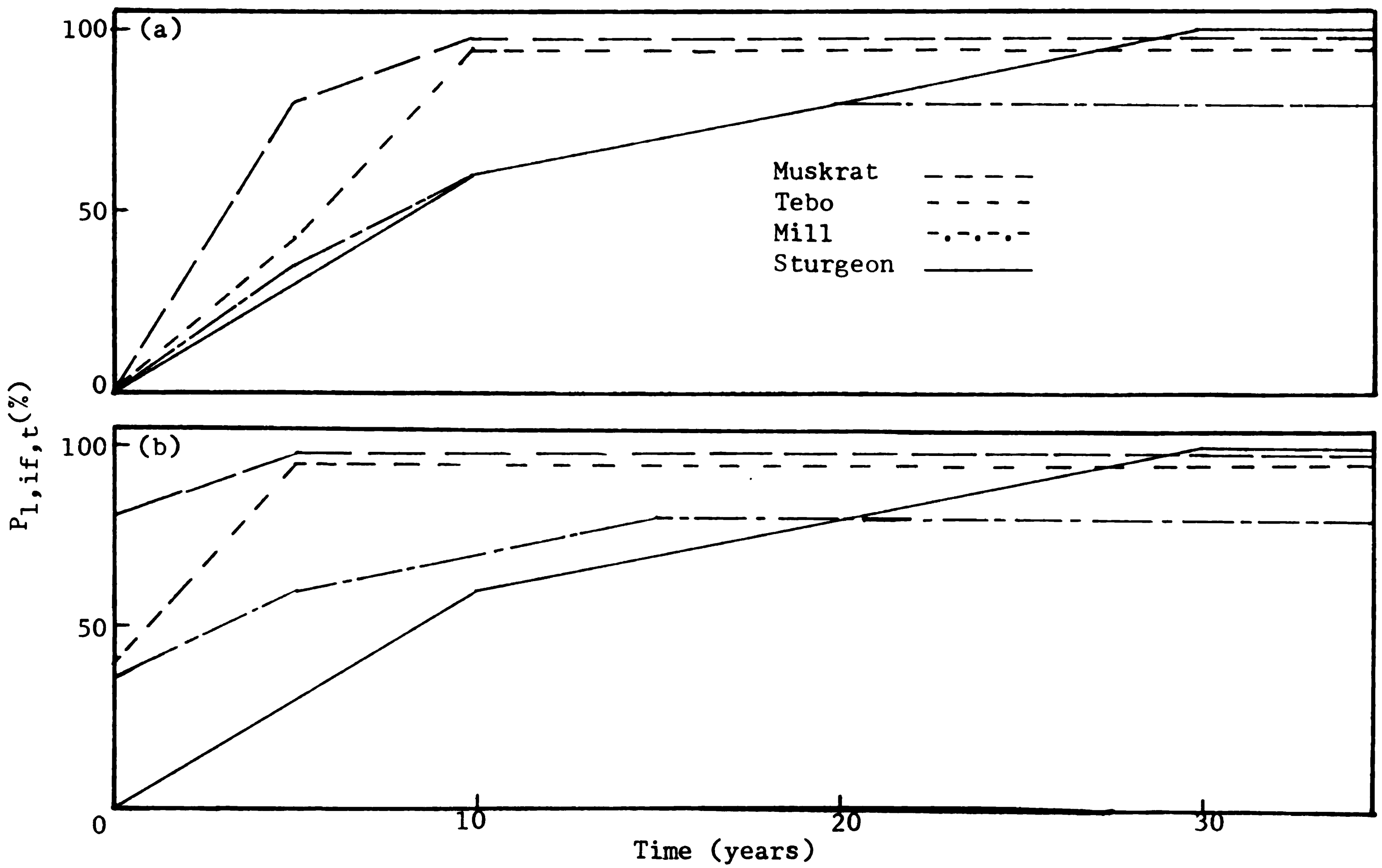
Source: Based on data for the Mill Creek project, MILUB; see Appendix, Table 2.

cash flows for SCS B/C (meaning DNR, FWDC, ACOM and amortized ACK). Similarly, the area under an EB growth curve can represent the undiscounted present value of some of the EB cash flows for alternative, non-SCS investment criteria, that is, only those directly determined for any year t by the EB achievement rate $P_{1,if,t}$ (meaning EB cash flows DNR, ACOM and FWDC). Again, the ACK cash flows for any year t for the alternative, non-SCS investment criteria are determined by the EB achievement rate difference $P_{1,if,t} - P_{1,if,t-1}$. That is, EB investment-rate flows ACK_t decrease rather than increase during the EB development period.

Figure 7.3 shows the EB growth pattern for the MILUB component (subscript if = 1) of EB for the Mill Creek project, with the SCS instant installation assumption dropped. The achievement rate $P_{1,if,t}$ reaches 35% of potential in year 5 (in equal annual increments of 7%), 60% in year 10 (in equal annual increments of 5% over years 6-10), and 80% in year 20 (in equal annual increments of 2% over years 11-20). The $P_{1,if,t}$ variable then remains constant over years 20-50.

This section opened with the supposition that the SCS instant installation assumption would be dropped for expository purposes. Figure 7.4b shows the effect of restoring this assumption, when compared to Figure 7.4a. Only the EB growth function for the Sturgeon is unaffected. Referring to the area under the growth function from time zero to the end of the evaluation period (to year T = 50 or 100, depending on the project) as the <u>growth polygon</u>, the effect of restoring this instant installation assumption is to truncate the growth polygons in Figure 7.4a to year 5 to obtain the polygons in Figure 7.4b (except for that of the Sturgeon). This truncation to year 5 does not remove

Figure 7.4. EB Growth Patterns for Four Michigan Projects.



Source: Appendix, Table 2. Figure 7.4a excludes and Figure 7.4b includes the SCS instant installation assumption. The EB growth patterns in Figure 7.4a were used in the original project evaluations by SCS.

5 years from the evaluation period. Rather, the effect is to make $P_{1,if,t}$ in Figure 7.4b equal to $P_{1,if,t+5}$ in Figure 7.4a. Essentially, the whole growth polygon is shifted leftward 5 years, and the growth function is extended 5 years. Therefore, the present discounted value of the EB cash flow for any year is increased. The areas under the growth functions in Figure 7.4b are larger than the areas under those in Figure 7.4a (except for the Sturgeon).

Sensitivity Analysis Results

The EB cash flow achievement rates assumed by SCS will be changed. The achievement rates refer to the vertical distance from the horizontal axis to the EB growth functions, as shown in Figures 7.3 and 7.4, that is, the values of the variable $P_{1,if,t}$ for various years. Recall that the $P_{1,if,t}$ data are used only in computing EB, and not in computing FWDRB, nor in computing OTHERB (non-FWDRB and non-EB benefits, excluding secondary benefits). Also the $P_{1,if,t}$ data do not affect the structural costs (SCK and SCOM).

Alternatives A and B in Table 7.5 reduce the achievement rates, $P_{1,if,t}$ for all years to 75% and 50% of those assumed in the base estimates. Coincidentally, the NPV sums are reduced to 75% and 50% of the base level, respectively.

Alternatives C and D in Table 7.5 discard the SCS instant installation assumption so far as enhancement benefits are concerned. SCK are not affected, although they are in similar assumption changes considered later in this chapter. Alternative C is based on the assumption that the SCS maximum EB rate (maximum $P_{1,if,t}$) will occur in all years rather than after the completion of the EB development period, usually 15-20

Table 7.5. Changed EB Achievement Rates, 12 Michigan PL 566 Projects.

Rate change	NPV sum at 5%, $ millions		Number of projects with IRR's< 5%	Number of projects with SCS B/C's≤1.00
Base estimate	13.5	100	1	None
(A) SCS rates x .75	10.1	75	3	1
(B) SCS rates x .50	6.7	50	6	4
(C) SCS maximum rate, all years	15.6	116	None	None
(D) 100% rate, all years	19.9	147	None	None

Source: computed, program input data, Appendix, Tables 1-3.

years. Alternative D is similar except that the SCS partial-achievement rate for EB is discarded in favor of full, 100% achievement in all years ($P_{1,if,t}$ = 1.00). As expected, the 12-project NPV sum increased for both alternatives C and D, as compared to the base-estimate NPV.

Examination of the EB growth polygons in Figure 7.4b suggests that the impact of alternatives A-D, Table 7.5, will differ by project. Consider the effect of alternatives C and D in Table 7.5 on the EB growth functions for the Sturgeon and Muskrat projects. For assumption alternative C, the Muskrat growth function would be at $P_{1,if,t}$ = 98% for all years. The Sturgeon function would be at $P_{1,if,t}$ = 100% for alternative C. The functions for both projects would be at $P_{1,if,t}$ = 100% for all years in alternative D. The growth polygons become rectangles, whereas with the SCS-assumed $P_{1,if,t}$ achievement rates they were rectangles with the upper lefthand corners cut off to form various growth patterns.

The impact of these alternative EB growth patterns is much greater for the Sturgeon, because its growth polygon (based on SCS-assumed $P_{1,if,t}$ data) was less rectangular in shape, compared to the Muskrat's growth polygon. This is revealed in the following NPV data.

	Base-estimate $1,000's	Alternative C, Table 7.5 $1,000's	Alternative D, Table 7.5 $1,000's
Muskrat, NPV at 5%	263	273	281
Sturgeon, NPV at 5%	371	590	590
Muskrat, NPV at 10%	47	53	55
Sturgeon, NPV at 10%	-25	83	83

The Sturgeon River project NPV's are considerably increased by the alternative EB farm-income growth patterns, whereas the Muskrat Creek NPV's are affected relatively little. While these two projects were selected because of their clearly divergent base-estimate growth polygons (in Figure 7.4b), other projects are also affected by the postulated growth-pattern changes. This is indicated by the 16% (alternative C) and 47% (alternative D) increases in the 12-project NPV sum (at 5%) in Table 7.5.

Incidentally, the effects of alternatives A and B in Table 7.5 can be visualized in Figure 7.4b. Alternative A reduces the $P_{1,if,t}$ data for all years to 75% of the base-estimate level. Therefore, the heights of all growth polygons in Figure 7.4b are reduced to 75% of the heights shown. The effect of alternative B is similar except that the $P_{1,if,t}$ data and growth polygon heights for all years are reduced to 50% of the base level.

The effect of alternatives A-D in Table 7.6 may be visualized by referring to Figure 7.3. For all alternatives a 20-year, straight-line growth functions is assumed. The SCS-assumed, eventually-achieved $P_{1,if,t}$ rate occurs in year 20 for all projects. In addition a 20-year associated capital cost (ACK) economic life is assumed. These two changes alone reduced the 12-project NPV sum (at 5%) to 52% of the base amount of $13.5 million (alternative A in Table 7.6). For alternatives B-D, Table 7.6, additional changes are introduced. The SCS-assumed, eventually-achieved farm income levels are reduced to 75%, 50% and 25% for alternatives B, C and D, respectively. This has the effect of reducing the height of the EB growth polygon in Figure 7.3 (for the straight-line constant rate EB growth pattern); that is, the $P_{1,if,t}$ data are reduced for all years. As expected, these changes have a significant impact on the 12-project NPV sum. Each successive reduction in the achievement rate $P_{1,if,t}$ data of 25% causes the 12-project NPV sum to decline 13%.

SCS had been assuming a 50-year economic life for associated capital investments (ACK) in Michigan, but shortened this to 15-30 years, as shown in the Appendix, Table 2 (column 5). Yet, even 15-30 year lives may exceed those apparently recommended by the Agricultural Stabilization and Conservation Service (ASCS, not SCS) in connection

Table 7.6. Changed EB Achievement Rates and ACK Economic Lives, 12 Michigan PL 566 Projects.

