PRELIMINARY REVIEW AND ANALYSIS OF FLOOD CONTROL PROJECT EVALUATION PROCEDURES

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Preliminary Review and Analysis of Flood Control Project Evaluation Procedures

IWR

INSTITUTE FOR WATER RESOURCES

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

SEPTEMBER 1970

IWR REPORT 70-3

PRELIMINARY REVIEW AND ANALYSIS OF FLOOD CONTROL PROJECT EVALUATION PROCEDURES

A Report Submitted to the Planning Division
Office of Chief of Engineers, Department of the Army
and Published by the
U.S. Army Engineer Institute for Water Resources
206 North Washington Street
Alexandria, Virginia

by

N. V. Arvanitidis, R. C. Lind, J. Rosing, G. P. Johnson
INTASA
1030 Curtis Avenue
Menlo Park, California 94025

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September 1970

IWR Report 70-3

INSTITUTE FOR WATER RESOURCES

In 1969, the Subcommittees on Public Works, House and Senate Appropriations Committees, authorized formation of the Institute for Water Resources to assist in formulating Corps of Engineers water resources development planning and programming. Improved planning and evaluation concepts and methods are needed if development and utilization of these resources are to meet the public objectives of economic efficiency, protection and enhancement of the environment, regional development, income distribution, and general well-being of people. The Institute and its two Centers--the Center for Advanced Planning and the Center for Economic Studies--carry out both in-house and by contract, research studies to resolve conceptual and methodological problems involved in the development of our Nation's water and related land resources.

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R. H. GROVES
Brigadier General, USA
Director

FOREWORD

Purpose

This study was undertaken to clarify the economic consequences and effects of programs designed to protect or otherwise manage flood plains. A firm basis is required to appropriately distinguish between the source of change of a flood plain development from its economic effects. Specifically, there is a need to better understand the so-called "land enhancement" effects arising from the protection of lands that would remain undeveloped without protection, but would develop with protection afforded. There is a further need to explore alternative techniques for the measurement of these benefits. The study does not address the question of the distribution of income from flood plain use or its social consequence.

Findings

The study makes the following findings:

1. With and without analysis applied to evaluation for flood protection suggests two basic sources of economic effects and benefits. These are:

(a) Where the development in the flood plain will be the same with and without the project, benefits attributable to the project will equal total damages reduced.

(b) Where there is project induced growth, the benefits attributable to the project are equal to the net increase in productivity of the economy due to the relocation of activities both inside and outside the flood plain.

2. Regardless of the source of flood plain change, the economic effects for both cases reflect increased productivity and serve as a measure of economic efficiency gains.

3. Benefits from project induced growth (so-called "land enhancement" benefits) can be measured by the difference between the net income (profits) of activities which move into the flood plain with protection and the net income they could earn outside the flood plain.

4. In the absence of direct observation of change in net income, benefits from project induced growth can be measured in terms of simulating damages reduced to new activities that would located in the flood plain with protection.

5. Differences in land values can also be used as a measure of project induced benefits provided they are evaluated in the context of with and without a project and are adjusted to eliminate expectation about future developments not associated with the project.

6. Given the presence of a number of key variables affecting future flood plain change under with and without conditions, all subject to varying degrees of uncertainty, there is a need to develop a more systematic approach for evaluating project benefits and costs to test the sensitivity and reasonableness of assumptions that affect final decisions.

Assessment

In general, the study rests heavily on an interpretation of economic result theory, namely that profits will go to activity and landowner rather than to the landowner alone; and the assumption that competitive conditions hold outside the flood plain when activities relocate as a result of the project. The latter holds that the sum of activity profits and property values outside the flood plain sum to zero, and only the changes of activity profits and land values in the flood plain need to be considered. These assumptions appear to be most appropriate in light of the accompanying discussion.

The study provides a valuable contribution to the definition and measurement of benefits from flood control projects. It enables a clearer understanding of the basis for these benefits, the appropriateness of distinctions among types of benefits, and it offers a convenient framework for the calculation of these benefits.