Assumption alternatives	NPV sum at 5%, $ millions		Number of projects with	
			IRR's<5%	SCS B/C's≤1.0
Base estimate	13.5	100	1	None
(A) No reduction[a]	7.0	52	5	4
(B) Rates for A x .75	5.2	39	6	5
(C) Rates for A x .50	3.5	26	9	8
(D) Rates for A x .25	1.7	13	9	9

Source; computed, program input data, Appendix, Tables 1-3.

[a]Assumes 20-year EB development period and 20-year ACK life only, and no reduction of EB achievement rates $P_{1,if,t}$.

with ACP (Agricultural Conservation Program) payments, for which most, if not all ACK investments would qualify. This information has been available at least since 1957, meaning that it could have been used in all 12 of the studied PL 566 project analyses. Under Michigan conditions an economic life of 15 years may be appropriate for tile drainage systems, which probably account for the bulk of ACK investments.[12]

Thus, the 20-year economic life assumed for ACK investments in alternatives B-D, Table 6.7, is close to recent SCS practice and to the preceding ASCS recommendations.

Cash Flow Timing and Instant Installation

As already explained in the methodology section, SCS simplifies the computation of the benefit cost ratios for PL 566 projects by assuming "instant installation." Essentially, this means that investment schedules shown in the SCS project work plans for structural capital cost inflows (SCK_t) and land treatment costs (and by implication, associated capital cost inflows, ACK_t) are ignored. The SCK capital

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[12]See USDA, SCS, Engineering Division, a letter on the subject: "Life Span of ACP Practices," dated April 25, 1957, from C. J. Francis, Engineering Division director, with recommended life data attached, and with designations from the "1957 National ACP Bulletin."

Some of the recommended lives are as follows, although it is not precisely clear from the letter that ASCS recommended them: C-1, permanent sod waterways, 10-15 years; C-4 to C-6, terraces, ditches, dikes and small dams, 10-25 years; C-7, channel linings, chutes, drop spillways, pipe drops, etc., 20 years and up; C-8, streambank or shore protection, channel enlargements, floodways, levees, etc., 15-25 years; C-9, open ditches, under 3 feet deep, 5-10 years, or over 3 feet deep, 10-20 years; C-10, underground drains, 15-25 years, with a shorter expected life span applicable if "tile is laid in sandy or organic soils, or flatter grades" (underline added); C-12 to C-16, various irrigation practices, 10-25 years.

inflows occurring over the typical 5-year installation period are counted as if they all occurred at time zero. EB achievement rates ($P_{1,if,t}$) are advanced in time 5 years. These achievement rates are applied to amortized ACK data in the SCS annual benefit cost ratio, and the year-to-year changes in the rates are assumed to provide an ACK capital inflow schedule for non-SCS investment criteria, as indicated in the methodology section.

In this section the SCS simplifying assumption of instant-installation will be discarded. Instead:

(1) Structural capital costs (SCK) are allocated over four years using investment schedule data provided in SCS watershed work plans for fiscal and budgeting purposes, but not actually used in project evaluations.

(2) Associated capital costs (ACK) are allocated over a period of usually five years, using data provided in SCS watershed work plans for land treatment costs. Land treatment costs are similar to ACK, except that they are for the entire watershed area, whereas ACK are for the project-benefited area. Recall that since the SCS evaluations assume only partial completion of the initially-computed EB farm income, this same assumption applies to the ACK amortized inflows, and to the ACK capital inflows for non-SCS investment criteria. Here 100% of the SCS-estimated ACK are assumed to be incurred.

(3) The EB farm income levels that SCS assumes will occur at time t = 0 are allocated to occur in equal annual increments over years 1-5. That is, the approach of Figure 7.4a is used rather than that of Figure 7.4b.[13]

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[13]An alternative approach to eliminating the instant installation assumption would involve defining the "present" as occurring at year 5 in Figures 7.3 and 7.4a. Net cash flows would still be counted for years 1-T (1-100 or 1-50, depending on the project), that is, for the full number of years (T) in the project evaluation period. However, net cash flows from time zero to the redefined present (year 5) would be accumulated at interest.

Whichever approach is used, the importance of counting all net cash flow components must be kept in mind. Thus, if the redefined "present" (year 5) is used as a point of reference for computing

Table 7.7. Effect of Altered Installation Timing, 12 Michigan PL 566 Projects.

Assumption alternatives	NPV sum at 5%, $ millions		Number of projects with IRR's<5%	Number of projects with SCS B/C's≤1.0
Base estimate	13.5	100	1	None
(A) SCK only[a]	11.8	87	2	---[b]
(B) SCK and ACK[c]	8.5	63	5	2

Source: computed, program input data, Appendix, Tables 1-3.

[a]Uses main text assumption 1, but not 2; 3 is modified so that the redefined enhancement benefits achievement rates (as in Figure 7.4a) apply to all EB components, including ACK.

[b]Not computed.

[c]Uses all main text assumptions, 1-3.

Introducing each of these assumptions, in the order presented, has the following effects. Allocation of structural capital costs (SCK) to years 1-5 rather than just to year 1 slightly increases the NPV's. As shown in Table 7.8 (Mill Creek project data only), the net cash flows for subsequent years, besides year 1 may become negative, although this is in part due to the delayed EB farm income flows (because of using the patterns of Figure 7.4a, rather than 7.4b). Secondly, use of the full amount of ACK and allocation of ACK over 5 instead of the typical 15 years reduce the NPV's. Thirdly, deferral of SCS-assumed EB achievement rates (in the fashion of Figure 7.4a, instead of 7.4b) reduces NPV's.

If one assumes that ACK and land treatment investments are distinct and separate, and that EB growth patterns properly specify ACK investment rates, then alternative A in Table 7.7 would represent the effect of

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[13]present values, it would be improper to accumulate just SCK_t and ACK_t inflows at interest. That is, by definition net cash flows for all years also include flows of FWDRB, OTHERB, DNR, FWDC, ACOM AND SCOM. (See discussion in the methodology section.)

Table 7.8. Undiscounted Net Cash Flows, Mill Creek Project.

Year[a]	Base estimate $1,000's	Instant installation discarded[b] $1,000's
1	-1,087	-140
2	185	-727
3	201	-11
4	218	-18
5	234	97
6	250	113
7	288	129
8	294	146
9	300	287
10	306	303
11	313	309
12	319	315
13	325	321
14	331	327
15	337	333
16	343	339
17	364	345
18	364	351
19	364	357
20	364	364
21-50	364	364

Source: computed, program input data, Appendix, Tables 1-3.

[a]Cash flows are discounted as occurring at the beginning of the year; thus, the year 1 flow is discounted as occurring at time zero.

[b]Net cash flows for alternative B, Table 7.7.

discarding the SCS instant installation assumption. Alternatively, if one assumes that SCS EB growth patterns refer only to net return achievement, and that they are applied to ACK only as a procedural convenience, then perhaps the land treatment investment patterns shown in SCS work plans represent the agency's better "guesstimate" of investment rates. If this is so, then these land treatment investment patterns should be applied to ACK. In this case, alternative B in Table 7.7 represents the effect of discarding the SCS instant installation assumption.

Judging from comments and practices by the SCS Planning Party in Michigan, these land treatment and SCK investment patterns or schedules are shown in work plans only to assist top-level, intra-SCS budget planners to forecast funding requirements to keep various projects on a satisfactory rate of progress. Thus, the schedules have no effect on SCS investment-justifying benefit cost analyses.

Concentrating on the explicit land treatment versus implied ACK investment rate patterns (i.e., implied in EB data), the land treatment pattern involves a more complete and rapid investment. This may be compatible with the less complete and slower growth rate for EB net return increases. Recall, SCS may use the EB growth rates on ACK amortized costs (not capital inflows) only as a matter of procedural convenience and simplification. Regardless, how can faster and more complete ACK investment rates be compatible with slower and less complete EB growth rates?

The answer would appear to be that SCK and ACK investments <u>alone are not sufficient</u> to assure full or even partial achievement of with-project farm income levels. These net return benefits credited to a PL 566 project <u>assume</u>: (1) improved farm management, both with respect to successfully operating with newly-drained soils (in Michigan typically) and otherwise; (2) increased usage of fertilizers, pesticides and herbicides, and possibly other inputs in the crop production process; and (3) shifts to crops with higher net returns per acre, and with (in Michigan) lower excess-moisture tolerance. Generally, these changes are presumed to represent what is possible with a given level of farm and crop production technology in the society as a whole, but they do imply a micro or on-farm, in-watershed technological shift.

FWDRB Redefined

In this section agricultural FWDRB (floodwater damage reduction benefits) will be redefined and counted as an EB (enhancement benefits) component, along with other net farm income. This redefinition is in accord with the concept that the project causes a shift from a lower to a higher net farm income level. For some projects SCS employs this simpler approach, simpler because computation of FWDRB is quite tedious, as explained in chapter 3. SCS personnel have devised procedures that both separate and emphasize FWDRB, at the expense of other forms of farm income. In this author's view, this is as much due to "flood control illusion" as it is to the technical, hydrological rationale for damage estimation. Among proponents of Federal underwriting of flood-control investments, there seems to be the view that FWDRB -- for PL 566, Corps of Engineers, or other projects -- represent loss reductions that are peculiarly in the national interest, whereas drainage and irrigation investments are more private matters which have the disquieting quality of increasing crop production. FWDRB and project investments justified by FWDRB tend to be held less blameful on this account, as discussed in chapter 2.

Apart from the separate computation of FWDRB, they are emphasized via EB reductions: EB net income components have associated costs deducted, but FWDRB do not. These reduced EB annual streams do not accrue at their eventually-achieved annual rates until a growth period has elapsed. Even then they do not reach the 100% rate assumed for FWDRB instantaneously (at time zero in the evaluation period).

The computation of EB is explained in the methodology section of this chapter for both SCS and non-SCS criteria. The EB component of farm income is DNR (the difference between with and without project net farm income, $DNR = NR_2 - NR_1$, excluding FWDRB). To combine all forms of project-credited net farm income it is necessary to add FWDRB and DNR. By way of explanation, recall that:

$FWDRB = FWD_1 - FWD_2$ (the difference between without and with project floodwater damages)

$DNR = NR_2 - NR_1$

Redefining DNR as DNR*, we have:

$$DNR^* = NR^*_2 - NR^*_1 = (NR_2 - FWD_2) - (NR_1 - FWD_1)$$

$$= (NR_2 - NR_1) - (FWD_2 - FWD_1)$$

$$= (NR_2 - NR_1) + (FWD_1 - FWD_2)$$

$$= (NR_2 - NR_1) + FWDRB$$

Using this redefined DRN* in place of DNR significantly affected the NPV's for only 3 of the 12 projects. Each of the remaining 9 projects has unimportant FWDRB. The 12-project NPV sum at 5% was reduced from $13.5 to $11.5 million, or 15%. For projects elsewhere in the country the redefinition could be more important. For the three affected projects:

	Ratio: [FWDRB / (ave. annual benefits)][14]	NPV reduction
Cass, S.	.26	33%
Misteguay	.42	21%
NMBC (Mill Creek)	.29	12%

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[14]Source; Appendix, Table 5. Project average annual benefits exclude secondary benefits.

Adverse Farm Income and Capital Cost Changes

In this section four kinds of adverse changes are considered and summarized in Table 7.9. Farm income and other benefits (OTHERB) are reduced by application of factors .9, .8, .7, .6 and .5. Recall that project-credited net farm income consists of FWDRB (floodwater damage reduction benefits) and EB farm income. Other benefits (OTHERB) include non-FWDRB and non-EB. However, secondary benefits are excluded in all computations in this chapter. The other three kinds of adverse changes affect capital investment costs. Either associated capital costs (ACK) or structural capital costs (SCK) or both ACK and SCK together are increased by application of factors 1.1, 1.2, 1.3, 1.4 and 1.5.