Status

The contents and conclusions of the study are subject to further review and therefore do not necessarily represent the views of the Corps of Engineers. Policy or procedural changes which may result from the study will be implemented by means of directives and guidance provided by the Chief of Engineers through command channels.

Additional study is required to field test the concept of measuring project induced growth benefits through damage reduction measures. There is a further need to develop and to test a more systematic approach to make the overall evaluations for flood control projects allowing for variations in the key assumptions.

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PROJECT SUMMARY

A. Background

On September 26, 1969, Mr. Robert M. Gidez, Chief of the Economics and Evaluation Branch, Planning Division, Office of the Chief of Engineers, U. S. Army Corps of Engineers, and Dr. Robert C. Lind of INTASA discussed a forthcoming review by the Corps of policies relating to the development of flood plains. Mr. Gidez suggested that INTASA submit a proposal for a preliminary study to review and analyze some of the important issues generally related to the evaluation of benefits from flood control, and particularly related to two specific projects in Southern California. In October 1969, a proposal was submitted and on December 16, 1969, the Corps contracted with INTASA for the above task. This Final Report describes the work completed by INTASA under Contract No. DACW07-70-C-0050 with the Department of the Army for the U. S. Army Corps of Engineers.

B. Scope

The contract calls for INTASA to provide consultation to the Corps in a preliminary analysis of the planning and evaluation procedures for flood control projects with emphasis on analytical methods which may be employed in estimating benefits from flood protection. The primary objectives of the contract include the following tasks:

1. Investigation of practical and analytical procedures that can be incorporated into present project analyses with particular reference to the "with and without" concept in benefits evaluation.

2. The accurate identification of benefits from flood control, and particularly, the distinction between land enhancement benefits and flood damages prevented.

3. The establishment of an economic basis for measuring land enhancement benefits in terms of net incomes and/or net earnings; and, on a preliminary basis, the determination of feasible alternative techniques for measuring these benefits.

4. The preliminary examination of several ways by which net earnings can be measured either directly or indirectly; namely through (a) increased net earnings from growth of activities in the flood plain, (b) direct observation of real changes in land values, and (c) simulating land value changes using flood damages prevented as a proxy measure.

5. The review and analysis of two specific projects in Southern California. The projects selected were Newhall, Saugus and Vicinity, in Los Angeles County, and Day, East Etiwanda, and San Sevaine Creeks, in San Bernardino and Riverside Counties. In the reviewing process, emphasis should be placed on the application of economic concepts to project evaluation. Particularly (a) application of "with and without" analysis, (b) the reasons for using damage reduction as the primary source of benefits for one of the projects but not for the other, and (c) the measurement of land enhancement benefits.

6. Recommendations in regard to the above and related topics together with an outline of a research program to revise and improve Corps policies and procedures relating to flood plain development.

In addition, if time permits, INTASA should consider problems related to

7. flood plain redevelopment over the project life,
8. cost sharing and local participation,
9. optimal sizing and timing of protection measures, and
10. the development of an overall decision framework for evaluating alternatives.

Part One of this report is mainly concerned with the first four tasks, whereas Part Two covers the review and analysis of the two specific projects in Southern California. In Part One emphasis has been placed on a detailed investigation of the proper application of "with and without" analysis to a variety of practical situations; on the proper identification and definition of benefits from flood control, and, in particular, the distinction between land enhancement benefits and damage reduction; on the measurement of benefits using indirect methods; and on the preliminary investigation of measuring land enhancement benefits through damages reduced. Part Two provides a summarized description of the two projects in Southern California and where appropriate, it analyzes and discusses procedures presently used by the Corps.

C. Summary of Basic Methods and Assumptions

A basic analytical tool used by the Corps for project evaluation is benefit-cost analysis. This technique measures changes in the net productivity of the economy in terms of willingness to pay. More specifically, the benefits and costs, to whomsoever they may accrue, are calculated on the basis of willingness to pay over the life of the project and discounted to their present value.