The farm income decreases are more severe in effect than the capital cost increases. A 10% decrease in farm income (and OTHERB) reduced the 12-project NPV sum to 79% of the base estimate of $13.5 million. This same NPV reduction would require a 50% increase in either ACK or SCK or a 20% increase in ACK and SCK together.

As indicated in chapter 6, project-credited farm income estimates are based on a number of crop enterprise assumptions that may be questioned. For example, without government programs, U.S. net farm income would have been 25-50% lower since 1955, according to Tweeten's summary and critique of several economists' studies.[15] As shown in Table 7.9, net farm income reductions in the 25-50% range would reduce

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[15]Luther G. Tweeten, "Commodity Programs for Agriculture," in U.S. National Advisory Commission on Food and Fiber, Agricultural Policy: A Review of Programs and Needs (Washington, D.C.: USGPO, 1967), vol. 5 of the Technical Papers, pp. 107-130.

Table 7.9. Comparison of Adverse Net Farm Income and Capital Cost Changes, 12 Michigan PL 566 Projects

Change from base estimate data	NPV sum at 5%, $ millions		Number of projects with IRR's<5%	Number of projects with SCS B/C≤1.00
Base estimate	$13.5	100%	1	None
Farm income and OTHERB are reduced by:				
(A) 10%	$10.6	79%	2	None
(B) 20%	7.8	58	5	2
(C) 30%	4.9	36	5	5
(D) 40%	2.0	15	8	8
(E) 50%	-0.9	-6	10	10
Associated capital costs (ACK) are increased by:				
(F) 10%	$12.8	95%	2	None
(G) 20%	12.0	89	2	None
(H) 30%	11.3	84	2	None
(I) 40%	10.5	78	2	None
(J) 50%	9.8	73	4	2
Structural capital costs (SCK) are increased by:				
(K) 10%	$12.9	96%	2	None
(L) 20%	12.4	92	2	None
(M) 30%	11.8	87	2	1
(N) 40%	11.2	83	4	1
(O) 50%	10.6	79	4	2
Both structural and associated capital costs are increased by:				
(P) 10%	$12.2	90%	2	None
(Q) 20%	10.9	80	4	None
(R) 30%	9.5	71	5	3
(S) 40%	8.2	61	5	5
(T) 50%	6.9	51	6	5

Source: computed, program input data, Appendix, Tables 1-3.

the 12-project NPV sum from a base level of $13.5 million to perhaps somewhere in the range of $-0.9 million to $6 million, all computed at a 5% discount rate. At higher discount rates the relative decrease in NPV would be greater (see data in Table 7.4 for the effect of a 10% farm income reduction at various discount rates). Regardless of discount rate chosen, it can be appreciated that removing the effect of government farm programs by reducing project-credited net farm income has a significant impact on project benefits.

In chapter 6, use of George Brandow's projected prices, which were intended to remove the effect of government programs, reduced the Mill Creek annual benefit cost ratio from a base of 6.96/1 to 2.60/1 (Table 6.8, alternative F). Due to computational differences, the base ratio for this project in chapter 7 is 7.35/1 (Table 7.1). Farm income decreases of 10-50% (Table 7.9, alternatives A-E) reduced the Mill Creek project's SCS B/C from 7.35/1 to the range 6.48/1 (10% decrease in farm income) to 2.97/1 (50% decrease in farm income). The results of the two approaches to removing the effect of government farm programs seem roughly comparable. Given the computational program data inputs used in chapter 7, it is not possible to show the effect of changing crop prices as in chapter 6. However, the computer program of chapter 7 is far simpler than that of chapter 6.[16]

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[16]The computer program of chapter 6 is an operational form of the SCS model described in chapter 3. It uses a host of crop enterprise and watershed data as inputs. The computer program of chapter 7 takes all of this as given and uses DNR, FWDRB, ACK, SCK, and other data as inputs. The DNR and FWDRB data may be viewed as intermediate outputs of the computer program of chapter 6.

Besides questioning agency estimates of project benefits because they incorporate the effect of government programs, one may question hydrological, crop yield, crop cost and other assumptions. All of these assumptions affect FWDRB (floodwater damage reduction benefits) for agricultural areas. Therefore, there may be several reasons for studying the effect of reductions in project-credited net farm income, as in Table 7.9, alternatives A-E.

One may also wish to study the effect of capital cost increases (Table 7.9, alternatives F-T) for various reasons. They are used here primarily to show that equivalent percentage decreases in net farm income (on an annual recurring flow basis) and increases in capital costs (on a present value or stock basis) differ in impact. This difference is quite apparent in Table 7.9, regardless of whether one uses the net present value sum, the internal rate of return or the SCS annual benefit cost ratio as a yardstick.

Summary

This chapter opened with a discussion of various investment criteria. The SCS B/C is the name given to mathematical formulation that provides annual benefit cost ratios approximating those originally computed by SCS. The procedures actually used by SCS are described in chapter 3. Three alternative, non-SCS investment criteria were selected and their mathematical formulations are explained in the methodology section of this chapter. In all three an investment is defined as a negative net cash flow for any year t. In this definition there is no distinction between capital and annual recurring costs. The discounted values of negative net cash flows are summed and counted as the present value of costs. Similarly, positive net cash flows are discounted and summed as the present value of benefits. These present values are then used to compute present value benefit cost ratios, net present values and internal rates of return for the projects.

Compared to these other criteria, the SCS annual benefit cost ratio may be conceptually criticized chiefly for the way it incorporates associated capital cost inflows. To be sure, criticism may also be leveled at the agency's discount rates and the way in which they arrange cash flow components in the benefit cost ratio.

While there are several problems that may prevent specific conclusions on project rankings, the 12 projects were ranked using selected investment criteria devices. Several of these devices provide similar project rankings: the SCS annual benefit cost ratio (SCS B/C), the internal rate of return (IRR), the present value benefit cost ratio (PV B/C, at 5%) and the single interest rate which, if used in place of the SCS-assumed multiple rates of interest, would provide an SCS B/C = 1. The foregoing project rankings diverge from rankings via net present value data. That is, projects change rank among all criteria, but rank changes are greater in going from the NPV to other investment criteria.

There are significant differences in SCS-assumed enhancement benefits (EB) achievement rates for the 12 studied PL 566 projects. Changing the assumed growth patterns affected the computed investment criteria data. Changing both SCS-assumed EB growth patterns and capital investment rates also affected the investment criteria data. For comparison with chapters 5 and 6, SCS-computed farm income amounts were changed. Also, alternative discount rates were introduced.

Given the number of variables, the number of combined effects that could be studied is large. Therefore, few changes were combined. It may be argued that several of the studied alterations are reasonable alternatives to SCS assumptions. Their use in original SCS evaluations would have put some or even all of the projects in a rather bad light. Of course, what is "reasonable" in the way of data and assumptions is open to discussion and question. Surely, these are matters that public officials may want to consider in determining policy.

Keeping in mind the point that what is "reasonable" in the way of assumptions and data is open to question and discussion, perhaps some numerical comparisons may be useful. For the SCS-assumed multiple interest rates, of which there may be as many as four per project, with rate sets differing through time, the 12-project net present value sum is $19.7 million (Tables 7.1 and 7.4). An NPV sum of $13.5 million is used throughout this chapter as a basis of comparison; it is computed as an across-the-board discount rate of 5%. At a discount rate of 10% the NPV sum is $1.8 million, and at 12% it is $-0.4 million (Table 7.4).

Eliminating the effect of government programs could reduce the NPV sum from $13.5 million to somewhere in the range of $-0.9 million to $6 million (Table 7.9), with all NPV's computed at 5%.

If the SCS instant installation assumption were discarded and the capital cost investment schedules shown in SCS work plans were applied, the NPV sum would be reduced to $8.5 million from the base level of $13.5 million, with all NPV's computed at 5% (Table 7.7). If in addition SCS-assumed enhancement benefits achievement rates were reduced, further declines in the NPV sum could be expected, perhaps to somewhere in the \$1-5 million range, assuming some combination of results in Tables 7.5-7.7.

Depending on one's assessment of agency assumptions and biases, various combinations of these or other alterations could reflect the effect of removing agency optimism bias in the statement of outcomes.

CHAPTER VIII

INTEGRATION AND SUMMARY

While this chapter is not intended as a summary of individual chapters, some summarization is necessary to integrate the discussion. This will be done in interpretive fashion. The topics include the following: the SCS model, investment criteria, sources of possible error, conclusions, and recommendations.

The SCS Model

The SCS model described in chapter 3 systematizes SCS procedures for evaluating PL 566 project agricultural benefits. This model is the basis of a computer program used in chapters 5 and 6. Chapter 7 employs a much simpler program and takes agency computed net farm income and other data as given. The mathematical formulations of several investment criteria are shown in chapter 7, including the SCS annual benefit cost ratio.

SCS estimates agricultural benefits for PL 566 projects on an annual basis. For policy reasons SCS separates these benefits into FWDRB (floodwater damage reduction benefits) and EB (enhancement benefits). Both relate to the increase in net farm income credited to the project. FWDRB are farm income alone. EB have associated costs deducted. This deduction serves to emphasize FWDRB at the expense of EB. Furthermore, bringing FWDRB into the EB formulation would reduce project benefits, as shown in chapter 7.

The distinction between FWDRB and EB is computational. Subsequent to their computation, some EB are counted along with FWDRB to form flood prevention benefits (FPB), as shown in SCS work plans. Actually, both separations relate to policy preferences associated with what may be called the "flood control" illusion (discussed below). The following separation of flood prevention and agricultural water management benefits was used for the Mill Creek project:

FPB = FWDRB + 1/2 EB = FWDRB + 1/2 MILUB + 1/2 LUCB

AWMB = 1/2 EB (AWMB sub-categories are not shown in SCS work plans)
The further separation of enhancement benefits is to show the portion for previously cropped land (more intensive land use benefits, MILUB) and uncropped land (LUCB, land use change benefits).

USDA policy preferences were formulated in 1967: no restrictions were placed on FWDRB, nor on FPB-MILUB; AWMB-MILUB are not to be based on the increase of output of crops already in surplus. Also, LUCB (both FPB and AWMB-LUCB) are not to be a dominant form of benefit. All restrictions are discarded for projects planned in specially designated low-income areas. Benefits and costs are allocated according to different rules; therefore, these USDA policy preferences do not have the same meaning as the 1967 House Agricultural Committee policy statement. Flood prevention is to be the unmistakably dominant purpose of projects this committee approves (meaning medium sized projects).

The "flood control" illusion mentioned previously relates to the way various project purposes are conceived, regardless of whether the conception is politically or technically motivated. Although all PL 566 project agricultural benefits are based on project-credited increased net farm income, FWDRB are emphasized as being the result of reduced losses, and EB are relegated to the seemingly less desirable role of being increased gains. At the policy level, no question has been raised about FWDRB being in the national interest. Finally the Department of Agriculture did place some restriction on FPB-LUCB, that is, benefits coming from bringing new land into production via flood prevention. Previous to this 1967 restriction, the constraint related only to AWMB-LUCB, that is, benefits coming from bringing new land into crop production via irrigation or drainage. Furthermore, as already indicated in the preceding paragraph, FPB-MILUB are accepted, but AWMB-MILUB are disesteemed, unless based on "efficiency" (as contrasted with being based on increasing production of crops already in surplus).

The effect of the "flood control" illusion is that farmers whose problems relate to flooding, rather than drainage or irrigation, receive preferential treatment. That is, potential income gains (reduced losses) are allegedly more in the "national interest" for them, while farmers who may be suffering losses in potential income, due to irrigation or drainage problems, have potential reduced losses (increased gains) not in the "national interest."

Investment Criteria

One explanation for possible bias in the estimation of FWDRB may be the policy preference for FWDRB, a preference that relates to the entire federal flood control program, not just to SCS. However, the charge of optimistic bias on the part of agencies concerns the estimation of all benefits and costs. One hypothesis is that agencies overstate project net present values (or benefit cost ratios) out of self interest. A counter hypothesis is that economists are overly concerned with some market valued objectives.

While the evidence is scanty, several studies suggest that agricultural and water resource programs have not been very effective instruments for "improving" income distribution, the most often proposed non-efficiency objective. As a matter of fact, these programs may have "worsened" the income distribution. If this is the case in general, it would appear that agency statements of net present value should be revised downward, rather than upward from their market valued objective base to incorporate the effect of distributional objectives.

The three prominent expressions of market valued objectives are equivalent for project set selection with no budget constraint, but not for ranking. Projects may be selected if NPV exceeds 0 or if B/C exceeds 1 at the chosen discount rate or if the IRR exceeds this rate. According to work by Jensen, the net present value is preferable for ranking to either the internal rate of return or the benefit cost ratio because of its responsiveness to changes in investment timing, patterns and scale.[1] Such changes are studied in chapter 7, and the NPV is the primary measure of responsiveness. IRR's and benefit cost ratios are used, but only in a qualitative sense. While Jensen employed NPV and

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[1]For the type of changes considered by Jensen, only the NPV is responsive; that is, the computed B/C and IRR data do not change. For the type of changes considered in chapter 7, data computed for all criteria changed, but relative responsiveness may vary according to the criterion. See R. C. Jensen, "Some Characteristics of Investment Criteria," Journal of Agricultural Economics, vol. 20, no. 2, May 1969, pp. 251-268.

benefit-cost curves to demonstrate the inconsistency of rankings at various discount rates, the author uses NPV curves only, and they suffice to explain the inconsistency between the IRR and NPV rankings.

In chapter 6 it may have been desirable to use NPV's. However, since the primary concern is with benefit responsiveness, rather than with changes in investment timing, scale and patterns, as in chapter 7, the SCS annual benefit cost ratio is probably an adequate scaling device.

With respect to incorporating budget constraints into investment criteria there are several approaches. Eckstein had proposed the use of a benefit cost ratio with Federal cost in the denominator, as discussed in chapter 4. His approach is closest in nature to the agencies' criteria, simply because the agencies use benefit cost ratios. However, the application of his budget constraint device is not as straightforward as may appear at first glance. The agencies' B/C ratios probably are in accord with Senate Document 97, which the agencies authored in 1962. This means that associated costs are counted in the numerator and structural costs in the denominator, as in the SCS benefit cost ratio. Given the data for the 12 Michigan PL 566 projects studied by the author, a B/C ratio with Federal costs only in the denominator could be obtained by shifting SCK_{local} to the numerator along with SCOM, while leaving $SCK_{Federal}$ in the denominator. Besides this, the Federal portion of ACK (paid via ACP payments) should be shifted to the denominator, leaving ACK_{local} and ACOM in the numerator. For other agencies this pattern of cost shifts may be inappropriate.

The foregoing division of costs ignores the Federal budget impact of loans. If the Federal Government loans to local sponsors and to individual farmer funds to cover all or a part of their portion of project capital costs (both SCK and ACK), then these loans as well as the outright Federally-paid capital costs constitute demands on the Federal budget.

Besides the problem of rearranging cash flows in the benefit cost ratio to accomodate the concept of a Federal budget cost constraint in the denominator, there is the problem of assigning discount rates and timing patterns to various capital inflows. Because of these several difficulties, some computed benefit cost ratios based only on the rearrangement of cash flows are not reported in chapter 7.

The question of discount rates is relevant, because of the possibility of Federal loans as well as grants, as indicated previously. If one is going to develop an investment criterion to reflect the difference in risk between publicly borne and privately borne benefits and costs, as suggested by Arrow and Lind (cited in chapter 7), repayment policies and loan terms are of interest. The rationale for this concern is not to establish private borrowing costs, which SCS uses in setting amortization rates for associated capital costs (ACK). As a matter of fact, Eckstein rejects borrowing costs as a basis for multiple rates (as indicated in his discussion of the Greenbook, cited in chapter 7). Rather, the reason for concern with Federal loan term and repayment policies, as well as with the direct Federal grants (for both SCK and for ACK, via ACP), is that favorable loan policies constitute another element of publicly borne costs for PL 566 projects.

All of this suggests that development of a Federal budget constraint investment criterion is not as straightforward as may seem at first glance, as previously stated.

SCS benefit cost ratios represent some sort of mixed budget constraint. Incidentally, it would seem to the author that there may be some ambiguity in the classification of capital costs between what is counted in the numerator (associated capital costs, ACK) and what is counted in the denominator (structural capital costs, SCK). SCK are presumably for major, mainstream works of improvement, and ACK are for on-farm and inter-farm investments. As suggested in chapter 2, there may be some question about classifying costs for critical-area land treatment practices which are intended to control erosion and runoff above mainstream flood-detention structures. More generally, there may be some question of classification between inter-farm (ACK) and mainstream (SCK) investments.

Sources of Possible Error

The sources of possible error in the statement of PL 566 project benefit and cost data depend on the assumptions one makes. Certainly consideration should be given to underlying data inputs, procedures and assumptions, as in chapters 5-7. Sensitivity analysis can suggest those items requiring further study. As further studies become available, it will be possible to make some assessment of the degree of error in agency benefit and cost data.

FWDRB and Hydrological Assumptions

Compared to the base estimate of $75,715, it was found that certain assumption changes could reduce FWDRB (floodwater damage reduction benefits) for the example project. In the author's judgment this degree of sensitivity is probably characteristic of the storm-to-loss synthesizing model, if the assumptions are the same as for the example project. The flood-to-loss synthesizing model was not studied, but it may also have some problematic assumptions.

Hydrologists have adapted assumptions used in developing engineering design criteria for project structural improvements (dams, reservoirs, spillways, channel enlargements and so on) to the estimation of FWDRB. FWDRB are computed on the basis of mathematicaly expected hydrological events, and relatively frequent events contribute most to annual expected FWDRB. On the other hand, engineering design criteria are based on less frequent events. Relatively frequent storm rainfall events or flood discharge events are much closer to the critical minimum or threshold level necessary to cause damage; therefore, they are more sensitive to the assumptions of the storm-to-loss or flood-to-loss translation process. Much of the conservatism applicable in the development of engineering design criteria is probably incorporated into the estimation of FWDRB, regardless of whether storm or flood event data is used. This conservatism is geared to building structures with a safety factor; that is, capacities are biased on the large side so as to cope with the more unusual combinations of hydrological events that lead to severe flooding. Hydrologists indicate that the marginal cost of these safety factors is modest when compared to the initial cost of installing a structure of any size.

In estimating agricultural FWDRB a problem arises that is not common to assessing other kinds of flood damages and their aversion. This has to do with the timing of floods during the growing season, for values subject to loss are extremely variable among months and have a range of 70:1. The SCS model assumes that storms, floods and loss events have the same monthly probabilities of occurrence. The modal month for storms is August, for values subject to loss it is July, but for floods in Michigan it is March. Even the use of flood in place of storm monthly probabilities of occurrence could reduce FWDRB perhaps 50-90%, with the reduction being proportional to watershed size. This does not take account of possible loss avoidance reactions on the part of farmers when floods are most likely (in the months of March, April and May in descending probability order, see Table 5.3). Furthermore, this reduction does not take account of possible upward bias in the estimation of expected acreage flooded, as discussed in the preceding paragraph.

Sources of possible error in the estimation of FWDRB for PL 566 projects, as well as those planned by other agencies, are important because of the policy emphasis on FWDRB. As explained in chapter 3 and earlier in this chapter, all agricultural benefits result basically from the project-credited increase in net farm income. Their separation is based on an apparent effort to emphasize FWDRB to conform with this policy preference (see chapter 2).

Crop Enterprise Assumptions

SCS assumptions for crop prices, costs, yields and planting patterns can be changed by applying adjustment factors to the variable or variables in question. For example, SCS-assumed prices may be increased by 10% for all crops. Another approach is to introduce an alternative set of crop prices. Both approaches were used in chapter 6. For the first approach, the percentage change in benefits ranged from one to eight times the percentage change in the independent variable. Enhancement benefits (EB) are more sensitive to crop data changes than floodwater damage reduction benefits (FWDRB), because EB include the associated cost deduction, whereas FWDRB are farm income alone.

In the author's judgment, SCS use of mid-evaluation period yields overstates project benefits, because a high proportion of the eventually achieved level of farm income occurs at time zero in the evaluation period. FWDRB are based on without-project yields and accrue at their full 100% rate at time zero. EB are based on both with and without project yields, and the annual farm income flows increase during the EB development period, although SCS typically assumes that a high proportion of the eventually-achieved annual flow occurs at time zero.

In contrast to the author's assertion, it may be argued that use of mid-evaluation period yields to represent the whole period overstates annual farm income flows for the early part of the period and understates flows for the latter part of the period, assuming an increasing trend of farm income. This is granted. However, the present values of the flows do not balance out. For example, if a $1,000 overstatement occurs for year 1, it is worth $952 at time zero for a discount rate of 5%. A $1,000 understatement for year 50 is worth about $87. The differences in symmetrical pairs of annual flows decrease as one moves toward the middle of the evaluation period, but this does not distract from the fact that using yield assumptions for the middle to represent the entire evaluation period results in an overstatement of the present value of the annual income flows.

Government programs have a significant impact on net farm income. Estimates used in chapters 6 and 7 suggest that net farm income would be 25-50% lower without government price and income support programs.

The AN (adjusted normalized) crop prices, which have been used by SCS in PL 566 project evaluations since about 1966, are intended to partially remove the effect of government programs. For field crops the AN prices are about halfway between the older PLT (projected long term) crop prices, which were used in the period 1957-66, and George Brandow's projected prices. However, for the Mill Creek project, PLT, AN and state average 1959-63 prices and cost adjustment factors all produced about the same level of benefits. For a project with less of the benefited area in the watershed planted to vegetable crops, results might differ.

A simpler approach to studying the effect of removing government farm programs on project benefits is used in chapter 7. By directly reducing project-credited farm income for 12 Michigan PL 566 projects by decrements of 10 percentage points over the range 10-50%, it was found that the net present value sum (as computed at a discount rate of 5%) could be reduced from a base level of $13.5 million to $10.6 million (for a 10% farm income reduction) or to $-0.9 million (for a 50% farm income reduction). At this lowest extreme only 2 of 12 projects had internal rates of return exceeding 5% (meaning also that their NPV's were positive). Such changes could represent the effect of removing government programs.

What about the effect of reducing yield assumptions, reducing or removing FWDRB, or changing crop planting pattern assumptions? In the author's judgment it would not be difficult to produce NPV sums for these 12 projects in the range of say $-10 million to $+30 million, all at a discount rate of 5%. Conceivably this could be done by selecting crop enterprise assumptions and hydrological assumptions in the range over which reasonable men might disagree.

It should be added that NPV reductions for farm income decreases are relatively greater at higher rates of discount. For example, as shown in Table 7.4, a 10% farm income reduction decreased the 12 project NPV sum 19% at a discount rate of 5% and decreased the 12 project NPV sum 87% at a discount rate of 10%.