Benefits are defined as the amounts, positive or negative, that individual households and businesses are willing to pay for the project. Costs are equal to the costs of resources required by the project. Under competitive conditions, market prices can often be used in measuring costs and benefits. In applying this concept to the evaluation of flood control projects, it is assumed, implicitly or explicitly, that prices other than the price of land are unaffected by the project. From this assumption, it follows that all benefits accrue to landholders through changes in land values or to activities in the form of increased profits. Individuals in their role as suppliers of labor or buyers of goods do not benefit from the project because wage rates and the prices of consumption goods are unchanged.

The activities considered here may either be firms or households. The meaning of profit for a firm is clear. The profit of a household which supplies itself with housing or other services requiring land is, in this report, defined to be the difference between the market value of the good or service supplied and the cost of producing that service. This definition is consistent with the definition of profits for a business.

In addition, the distinction is made between the landowner and the owner of the activity on the land in order to systematically distinguish between the return to land and the return to capital and entrepreneurship that constitutes the profit of an activity. In many cases, the landowner will also own the activity located on the land, and in such case he will gain through both increased profits and increased land values. A profit maximizing activity will, however, consider the implicit cost of land owned by the activity in choosing the optimal location and mode of operation.

This illustrates a point which is essential to the arguments throughout the report. Suppose S_x is the profit of activity x exclusive of the cost of land at a particular location and $S_x - p$ is net profit after paying the cost of land. If the price of land increases, the profit to the activity located on that land decreases by an amount equal to the price increase; the sum of profits to the activity and the return to land remains, however, unchanged. More generally, since all benefits accrue to people in their role as landowners or the owners of activities it follows that changes in land prices will simply affect how these benefits are divided among activities and landowners. This can be seen in terms of specific examples in the report.

A few basic points are demonstrated throughout this report. First, total benefits equal the total of changes, positive or negative, in land values and profits within the economy as a result of the project. The problem is to identify the sources of these benefits and ways of measuring them. Second, benefits, regardless of how they are created, measure net changes in productivity in terms of willingness to pay. Categories of benefits by source may be developed for purposes of identification or to facilitate measurement, but these benefits are not different in kind. Third, many different methods may be derived for measuring benefits, but what they measure is the same. This distinction between what is measured and how it is measured is important as different techniques of measurement have created the mistaken impression that they correspond to different types of benefits.

D. Results and Conclusions

The following results and conclusions are derived from the analysis in Part One.

1. The application of with and without analysis can be reduced to two basic cases:

a. Where there is no project induced growth, so that development in the flood plain will be the same with and without the project, benefits attributable to the project will equal total damages reduced. These benefits will be divided between owners of land and of activities, and will take the form of increased wealth of landowners and of profits, respectively. This counting of both the increased land values and increased profits does not involve double counting. Profits to the activities will decrease by an amount equal to the increase in land values, leaving the total benefit unchanged.

b. Where there is project induced growth, so that the flood plain will develop differently with and without the project, the benefits attributable to the project are equal to (1) the net increase in productivity of the economy due to the relocation of activities both inside and outside the flood plain, plus (2) the reduction in damages to activities which will locate in the flood plain with or without protection. These benefits will be divided among all owners of land and activities inside the flood plain and those outside the flood plain that are affected.

The results above were derived from the systematic application of with and without analysis to a number of situations including rational and irrational decisions regarding location in the flood plain and considering both awareness and ignorance of flood hazards. These results are developed in Chapter II of Part One.

2. The distinction between land enhancement benefits and damage reduction is one of definition and is useful for the purpose of benefit measurement. It should not be inferred from this distinction that these benefits are different in kind. They both represent increased productivity as defined in benefit-cost analysis. The basis for determining whether benefits should be designated as damage reduction or land enhancement depends on the presence of project induced growth.

a. When there is no project induced growth, there are no land enhancement benefits, and total benefits are given by damages reduced.

b. When there is project induced growth, damage reduction is only one source of benefits and land enhancement is another, where land enhancement benefits are introduced to measure benefits resulting from the relocation of activities due to the project.

The precise definition of land enhancement benefits and their distinction from damages reduced are explored in Chapter III of Part One.