For comparison, the 12 project NPV sum is $13.5 million at a discount rate of 5%, and increasing the discount rate to 12% would reduce the sum to $-0.4 million, while decreasing farm income by 50% would reduce the sum to $-0.9 million. In other words, a 50% decrease in farm income has about the same effect as a 140% increase in discount rates.

Benefit and Cost Timing, Levels and Patterns, and Discount Rates

In terms of present values, changes in the level, timing and pattern of benefit and cost flows, and changes in discount rate may all be significant. Given a set of net cash flow data, with one annual flow for each year in the project evaluation period (of 50 or 100 years), altering the discount rate has the effect of changing the present value of the cash flows. For example, consider flows for the following discount rates, assuming in each case that the value of the undiscounted annual flow is $1,000, and assuming flows for years 10 and 30;

	Present value of $1,000		Relative present value
	year 10	year 30	of annual flows
r = 0%	$1,000	$1,000	1/1
r = 5%	614	231	3/1
r = 10%	386	57	7/1
r = 15%	247	15	16/1
r = 20%	162	5	32/1
r = 25%	107	1	107/1

Thus, not only does increasing the discount rate decrease the present value of future annual flows, but it also changes the relative value of the discounted flows. It is for these reasons that low discount rates promote long-lived projects; that is, at high discount rates, distant-year benefits would have very low present values. At low discount rates distant-year benefits have higher present values in terms of dollar amounts, and they are relatively more important (than they are at high discount rates) compared to near-year benefits.

The choice of discount rates is, therefore, an important policy decision, not only for project evaluation computations, but for project planning. In other words, if projects are evaluated using relatively high discount rates, the agency will be encouraged to plan shorter-lived projects, simply because distant-year benefits are worth very little in helping to justify projects (i.e., in helping to raise the benefit cost ratio to unity or above).

Project economic life and capital intensity are often discussed as being dependent on discount rate and as if they referred to the same thing. This equating may be misleading. It may be related to the simplified (second) presentation of B/C_1, following. Here, B/C_1 is an annual benefit cost ratio and B/C_2 is an equivalent present value benefit cost ratio, neither of which is intended to represent the SCS ratio.

$$B/C_1 = [A \times \sum_t^T (\text{benefits})_t \times (1 + r)^{-t}] \;/\; (K \times A + OM)$$

$$B/C_2 = [\sum_t^T (\text{benefits})_t \times (1 + r)^{-t}] \;/\; [K + \sum_t^T OM_t \times (1 + r)^{-t}]$$

$$B/C_1 = B/C_2$$

where; A is an amortization factor for economic life T and discount rate r.

K represents capital cost.

OM represents annual recurring operation-maintenance costs.

r is the discount rate.

$(1 + r)^{-t}$ is the discount factor, equal to $1/(1 + r)^t$

T is the project's economic life.

Usually B/C_1 is stated as follows:

B/C_1 = (average annual benefits) / (K x A + OM)

In the second presentation of B/C_1 the benefit summation process is not shown, and it is possible to lose sight of this process and to concentrate on the capital intensity ratio (K/OM ratio) in the denominator. By concentrating on the capital intensity ratio (K/OM ratio), it would appear as if the only effect of changing discount rates is to change the relative importance of amortized capital costs (K x A) as compared to annual recurring operation-maintenance costs (OM). That is, in B/C_1 attention is drawn to the ratio (K x A/OM), if the numerator of the B/C_1 formulation is taken simply as "average annual benefits," or as "B" in B/C_1 = B / (K x A + OM).

However, the first formulation of B/C_1, preceding, shows that discount rate does have an effect on the numerator of the B/C ratio. The equivalent present value benefit cost ratio B/C_2, preceding, focuses even more attention on the variables being considered. That is, there are annual benefit flows, $(\text{benefits})_t$, annual recurring costs, OM_t (recurring in the sense that they are usually assumed to be constant and in the sense that they occur in all years), one-time capital costs, K, a discount rate, r, and an assumed economic life, T. Changing the

discount rate affects the impact of these various cash flows in determining the B/C ratio.

Cash flows are summed over the range t = 1, ..., T, in which T is usually intended to mean project economic life in years. For most PL 566 projects T is 50 years, and beyond this cutoff cash flows are ignored in the summation process. However, the preceding comparison of discounted cash flows of $1,000 for years 10 and 30 shows that at relatively high interest rates distant-year flows are worth very little in helping to justify a project (i.e., in helping to raise its benefit cost ratio), even though cash flows are counted to year T. For example, at 5%, flows beyond year 30 are worth less than $231, decreasing in value with time; at 25%, flows beyond year 30 are worth less than $1, adding virtually nothing to the present value sum, even though their undiscounted value is $1,000.

Mathematical formulations for the SCS annual benefit cost ratio and non-SCS investment criteria were presented in chapter 7. Simply stated, the SCS annual benefit cost ratio, SCS B/C, may be presented as follows:

$$\text{SCS B/C} = (\text{average annual benefits}) \,/\, (\text{SCK} \times A_4 + \text{SCOM})$$
$$= (\text{FWDRB} + \text{EB} + \text{OTHERB}) \,/\, (\text{SCK} \times A_4 + \text{SCOM})$$

Since FWDRB, OTHERB and SCOM are constants for all years, t = 1, ..., T, this simplified formulation is acceptable for them. However, EB are derived from an amortized present value sum of annual flows and this simplified formulation is misleading.

$$\text{EB} = A_3 \times [\sum_{t}^{T} \sum_{if}^{3} (\text{DNR}_{if} - \text{ACK}_{if,1} \times A_1 - \text{ACK}_{if,2} \times A_2 - \text{ACOM}_{if} - \text{FWDC}_{if}) \times P_{1,if,t} \,/\, (1 + r_3)^{t-1}]$$

The principal weakness of this definition of EB is that significant capital costs are treated as if they were ordinary annual recurring flows. The non-SCS investment criteria used in chapter 7 compute ACK_t as capital inflows rather than as amortized inflows, using the mathematical formulation shown in the methodology section of chapter 7. In these non-SCS investment criteria the capital inflow pattern is based on the EB achievement rate, $P_{1,if,t}$, which increases during the EB development period, reaching the SCS-assumed maximum typically by year 20, after which $P_{1,if,t}$ remains constant. The author assumed that these achievement rates actually refer to EB farm income (DNR), but that applying them to ACK data to obtain ACK_t flows probably represents what SCS might do.

Even so, capital investment rates are not actually specified in the SCS project evaluation procedures, except by implication. However, agency personnel do allocate structural capital costs (SCK) and land treatment costs over a period of a few years for budget planning. The capital investment patterns are shown in SCS watershed work plans, and those for SCK may be adopted directly for use in non-SCS investment criteria. The author assumed that the land treatment investment patterns could be applied to associated capital costs (ACK), which are similar in nature, except that they are for the smaller, project-benefited area, whereas land treatment costs are for the entire watershed area. In addition, EB cash flow achievement rates were changed so as to discard the instant installation assumption in their domain. Thus, for one alteration from the SCS assumptions, involving actual specification of both ACK and SCK investment schedules and a delayed pattern of EB farm income achievement, the net present value sum for the 12 studied PL 566 projects fell to $8.5 million, compared to a base estimate sum of $13.5 million, both computed at a discount rate of 5% (as shown in Table 7.7).

Without altering the capital investment rates implicitly assumed by SCS, it was found that changing the EB cash flow achievement rates for EB farm income only (DNR) could significantly affect the 12-project NPV sum. Because these achievement rates differ among projects, specified changes from those assumed in SCS evaluations will vary in impact. As previously indicated, the EB annual flow rates increase during the EB development period, and reach the SCS-assumed maximum typically at about year 20 in the evaluation period (of 50 or 100 years, depending upon the project), after which they remain constant (see Figure 7.3).

In one alteration of the SCS-assumed EB cash flow achievement rates, the rates for all years, (t = 1, ..., T) were simply increased or decreased. In another alteration a 20-year straight-line development pattern was assumed (see Figure 7.3), with and without individual annual achievement rate changes. The results are presented in Tables 7.5 and 7.6 and will not be repeated here. Suffice it to say that NPV sums ranging from $1.7 to $19.9 million resulted for the 12 studied PL 566 projects, compared to the base estimate NPV of $13.5 million, with all NPV's computed at a discount rate of 5%.

Increasing the capital investments by as much as 50% did not produce such a significant change in NPV's. With only ACK increased 50% above the SCS estimated amount the 12-project NPV sum fell to $9.8 million. With only SCK increased 50% above the SCS estimated amounts, the NPV sum fell to $10.6 million. Even with both ACK and SCK investments for all 12 projects increased to 50% above the SCS estimated amounts, NPV fell to only $6.9 million. Again, all NPV's are computed at 5%, and the base estimate NPV sum is $13.5 million. These capital investment changes in effect change the capital intensity ratios for all projects [not just the simplified ratios, K/OM, suggesting concern only with the denominator of the benefit cost criterion, but the (SCK + ACK) / (SCOM + ACOM) ratios].

Conclusions

With reference to hypothesis 1 posed in chapter 1, the author's results show that data computed for various investment criteria are sensitive to underlying assumptions. With respect to hypothesis 2 of chapter 1, if one is willing to specify values for these underlying variables that differ from those assumed by SCS, it would be possible to considerably improve or worsen the apparent worth of the 12 studied PL 566 projects. If the SCS-assumed interest rates (which number as many as four per project and which differ among projects) are applied so far as possible to the various cash flows in a manner that may be assumed to represent what SCS might do, the 12 project NPV sum is about $20 million (i.e., this is the sum of the SCS NPV data for the 12 projects, as shown in Table 7.1). However, in the author's judgment it would be possible to produce a 12 project NPV sum anywhere in the range of say $-20 million to $+40 million, simply by selecting an appropriate combination of alternate assumptions.

The reader may ask: After studying SCS procedures and assumptions, could you not specify some alternate assumptions that would give me some idea of what these projects are worth? This is a difficult question to answer with present knowledge. Recall that the author has not actually examined the effects of these projects, even though many of them are now completed and operational. If this had been done, it would provide some appreciation of fairly immediate impacts only, whereas these projects are assumed to have an economic life of 50 or 100 years. Because of the higher degree of sensitivity of investment data to changes in project-credited farm income, what happens in the uncertain future is quite important to any assessment of agency evaluations.

In attempting to assess agency evaluations, the problem of assessments being interpreted as critical attacks arises. That is, although the author has assumed that variables and procedures used by SCS in project evaluations represent in essence an expression of agency policy, by virtue of the fact that project evaluations are submitted to an internal agency review process and thereby have the tacit approval of reviewers at the regional level (or even the national level in some cases), there is often some element of innovation in many projects. This type of innovation may come forth at the basic planning level, that is, for example, within the SCS Planning Party in Michigan.

However, the following assessments are not intended as critical attacks, but only to indicate the variables where data is important for project selection. To reiterate, it is assumed that variables and assumptions used in project evaluations represent agency policy. And, incidental to this point, it is also assumed that any errors of computation in agency evaluations are of minor importance, as discussed in chapter 1.

Disregarding any other problems, Table 7.1 shows that only 3 of the 12 projects have an internal rate of return exceeding 10%, at which the 12-project net present value sum is $1.8 million. Altering assumptions other than discount rate could reduce the NPV to this level, and if combined with higher discount rates than were used by SCS, the NPV would be negative.

It should be remembered that the problem addressed in this study is the effect of changes in physical and economic variables related to market valued objectives. Even if further study should indicate that changes in data and procedures are warranted and that these changes would reduce the NPV of the 12 projects closer to zero, it still does not answer the broader question of whether the projects are justified on other grounds, such as income distribution or non-market conservation values.

Recommendations

Given the scope of this study, some recommendations can be made. However, review of the sensitivity analysis results is necessary, as is some sense of perspective for the program as a whole.

Program Objectives

PL 566 projects relate to market oriented, conservation, development, flood control (flood prevention), irrigation, drainage and other purposes, objectives and goals. However, improved clarity and understanding in this matter would be helpful. Agricultural FWDRB (floodwater damage reduction benefits) are perceived as being peculiarly in the national interest, but they are in effect just one kind of farm income credited to a project in an agricultural area. Congressional and agency policy statements do not recognize that these effects on income come largely by way of increased output. Yet, there is some constraint on planning and building projects, if the increased income is associated with drainage, irrigation, increased output of surplus crops or increased acreage in agricultural usage.

If increased farm income is the objective of this program, then it would be useful to know the costs and benefits of alternative means of accomplishing this objective. If flood loss reduction is the objective of the PL 566 program, then information on alternative means of achieving this objective would be helpful, hopefully including means that would not at the same time increase agricultural output. For example, shifts from crop to pasture usage of farm land in frequently flooded areas would reduce flood damages, but farm income would probably also be reduced. By contrast, projects reduce damages by decreasing flood hazards rather than by decreasing the values subject to loss.

Sources of Possible Error in FWDRB Estimates

FWDRB (floodwater damage reduction benefits) are the most important category of benefits for the PL 566 program nationally (Appendix, Table 5). They are obtained as the difference between without and with project damages which are computed in accordance with the concept of mathematical expectation (see chapters 3 and 5). Consequently, relatively frequent events account for the bulk of expected damages. Because of this, typical acre loss values (composite acre values, CAV) for say the 10-15 year flood zone could be used to estimate FWDRB, rather than loss values based on the assumption that cropping patterns and land use are homogeneous throughout an entire economic reach (including area beyond even the flood zone for the largest flood used to estimate FWDRB, usually a 50-year or 100-year flood). The use of loss values for the smaller area would be based on the assumption that farm managers change land use in frequently flooded areas as a loss-avoidance reaction.

Another source of possible error in the estimation of FWDRB has to do with the use of storm instead of flood data in forming sets of monthly probabilities of loss. The modal month for storm probabilities is August, and that for floods is March in Michigan; use of flood in place of storm data would considerably reduce FWDRB (Table 5.3).

Furthermore, there are several technical hydrological assumptions that are part of the process of translating storm into flood magnitudes, and changes in any one of these could significantly affect FWDRB (chapter 5). Even a seemingly minor error in estimating the runoff curve number could change FWDRB by ±50% (pp. 146-147).

Changes in crop enterprise assumptions could significantly affect the relative importance of FWDRB (see chapter 6, especially the relative benefit data in Table 6.1, p. 186 and that in the informal table, p. 207); so would separation of associated costs from enhancement benefits (see Tables 3.7 and 3.9 and chapter 7).

Sensitivity of Benefits
to Farm Income Assumptions

The several possibilities of error might lead one to discard agricultural FWDRB estimates (floodwater damage reduction benefits estimates). Thus, one could simply compute project benefits on the basis of the difference between with and without project net farm income (an alternative sometimes used by SCS, see Table 3.1 and related discussion in chapter 3). This was done for the Mill Creek project. Reducing

without-project (flood-free) yield levels to a with-flooding level gave the same benefit cost ratio, as explained in chapter 6 (see pp. 193-194). That is, the without-project farm income level was reduced so that the project-credited amount of farm income increased. Essentially, project benefits are computed in the enhancement benefits (EB) sub-routines when FWDRB are not estimated.

While FWDRB deserve special attention because they constitute over half of the benefits used to justify PL 566 projects for the nation as a whole (see Appendix, Table 5 for data), their elimination would not entirely remove agency estimates from the realm of doubt as to the possibilities of error. As explained in chapter 6, all agricultural project benefits depend upon certain crop enterprise assumptions, namely crop prices, production costs, yields and planting patterns. EB (enhancement benefits) are generally more responsive to changes in these variables than are FWDRB, because EB are partially net benefits (project-credited farm income with associated capital costs deducted), while FWDRB are project-credited farm income alone. Benefit response coefficients for these variables are shown in Table 6.2.

It would be useful to compare the sensitivity of these crop enterprise variables with the sensitivity of hydrological variables. Unfortunately, changes in hydrological variables, as studied in chapter 5, can not be readily expressed in percentage terms; therefore, benefit response coefficients can not be used to express the results of chapter 5. The picture of relative importance of different variables is further clouded by the fact that not even all of the crop enterprise variable changes in chapter 6 lend themselves to expression in terms of benefit response coefficients. In addition to crop enterprise and hydrological variables, it would be useful to compare the effects of changes in things like investment criteria, discount rates, and benefit and cost flow rates. This is difficult because the benefit response information in chapter 6 is not readily comparable with the effects of alternative investment criteria variables in chapter 7; that is, benefits, the numerator of the benefit cost ratio as defined by SCS, are used as the primary measure of response in chapter 6, whereas net present value is used in chapter 7. It is inherently difficult to speak of a given unit of change in these various kinds of estimation components. Still, some comparisons are possible, but they require an appreciation of the relationship between the SCS annual benefit cost ratio and the net present value (see the detailed presentation in the methodology section of chapter 7). For purposes of rough comparison, if the SCS annual benefit cost ratio is unity (benefits / costs = 1), the net present value is zero. It should also be kept in mind that the benefit cost ratio data in chapters 5 and 6 are for one project, while the net present value sums in chapter 7 are for 12 projects.

To reduce the 12-project NPV sum to zero would require an interest rate of about 11% [120% above or 2.2 times the 5% rate used to obtain the base estimate NPV sum of $13.5 million (Table 7.4)]. Given the assumptions on cash flows used by SCS (chapter 7), perhaps a 100% increase in capital costs would also reduce the 12-project NPV sum to zero (at 5% interest, Table 7.9). At 5% interest, a 50% decrease in project-credited farm income would reduce the NPV sum to zero (Table 7.9), although at higher interest rates NPV-sum responsiveness is greater (Table 7.4). Assuming that a 12-project NPV sum of zero is roughly comparable to an SCS annual benefit cost ratio of unity, any of the following adverse changes in crop enterprise variables could reduce the NPV sum to zero: (1) a 5-25% reduction in with-project yields (yield set 2), (2) a 12-35% increase in without-project yields (yield set 1), (3) a 25% decrease in crop prices, or (4) a 35-45% increase in crop production costs (p. 192). Simultaneous reduction of about 40% in both yield sets might reduce the ratio to SCS B/C = 1, or make NPV = 0.

Extension of conclusions would require consideration of the importance of benefit categories (Table 6.1), because the example projects' responsiveness of benefits (Table 6.2) relates to the responsiveness of enhancement benefits which dominate (comparing the sum of MILUB and LUCB to FWDRB in Table 6.1).

Specifically, responsiveness of FWDRB to changes in crop enterprise variables should be noted, since FWDRB account for a larger portion of total benefits for PL 566 projects nationally than they do in Michigan (Appendix, Table 5). Suppose that a project were justified only by FWDRB, then comparisons between the results in chapters 5-7 may become more meaningful. In chapters 5 and 6, the Mill Creek project would have a benefit cost ratio of about 1.9/1 (FWDRB / annual costs = $75,715 / $40,520 = 1.9, Table 6.1), and reduction in benefits of about 50% would reduce the ratio to SCS B/C = 1, or make NPV = 0. This 50% reduction in FWDRB would be the result of any of the following changes; a 25% decrease in crop prices, a 40% increase in crop costs, or a 60% decrease in without-project yields (yield set 1, Table 6.3).

FWDRB responsiveness differs for the Tebo Erickson project, and a 50% decrease in FWDRB would result from the following respective changes in these crop enterprise variables: prices, -30%; costs, +70%; and without-project yields, -50% (Table 6.4).

Thus, a re-ordering of the impact of crop enterprise variables is necessary if FWDRB dominate, because of differing benefit responsiveness. For overall benefits, for the example projects in chapter 6, the ordering of adverse crop enterprise variable changes to make SCS B/C = 1 is as follows: with-project yields, without-project yields, crop prices and crop costs or simultaneous yield set changes. For FWDRB alone the ordering is prices, costs and without-project yields.

Any one of a number of changes in hydrological assumptions or variables could reduce FWDRB by 50% (see chapter 5, summary). For example, (1) a slight field error in the estimation of the runoff curve number, (2) a shift to by-month runoff curve estimation (Table 5.4), (3) use of the point-area rainfall correction and annual-maximum series rather than point-estimate partial-duration series storm rainfall data, (4) a shift from storm to flood data as the basis for developing monthly probabilities of flood loss (Table 5.3), or (5) some combination of these changes. Therefore, hydrological assumptions are critical in the justification of projects where FWDRB dominate, as they do for the nation as a whole (Appendix, Table 5). However, if these hypothetical changes should later be discovered to be factual by further research, there remain some serious questions about the impact of crop enterprise variables as a source of possible error.

Sensitivity of Project Worth to Benefit and Cost Timing, Pattern and Rate Assumptions

Given the computed farm income amounts, they must be further specified as cash flow rates for all years in the evaluation period. Also, capital investment rates must be specified, since PL 566 projects involve multi-period rather than single-time (time zero) capital investments. SCS procedures involve some simplification in these matters, but specification of various cash flow rates is preferable.

Changes in various cash flow rates are studied in chapter 7. In the author's judgment, cash flow rates should be separately specified for project-credited farm income (which may consist of several components, with each component requiring a specified cash flow rate), associated capital cost investments (ACK) and structural capital cost investments (SCK). Of course, other kinds of benefits and costs may also require the specification of cash flow rates. The results in chapter 7 suggest several possibilities of error in actual project evaluations. Some of these results are based on the use of cash flow rates estimated by SCS, but not used by SCS in the project benefit cost evaluations (Tables 7.5-7.7). The effect of one alteration from SCS assumptions is shown in Table 7.8, which presents a comparison of annual net cash flows.

Recommendations for Further Study

Based on the preceding discussion of variable sensitivity, some recommendations for further study can be made.

(1) Assuming FWDRB (floodwater damage reduction benefits) are to continue to dominate total annual benefits for PL 566 projects as they have in the past, underlying hydrological variables should be given detailed consideration from the standpoint of FWDRB estimation. These variables have been studied by hydrologists primarily from the standpoint of developing engineering design criteria, but the flood discharge and runoff amounts used to estimate FWDRB are much closer to the critical minimum or theshold level just necessary to cause overbank flow onto the floodplain. Studies in other areas of the country are suggested because hydrological conditions may vary. Economists should not become obsessed with arguments over things like the discount rate and fail to see the critical sensitivity of benefit estimates to small changes in hydrological variables.

(2) Still assuming FWDRB dominance, there are a host of non-hydrological variables that deserve study. Even if the FWDRB procedure is discarded because of its high sensitivity to hydrological variables, for which refined estimates may be found to be simply not possible or too costly to obtain, many of these other variables remain to raise questions about the possibilities of error in the statement of project worths. Generally, variables affecting the estimated cash flows of farm income are more important than variables affecting capital cost flows and more important than discount rates.

(a) A major policy issue concerns whether projects should continue to be justified on the basis of crop prices and related input cost adjustment factors that are based in part on government farm price and income support programs. Water Resources Council price data do not remove all of the effects of these programs. This is an important policy choice because of the sensitivity of benefit estimates to crop prices.

(b) Mid-evaluation period yields essentially overstate project worth. The degree of bias depends on the interest rate chosen to discount future income streams. The higher the interest rate, the greater the degree of overstatement, since distant-year income streams, which would be understated (in terms of undiscounted values) by use of mid-evaluation period yields, are worth less and less as the interest rate used for discounting is increased. Therefore, the overstatements for years before the mid year are not balanced out, except at zero discount rate. Yield assumptions should be studied with this in mind.