3. Based on the assumption that competitive conditions hold outside the flood plain, it is demonstrated that land enhancement benefits can be measured by the difference between the profits of activities which move into the flood plain with protections and the profits they could earn outside the flood plain plus the increase in wealth of owners of flood plain land resulting from increased land values due to the project. In addition, it is demonstrated that:

a. Under certain conditions as stated in Chapter IV of Part One, differences in land values may be used as a measure of benefits. This method, however, is subject to two serious short-comings. First, land values before and after the project do not always correspond to those with and without the project, since many factors not associated with the project may lead to increased land values. Second, actual land prices will reflect expectations about future development and will not be the idealized prices which would be required for differences in land values to accurately measure benefits.

b. An upper bound to land enhancement benefits is the reduction in damages to the new activities; a lower bound is the reduction in damages to the displaced activities that would be in the flood plain without protection.

These results and conclusions are explored in Chapter IV of Part One.

4. Land enhancement benefits can be measured in terms of damages reduced.

These benefits are equal to the damages over and above the level of protection required to induce activities into the flood plain. This is because without this minimum level of protection, such activities would not locate in the flood plain and these damages would not occur and therefore cannot be counted as benefits. By providing protection above the minimum level the benefits simply equal the additional damages prevented. This leads to the following observation about benefits. Benefits from flood control result from the increased productivity of the land and, therefore, in a general sense all benefits involve land enhancement. At the same time, the only way which a project can affect the productivity of land is by reducing potential damages and in this sense all benefits result from damage reduction. It is therefore not surprising that land enhancement can be measured in terms of damages reduced. A more detailed discussion is presented in Chapter V of Part One.

The following tentative conclusions were reached from the analysis in Part One and the review of the specific projects in Part Two:

5. Development for which benefits are measured in terms of land enhancement is, to a large extent, determined by zoning regulations, and this is the most important difference between Newhall, Saugus, and Vicinity, and Day, East Etiwanda and San Sevaine Creeks flood plains. The first one has strict zoning regulations and, therefore, land enhancement benefits, whereas the second has neither. This leads to the conclusion that flood plain management is a crucial parameter in deciding whether a project offers land enhancement benefits, and, therefore, flood plain management should be based on sound economic reasoning.

6. Land enhancement benefits for the Newhall-Saugus project are measured as the difference in price of land with and without protection, where the price of land with the project is based on present and future expected land values outside the flood plain. For this to be a valid measure the following conditions should be satisfied:

a. The price outside the flood plain is adjusted for the residual damages inside the plain to reflect the differential flood hazards.

b. Land prices before protection do not include speculation on the construction of a flood control project.

c. Landowners receive all benefits from flood protection.

d. Increase in the value of the land is the result of the project and not of other economic and environmental influences unrelated to the flood protection provided by the project.

The above conditions are discussed in Chapter IV of Part One while a summary and discussion of the land enhancement benefits for the Newhall-Saugus is given in Appendix B, Section VI, of Part Two.

7. For both the Newhall-Saugus and the Day-East Etiwanda project, with and without analysis was applied properly, except possibly on some minor points. The different development of the flood plains, however, was not necessarily based on sound economic reasoning. That is

a. The zoning regulation effecting the development of the Newhall-Saugus area may not be the result of proper economic analysis,

b. The decisions of activities to move into the flood plain in the Day-East Etiwanda area may be the result of ignorance of potential flood damages.

The application of with and without analysis in cases of irrational decision making is explored in the last part of Chapter II.

8. For the enhanced land in the Newhall-Saugus project, the reduction in damages to the new activities that will locate in the flood plain as a result of protection should provide the upper bound on the land enhancement benefits. A comparison between the reduction in damages to non-enhanced land and the land enhancement benefits, given in Appendix B of Part Two, shows that testing of this upper bound may be useful in establishing the validity of the land enhancement benefits derived.

In addition the following tentative conclusions were reached as a result of the review of the projects in Part Two.

9. The land enhancement benefits are highly sensitive to the use of two different discount rates, one to obtain the present value and the other to obtain the average annualized benefits.