(c) Cropping patterns can affect apparent project worth. It is recommended that study be given to the cropping and land use patterns in the 10-15 year flood zone. If they are different than those in the surrounding area, it may be argued that they should be used to estimate FWDRB.

(d) Enhancement benefits achievement rates for farm income should be given separate consideration from capital cost investment rates. All of them can affect project worth. In this connection, the SCS instant-installation assumption and the use of amortized rather than capital cost flow rates may be viewed as computation simplifying assumptions that distract attention from important variables in the project analyses.

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APPENDIX

Appendix, Table 1. Project Cost Data, 12 Michigan PL 566 Projects, 1959-68, Data in Dollars.

Project name and documentation date		Structural costs				Associated costs		Land treatment cost
		SCK, local	SCK, Fed.	SCK, sum	SCOM	ACK[a]	ACOM	
Black	1963	41,835	53,121	94,956	862	121,861	331	49,155
Cass, M.	1963	155,614	261,495	417,109	3,441	983,394	2,977	611,526
Cass, S.	1961	576,156	1,445,142	2,021,298	15,683	1,924,107	16,508	2,129,418
Catlin	1966	52,300	30,640	82,940	875	133,380	386	78,195
Farm Creek	1965	18,513	36,987	55,500	780	13,525	388	49,230
Jo	1964	71,316	148,384	219,700	1,922	192,194	405	273,356
Little	1962	33,860	117,920	151,780	2,280	110,010	2,513	94,580
Misteguay	1959	428,592	551,944	980,536	11,166	5,409,496	29,650	2,762,998
Muskrat	1959	20,549	33,000	53,549	1,560	188,344	---	83,763
Mill Creek	1962	298,725	607,207	905,932	7,780	1,085,726	8,344	1,330,310
Sturgeon	1966	120,617	179,813[b]	300,430	9,330	247,333	6,203	332,700
Tebo	1968	156,520	276,640	433,160	3,350	346,640	347	140,240
				5,716,890		10,756,010		7,935,471

Source: USDA, SCS, watershed work plans and documentation. Associated costs from documentation only. Operation-maintenance costs (SCOM and ACOM) are adjusted downward from the rate for the documentation date by use of either the PLT (projected long term) or AN (adjusted normalized) index factor, usually in the 0.84 to 0.99 range as follows: .88, .86, .92, .84, .85, .84, .89, 1.00, 1.00, .84, and .99, respectively, for the 12 projects, as listed in the table. Capital costs (SCK and ACK and land treatment costs) are based on engineering estimates for the planning year.

[a]The divisions of ACK are not shown: $ACK_{if,1}$, on-farm; $ACK_{if,2}$, inter-farm; $ACK_{1,j}$, for MILUB; $ACK_{2,j}$, for pasture-idle LUCB: $ACK_{3,j}$, for farm woods LUCB. Perhaps 50% of ACK may be Federally paid via ACP (agricultural conservation program) assistance to farmers.

[b]Sturgeon, SCK, Federally paid, includes an Economic Development Administration (EDA), Department of Commerce, grant for $72,230; in the SCS work plan table, this $72,230 was counted in the category of "other" costs, meaning non-PL 566 funds, but not necessarily non-Federal.

Appendix, Table 2. Capital Investment Economic Life Data, Interest Rates Used by SCS for Capital Cost, Amortization Factors and for Enhancement Benefits (EB) Computations, and EB Achievement Rate Data.[a,b,c]

Project name and documentation date		Amortization periods (years) and interest rates (%'s)						EB achievement rate data[b]								Interest rates for EB computations (r_3)[c]
		Structural capital cost		Assoc. capital cost				Overall or MILUB				LUCB				
				on-farm		inter-farm		Time (years), t				Time (years), t				
		yrs.	%	yrs.	%	yrs.	%	0 %	1-5 %	6-15 %	>15 %	0 %	1-5 %	6-15 %	>15 %	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Black	1963	50	3	50	6	50	5	30	25	20	75	40	30	15	85	3
Cass, M.	1963	50	3	50	6	50	6	30	25	20	75	40	35	25	95	2-7/8[d]
Cass, S.	1961	50	2-5/8	50	6	50	5	30	25	20	75	30	25	20	75	4
Catlin	1966	50	3-1/8	50	6	50	6	40	30	20	90	--	--	--	--	3[d]
Farm Creek	1965	50	3-1/8	20	6	50	6	50	25	15	90	50	25	15	90	3-1/8
Jo	1964	50	3-1/8	50	6	50	6	60[e]	20[e]	0[e]	80[e]	--	--	--	--	3[d]
Little	1962	50	2-5/8	50	6	50	5	30	25	20	75	40	30	30	100	4
Misteguay	1959	50	2-1/2	50	4	50	4	40	30	0	70	--	--	--	--	4
Muskrat	1959	50	2-1/2	50	6	50	5	80	18	0	98	--	--	--	--	6
Mill Creek	1962	50	2-5/8	50	6	50	5	35	25	20	80	60[f]	20[f]	10[f]	90[f]	4
Sturgeon	1966	100	3-1/8	15	6	--	--	60[g]	40[g]	0[g]	100[g]	--	--	--	--	3[d]
Tebo	1968	50	3-1/4	30	6	--	--	40	55	0	95	--	--	--	--	3-1/4
Assumed	1970	50	4-7/8	25	6½	25	6½	--	--	--	--	--	--	--	--	4-7/8

Source: USDA, SCS, project documents, in SCS files and SCS work plans.

[a]Capital investment economic lives: For SCK (project structural capital costs) SCS assumes an economic life for the investment of 100 years, if the works of improvement are primarily for flood control, and 50 years otherwise. This SCK economic life determines the project life, that is the project evaluation period length. For ACK (associated capital costs) SCS assumed an economic life equal to that for SCK, except for recent projects. The shortened ACK economic life is more in accord with Agricultural Stabilization and Conservation Service (ASCS, not SCS) data, as explained in chapter 7.

Appendix, Table 2 (cont'd.)

[b]Interest rates (r): Rate r_4 (col. 4) was used by SCS in combination with the SCK economic life (col. 3) to form an amortization factor for SCK. Rate r_1 (col. 6) and on-farm ACK economic life (col. 5) were used to form an amortization factor for on-farm ACK (ACK_1). Rate r_2 (col. 8) and inter-farm ACK economic life (col. 7) were used by SCS to form an amortization factor for inter-farm ACK (ACK_2). Rate r_3 (col. 17) was used by SCS to compute enhancement benefits (EB). The use of these rates is explained in chapter 3 following SCS procedures. They are used in chapter 7 in mathematical formulations that are intended to produce computer output that approximates the SCS-computed benefit cost ratios.

[c]Enhancement benefits (EB) achievement rate data: Use of these data is explained in chapter 3 to follow SCS procedures. These data (as shown in columns 9-16) are used in chapter 7 to compute EB farm-income achievement rates for individual years. The annual achievement rates ($P_{1,if,t}$) increase during the EB development period, after which they remain constant. These annual achievement rates apply only to EB, and not to other kinds of project benefits (FWDRB and OTHERB). The data shown in columns 9-12 and 13-16 may be explained using data for the Black Creek project for illustration. For this project SCS assumed that the MILUB portion of EB farm income would accrue as follows during the 50 year evaluation period: 30% at time zero, another 25% by year 5 (with equal annual increments over years 1-5, 5% per year), and an additional 20% by year 15 (with equal annual increments over years 6-15, 2% per year). For years 15-50 the rate remains at 75% (75% = 30% + 25% + 20%). Notice that the rates in columns 9-12 and 13-16 differ for most projects. These rates assume instant-installation, meaning that all cash flows occurring during the project installation period are counted as if they occurred at time zero. This is explained further in chapter 7.

[d]Based on SCS documentation, rate r_3 is as shown in column 17. SCS computations were based on this rate. However, SCS watershed work plans state that the rate shown in column 4 was used.

[e]Jo: achievement rate data for t = 0 is 60%; another 20% is added over years t = 1-10.

[f]Mill Creek: achievement rate data shown are for pasture-idle LUCB, upon which $P_{1,2,t}$ annual rates are based; $P_{1,3,t}$ annual rates are based on the data for farm woods LUCB, 50%, 15%, 10%, and 75% for columns 13-16 respectively.

[g]Sturgeon: 60% over years t = 1-10, with an additional 40% over years t = 11-30.

Appendix, Table 3. Benefits and Related Data, 12 Michigan PL 566 Projects, 1959-68.

Project name and documentation date		FWDRB $	OTHERB $	Enhancement benefit net return increase		FWDC $	SCS-type B/C ratio		Ratio of time zero to average annual benefits (as in SCS B/C)
				MILU, $	LUC, $		Agency computed	Author's base est.	
Black	1963	265[a]	---	23,576	2,992	---	2.90	2.85	.46
Cass, M.	1963	---	3,681[b]	95,763	47,067	---	3.18	3.12	.48
Cass, S.	1961	30,091	10,343[c]	200,387	101,724	---	1.73	1.69	.60
Catlin	1966	---	-140[d]	17,899	---	---	1.92	1.75	.48
Farm Creek	1965	---	---	3,110	2,781	---	1.26	1.22	.59
Jo	1964	---	---	33,109	---	---	1.53	1.51	.76
Little	1962	26[e]	799[e]	9,590	11,666	---	1.33	1.33	.50
Misteguay	1959	196,110[h]	---	605,874	---	---	9.59	9.17	.78
Muskrat	1959	---	---	28,825	---	---	4.89	4.97	.79
Mill Creek	1962	84,256	---	258,042	110,563[f]	1,792[f]	7.06	7.35	.69
Sturgeon	1966	1,254	25,060[g]	47,531	---	---	2.30	2.00	.71
Tebo	1968	2,500	---	73,731	---	---	2.20	2.22	.47

Source: USDA, SCS, work plan documentation; data may not compare with that shown in work plans, for some data were categorized for computer programming purposes, rather than for consistency with work plans.

[a]Black, FWDRB of $265 = FWDRB - FWDC = $513 - $248.

[b]Cass, M., OTHERB = redevelopment benefits, $3,681.

[c]Cass, S., OTHERB = impaired drainage benefits, due to flood control of backwater flow, $10,243.

[d]Catlin, 21 project-removed acres caused a net return loss of $140 per year.

[e]Little, annual benefits, total, as used in SCS-computed B/C ratio, $10,310; FWDRB, $26; enhancement benefits, $9,485; therefore, unspecified other benefits equal $799 (OTHERB).

[f]NBMC, net return change, LUC: LUC-pasture-idle, $39,828; LUC-woods, $70,635; LUC-total, $110,563. FWDC, total, $1,792; FWDC-MILU, $1,320; FWDC-PI, $153; FWDC-woods, $319.

[g]Sturgeon, OTHERB = $25,060; sum of redevelopment benefits, $2,300; recreation benefits, $22,760.

[h]Misteguay, FWDRB, $196,110 was used erroneously in sensitivity analysis; FWDRB are $186,110, see Appendix, Table 5.

Appendix, Table 4. Names and Locations, 12 Studied and Other Michigan PL 566 Projects, 1957-70.