10. The general economic forecast for the area is one of the most important variables in the evaluation of the flood control benefits. Therefore, it would be useful if the assumptions on which these forecasts are based, as well as the uncertainties associated with them, were clearly stated. The uncertainty in these forecasts is illustrated by the difference in projected population densities for the two projects, probably made one year apart, as presented in the Summary of Part Two.

11. Based on general economic forecasts for the area, the use and rate of development of land in the flood plain, together with the value of property, are estimated with and without the project. Benefits are highly sensitive to these estimates, and it is, therefore, concluded that sensitivity of project benefits to changes in these estimates should be part of the analysis.

12. The evaluation of the average annual damage reduction is sensitive to the discount rate, the assumed rates in productivity increase that are used to estimate the value of property in the future, and to the assumed fixed ratio between damage reduction and property value. This relationship is explored in Section VI, Appendix C., Part Two.

13. The statistical procedures used for both projects to obtain the frequency-discharge relationships are subject to questioning. In one case regional frequency analysis is used, and in the other, the record of one stream flow is analyzed. The amount of data available in both cases is limited. A discussion of the procedures used and their implications are given in Appendices B and C, Part Two.

E. Recommendations

The major recommendations briefly stated here are based on: (a) the January 20th meeting between the Corps and INTASA, (b) the meeting with the Los Angeles District Office of the Corps, (c) the analytical results presented in the previous section and discussed in Part One, and (d) the actual review and analysis of the presently used Corps procedures as applied to the two specific projects in Southern California and presented in Part Two.

1. A systematic, computerized framework for evaluating project benefits and costs should be developed. The resulting computer program should be used to simulate the effect of the various parameters and assumptions to benefit and cost evaluation. Thus, the important parameters can be identified and further studied as required. This is envisioned as a practical tool to assist the Corps in moving away from specifying a fixed set of assumptions and, as a result, to allow for improved understanding as well as more reliable benefit and cost estimates. First such a simulator can be developed by systematizing and slightly modifying the presently used Corps procedures while additional research should be oriented towards improving the input information used by the program.

2. Basic to with and without analysis is the forecast of land use development with and without the project. The sensitivity of the benefits to this is demonstrated in the Appendices and could be easily verified beyond doubt by the use of a simulator. As a result, models capable of predicting land use and prices should be investigated in order to provide answers to the how of future flood plain development.

3. The different methods for measuring land enhancement benefits should be further analyzed; the method of using the difference in damage reduction between the actual level of protection and the minimum level of protection required to attract the activity into the flood plain appears very promising. The upper and lower bounds on land enhancement benefits should be used to test alternative methods for estimating these benefits as discussed in Chapter IV. It is also envisioned that still better bounds can be derived by considering particular instead of generalized cases.

4. In the case where land values are used to measure land enhancement benefits, the appropriate discount rate must be chosen. This is controversial in the sense that different discount rates may be appropriate in different aspects of benefit and cost evaluation. The sensitivity of the results to the different discount rates should, therefore, be tested.

5. When benefits are measured by damages reduced, the damage discharge relationship becomes extremely important. This relationship should be carefully investigated. The presently used assumption that damages increase proportionally to increase in property value should be studied since other assumptions are possible and would influence the benefits greatly. This also becomes important if damage reduction is used to measure land enhancement benefits.

6. The statistical methods used for arriving at discharge-frequency relationships are questionable. Lack of consideration of whether or not the events are dependent or independent , the hydrological region is homogenous, the samples of different streams are correlated, and the small data sample used is sufficient for extrapolation, could lead to distorted frequency-discharge relationships and therefore unreliable benefits. In addition, the statistical process should be clearly identified so that the variance of the estimated damages can be obtained. The variance provides assurance of the reliability of the estimate.

7. It was seen that the basis for land enhancement benefits in the Newhall-Saugus area is the county zoning regulations. These regulations in general determine whether or not benefits for a particular project should include land enhancement benefits. Therefore, flood plain management constitutes the basis for land enhancement benefits and as a result, should be established upon a sound economic basis. Flood plain management should provide the answer to how flood plains should develop.

Several other topics related to flood plain development were briefly considered in the course of this study. The problems of evaluating alternatives, staging of projects, optimal time and size of the project, and cost sharing are briefly addressed at various phases of this report. Because of large capital requirement and large time delays between the study period and actual construction, current interest rates can decrease benefits and cost considerably. Thus, optimal sizing, timing and staging of projects may significantly increase net project benefits. With the use of a simulator, as recommended above, different project sizes and timing and staging alternatives can be tested. For a small number of these alternatives, the simulator can be used to determine the best and therefore be used to optimize.

The choice of the optimal size of a project is further complicated by budget constraints and by the uncertainty in the benefit-cost values derived. If the budget was unlimited, and if the benefit-cost figures were completely certain, maximization of net benefits, marginal benefit-cost ratio of one, is the obvious criteria for the optimal size of a project, and this can be determined by simulating alternatives. If there is uncertainty, the expected net benefits can be maximized and, assuming the error to be normally distributed, in reality the actual marginal benefit-cost ratio of the optimum will be half of the time larger, and half of the time smaller than one. In many cases, however, the total budget of the Corps is limited and cannot support projects with a marginal benefit-cost ratio close to one. In that case, increments of projects with a benefit-cost ratio close to one are also not desirable, and the optimal size of the project will be determined by the budget constraint.

The sharing of project costs between the federal government and local interests that benefit from the project may have the objectives of (1) promoting an efficient allocation of resources (2) promoting a more equitable distribution of income, and (3) providing the necessary financing for the project. Economic justification of the above objectives, analysis of the rules presently used by the Corps for cost sharing, and the related topic of windfall gains to the landowners are not included in this report. However, it appears that a clear and precise method for establishing the basis for local contribution to project costs is needed. This method should depend on a clear understanding of the implications of various <u>sharing rules</u> and on determing a feasible set of such rules.

F. Interaction with the Corps

The Corps provided direction and assistance as needed throughout the current effort. Mr. Walter Yep of the South Pacific Division assisted INTASA in obtaining the two project reports for review and other material related to the project. In addition, through telephone conversation, he was most cooperative in answering questions vital to the progress and success of the project. Mr.

Robert Gidez provided the direction for the project. Upon his request a meeting was scheduled between the Corps and INTASA to review the progress and to jointly develop a strategy for the remaining work. The meeting took place on January 20, 1970, in San Francisco at the South Pacific Division office of the Corps. Present at the meeting were Messrs. Robert Gidez, John Hadd, and James Johnson from the Office of the Chief of Engineers, Messrs. Walter Yep, Edward Lofting and Kermit Spaeg from the South Pacific Division, Mr. Richard Howes from the Center for Economic Studies, and Messrs. Robert Lind and Nick Arvanitidis of INTASA.

Mr. Robert Lind presented the work completed to date by INTASA. Some of the most important issues discussed were:

1. Clarification of the basic nature of flood control benefits with respect to the distinction between land enhancement benefits and damage reduction.

2. The measure of land enhancement benefits in terms of increase in net productivity and the various ways of applying this measure. In particular, Mr. Gidez's idea about using damage reduction as a proxy measure for land value changes was extensively discussed and provided direction for INTASA's subsequent work on the contract.

3. The practical difficulties associated with applying with and without analysis to project evaluation. On this issue, it was agreed that forecasts of future land use would be essential in actually applying the concept.

4. The development of a systematic framework for project evaluation to be implemented on a computer. The computer program would simulate various assumptions and parameter values on a consistent basis and determine to which of these parameters and assumptions the evaluation procedure would be sensitive. The understanding was reached that the Corps is moving away from trying to specify a fixed set of assumptions for project evaluation, and, therefore, the above would be a very useful practical tool.

5. The review and analysis of the specific projects. The main conclusion was that a large number of assumptions which served as the basis for the analysis should be questioned and carefully examined. It was also concluded that the two project sites in Southern California should be visited and unresolved questions should be discussed with the District Office.