Project name and documentation date		Full project name and location, and documentation date for the original (first) SCS watershed work plan
12 Studied Projects, 1959-68:		
Black	1963	Black Creek-Mason Watershed, Mason County, Michigan, June 1963
Cass, M.	1963	Middle Branch of Cass River Watershed, Sanilac County, Michigan, December 1963
Cass, S.	1961	South Branch of Cass River Watershed, Sanilac and Lapeer Counties, Mich., Feb. 1961
Catlin	1966	Catlin-Waters Reynolds-Session Watershed, Clinton County, Michigan, February 1966
Farm Creek	1965	Farm Creek-Lee Drain Watershed, Gladwin County, Michigan, July 1965
Jo	1964	Jo Drain Watershed, Midland County, Michigan, October 1964
Little	1962	Little River Watershed, Menominee County, Michigan, April 1962
Misteguay	1959	Misteguay Creek Watershed, Saginaw, Shiawassee and Genesee Counties, Mich., June 1959
Muskrat	1959	Muskrat Creek Watershed, Clinton County, Michigan, October 1959
Mill Creek	1962	North Branch of Mill Creek Watershed, Lapeer, Saint Clair and Sanilac Counties, Michigan, February 1962
Sturgeon	1966	East Branch of Sturgeon River Watershed, Dickinson County, Michigan, February 1966
Tebo	1968	Tebo-Erickson Watershed, Bay County, Michigan, March 1968
Other Michigan PL 566 Projects, 1957-70:		
		Fowlerville Drain Watershed, Livingston County, Michigan, November 1963
		Little Black River Watershed, Cheboygan County, Michigan, May 1957
		Maple River projects, documentation date in 1969, plans in review stage, early 1970
		East Upper-Maple River Watershed, Clinton, Gratiot and Shiawassee Counties
		West Upper-Maple River Watershed, Clinton and Gratiot Counties
		Sanborn Watershed (Devils River), Alpena and Alcona Counties, Michigan, January 1959
		Truax Creek Watershed, Alpena County, Michigan, plan in draft stage, early 1970

Source: USDA, SCS, watershed work plans and interview with John Okay, SCS Planning Party economist in Michigan, January 15, 1970.

Appendix, Table 5. U.S. and Michigan PL 566 Project Benefits, Categorized, Data in Dollars.

Name	Flood prevention benefits (FPB)				AWMB	Redevel-opment	Recre-ation	Secondary[b]	Total[b]	Ave. annual costs
	FWDRB	MILUB	LUCB	Total						
Black	---	3,019[a]	3,018[a]	6,037	7,115	---	---	---	13,152	4,553
Cass, M.	---	---	---	29,440[c]	29,440[c]	3,681	---	17,687	62,561	19,654
Cass, S	40,434[d]	34,392	18,681	93,507	59,956	---	---	46,911	153,463	88,763
Catlin	3,480[e]	520	---	4,000	4,000	---	---	2,300	8,000	4,175
Farm	---	---	---	1,875[c]	1,875[c]	---	---	980	3,750	2,985
Jo	---	---	---	8,168[c]	8,168[c]	---	---	2,819	16,336	10,664
Little	---	3,145[a]	3,145[a]	6,290	4,020	---	---	---	10,310	7,765
Misteg.	186,110	---	---[f]	186,110	252,695	---	---	138,242	438,805	45,739
Muskrt.	---	8,249	2,284	10,533	6,314	---	---	3,919	16,847	3,448
Mill	84,256	67,232	33,650	185,138	100,882	---	---	90,256	286,020	40,520
Sturgn.	1,254[g]	---	---	1,254	17,665[h]	2,300	22,760	7,120	43,979	19,170
Tebo	2,500	21,890	---	24,390	21,890	---	---	12,440	46,280	20,990
Fowler	2,059[g]	---	---	3,159[c]	1,100	357	---	1,142	4,616	3,049
L. Black	6,173[g]	---	1,270	7,443	---	---	---	---	7,443	6,173
Sanborn	78	---	4,720	4,798	3,280	---	---	1,613	8,078	1,862
Mich.	326,344	138,447	66,768	572,142[i]	518,400	6,338	22,760	325,429	1,119,640	
Mich.	22.6%	9.6%	4.6%	39.6%[i]	35.9%	0.4%	1.6%	22.5%[j]	100.0% =	$1,445,069[j]
U.S.	52.2%	9.0%	5.5%	68.6%[k]	11.4%[l]	1.2%	10.2%	5.0%	100.0% =	$92,519,000

Source: Mich. data, USDA, SCS, work plans; U.S. data, USDA, ERS, NRED, "Inventory of Basic Public Law 566 Watershed Work Plans," October 1967, p. 7 (from the inception of the PL 566 program in 1954 to June 1967).

[a]The author allocated joint benefits: 50%, FPB-MILUB and 50%, FPB-LUCB.

[b]Secondary benefits not counted in project totals, see note j.

[c]The author allocated joint benefits: 50%, FPB and 50%, AWMB.

Appendix, Table 5 (cont'd.)

[d]Cass, S.: FWDRB include impaired drainage benefits, $10,343.

[e]Catlin: FWDRB procedure not used in computation.

[f]Misteguay FPB-LUCB of $29,081 are not shown, although they were shown in one of two SCS work plan tables; they were not shown in the work plan documentation; they were excluded in the summary table, as well as in the benefit cost ratio computed by SCS.

[g]All or mostly urban FWDRB.

[h]Sturgeon irrigation AWMB; all other Michigan projects have drainage AWMB.

[i]Includes allocated joint benefits, $40,583, or 2.8%, counted in this column, but not in the columns to the left; allocated by the author, as explained in note c.

[j]Includes secondary benefits of $325,429 not included in the separate project totals. The Michigan secondary benefits percentage, 22.5% is based on the ratio $325,429 / $1,445,069.

[k]U.S. data: FPB percentage, 68.6%, includes 1.9% for other FPB.

[l]U.S. data: AWMB percentage, 11.4%, does not include: 1.9%, municipal and industrial water supply; incidental recreation, 0.7%; and other, 0.5%. These additional percentages are counted in the 100% total. For the U.S. data, AWMB-drainage is 8.4%, and AWMB-irrigation is 3.0%. For Michigan data, AWMB-drainage is 34.7% and AWMB-irrigation is 1.2%; total of 35.9%.

Appendix, Table 6. Yield Data, Mill Creek Project and 1959-63 Michigan State Average

Crop	Unit	Flooding poor drainage (Y_{1-A})	Flood-free, poor drainage (Y_1)	Flood-free, poor drainage (Y_2)	1959-63 Michigan state average[a]
Corn, for grain	bu.	54.0	65.0	84.0	61.5
Corn silage	ton	10.0	11.0	13.5	10.2
Oats, for grain	bu.	40.0	51.0	66.0	47.3
Wheat	bu.	30.0	35.0	45.0	34.0
Dry edible beans	bu.	17.0	21.0	32.0	22.0
Sugar beets	ton	12.0	14.5	19.0	15.8
Clover hay	ton	1.6	2.0	3.0	1.84
Alfalfa hay	ton	2.0	2.7	3.9	1.84
Pasture, permanent	c.p.d.[b]	62.5[c]	75.0	120.0	75.0[c]
Lawn grass sod	sq. yd.	2277.9[c]	2733.5	2866.8	2300.0[c]
Potatoes	cwt.	175.0	219.0	293.0	144.0
Onions, fresh mkt.	cwt.	275.0	317.0	394.0	349.4
Carrots, fresh mkt.	cwt.	245.0	319.0	397.0	221.4
Celery, fresh mkt.	cwt.	400.0	475.0	572.0	378.5
Cabbage, fresh mkt.	cwt.	170.0	190.0	254.0	166.7
Lettuce, fresh mkt.	cwt.	110.0	130.0	180.0	173.3
Cucumbers, fresh mkt.	cwt.	55.0	69.0	87.0	65.1

Source: Mill Creek data from USDA, SCS, in-file documents; 1959-63 Michigan state average yields from USDA, Agricultural Statistics, 1966 (Washington, D.C.: USGPO, 1966), computed if necessary by dividing harvested acreage by production.

[a]Crop notes, 1959-63 Michigan state average yields: summer lettuce; late summer potatoes, onions, and cucumbers; combined early summer and early fall celery; and early fall carrots.

[b]C.p.d.: cow pasture days.

[c]Author's estimate.

Appendix, Table 7. Alternative Crop Prices in Dollars, for Michigan.

Crop	Unit	PLT	1959-63	1964-66	AN	Brandow[i]
Corn, for grain	bu.	1.40	1.03	1.17	1.06	0.77
Corn, silage[a]	ton	10.18[b]	7.42	8.42	7.63	4.16
Oats, for grain	bu.	0.76	0.63	0.66	0.58	0.41
Wheat	bu.	1.60	1.79	1.44	1.24	0.87
Dry edible beans	bu.	3.60	3.44	3.89	3.60	2.94
Sugar beets[c]	ton	15.60	13.22	13.18	11.12	10.54
Clover hay	ton	15.10	20.00	20.00	21.12	16.00
Alfalfa hay	ton	18.20	20.00	20.00	21.12	16.00
Pasture, permanent	c.p.d.[d]	0.16	0.15	0.15	0.16[e]	0.12
Lawn grass sod[f]	sq. yd.	0.25[b]	0.29	0.29	0.30	0.23
Potatoes	cwt.	1.75	1.97	2.82	1.97	1.58
Onions, fresh mkt.	cwt.	2.00	2.82	3.03	3.01[e]	2.26
Carrots, fresh mkt.[g]	cwt.	6.44	5.98	5.52	5.98[f]	4.78
Celery, fresh mkt.	cwt.	3.30	3.29	4.35	3.33[h]	2.48
Cabbage, fresh mkt.	cwt.	1.95	2.12	2.72	2.26[e]	1.70
Lettuce, fresh mkt.	cwt.	4.84	4.34	5.34	4.46[h]	3.47
Cucumbers, fresh mkt.	cwt.	4.54	4.89	6.03	4.98[h]	3.94

Source: PLT field crop prices: USDA, ARS and AMS, Agric. Price and Cost Projections . . . (Wash., D.C.: USDA, 1957). PLT vegetable prices: USDA, SCS, Michigan Planning Party. AN prices: U.S., Water Resources Council, Interim Price Standards . . . (Wash., D.C.: the Council, April 1966); supplemented by (for veg. crops) USDA, SCS, Economics Guide Notice 7 (Wash., D.C.: SCS, March 26, 1968). Brandow's projections for 1965 (with removal of govt. programs): Walter Wilcox, "Agric. Income and Adjustment Problems," in U.S., Congress, Joint Econ. Comm., Econ. Policies for Agric. in the 1960's (Wash., D.C.: USGPO, 1960).

[a] Silage price = 6.2 x grain price (source: Ray Hoglund, Dept. of Agric. Econ., Mich. State Univ.).

[b] Adjusted from the original price used by SCS.

[c] AN and Brandow prices exclude Sugar Act payments, \$2.22 for 1959-63 and \$2.17 for 1964-66.

Appendix, Table 7 (cont'd.)

[d]C.p.d.: cow pasture days.

[e]SCS computed: $AN_{Mich.} = AN_{U.S.} \times \frac{\text{1960-64 Mich. average price}}{\text{1960-64 U.S. average price}}$

[f]Author's estimate, based on SCS data and discussions with Jim Beard, Crop Science Dept., Mich. State Univ., April 1968.

[g]Carrot prices used are higher than those found in USDA's Agricultural Statistics (Wash., D.C.: USGPO, various years). Non-PLT prices based on: doubled price for carrots, Mich. points, topped, washed, 48 one-pound film bags, mesh, master containers; see USDA, Fresh Fruit and Vegetable Prices (Wash., D.C.: USDA, various years).

[h]Same as for e, but using 1959-63 prices to adjust the U.S. AN prices; author's computations.

[i]Only the corn, oat, and wheat grain prices were obtained directly from Brandow; the others are based on a 20% reduction of the 1959-63 prices shown, although Brandow's projections for 1965 (to remove the effect of government programs) included a 20% reduction in the USDA index of prices received by farmers from the 1959 (not 1959-63) level.