Following the January 20th meeting INTASA prepared a number of topics to be discussed with the Planning Branch of the Los Angeles District Office and these topics were submitted to Mr. Arthur Potter, Chief of the Planning Branch, while copies were forwarded to Messrs. R. Gidez and W. Yep. A meeting was scheduled between the Los Angeles District Office of the Corps and INTASA for February 26th and 27th. INTASA members R. Lind, P. Johnson and N. Arvanitidis met with Messrs. A. Potter and S. Light of the District Office and J. Tang of the Institute of Water Resources. The two project sites were visited and subsequent discussions were held on issues raised either by reviewing the reports or by the site visits.

Much of the discussion was oriented toward the difficulties in updating the evaluation results and the fact that it was extremely difficult to evaluate the effect of alternative assumptions and parameters on project benefits. An important conclusion reached in that meeting was that county zoning regulations determine whether a flood plain will develop without the project, and that this artificial barrier determines, to a large extent, the existence of land enhancement benefits to some projects and not to others. Mr. A. Potter expressed the need for a framework that would provide a practical tool for the measurement of flood control benefits. It was also concluded that a number of assumptions and parameters were derived from local flood control districts in the county, and a closer examination of the project would require some interaction with them.

Part One

ANALYSIS OF THEORETICAL CONCEPTS FOR PROJECT EVALUATION

I. SUMMARY OF PART ONE

Part One provides a preliminary review and analysis of procedures for evaluation of flood control projects. It focuses on the following analytical problems: (1) the application of "with and without" analysis in the evaluation of flood control projects, and (2) the identification and definition of benefits from flood control with particular emphasis on clarifying the distinction between land enhancement benefits and damage reduction, (3) the measurement of land enhancement benefits through indirect methods and (4) the measurement of land enhancement benefits through damages reduced.

Chapter II is totally devoted to demonstrating the proper application of the "with and without" concept. It illustrates the application of this concept in a number of situations. The objective is to evaluate the benefits to activities and landowners with the project and without the project, and to take the difference between these two. The analysis results in two basic formulas for benefit evaluation: one for the case where there is no project-induced growth and the other for the case where there is project-induced growth. These two formulas are used in subsequent chapters to identify sources of benefits and to develop practical methods of measuring them.

Chapter III identifies and defines sources of benefits for flood control. The distinction between land enhancement benefits and damage reduction is clarified and land enhancement benefits are precisely defined according to the current use of the term by the Corps. It is also pointed out that while a differentiation of benefits from different sources can be made, it is only a matter of definition and a generalized benefit from flood control may actually be more appropriate for analysis.

Chapter IV discusses measurement methods. In particular it derives a precise expression for land enhancement benefits, and it demonstrates that under certain assumptions, these benefits could be measured indirectly by using changes in land values. In addition, a lower and upper bound for land enhancement benefits is derived using damages reduced.

Chapter V investigates an approach for measuring land enhancement benefits through damages reduced. It demonstrates that if one can forecast the land use pattern for different levels of protection, land enhancement benefits can be measured as the difference between damages reduced to the new activities in the flood plain and damages to these activities at the minimum level of protection required to induce them into the flood plain.

II. BASIC ECONOMIC CONCEPTS IN PROJECT EVALUATION

A. Introduction

The basic tool used by the Corps for project evaluation is benefit-cost analysis. This technique involves the measurement of annual costs and benefits to whomever they accrue over the life of the project, and it requires the selection of the project that maximizes the annualized net benefits. In applying benefit-cost analysis to the evaluation of flood control projects, the assumption is made, explicitly or implicitly, that prices of all goods and services except the price of land do not change as a result of protection. Thus, all benefits accrue to individuals in their role as landowners or as owners of activities, where the term activities here applies to both businesses and households. The total benefits from flood control equals the sum of the changes in profits of activities and the changes in the wealth of landowners as a result of the project.

A basic problem in evaluating benefits is to determine what changes in future profits and land values can be attributed to the project. This is especially important when one is faced with relatively undeveloped flood plains where a multiplicity of environmental, social and economic factors can also influence development. In order then to determine the benefits and costs that are attributable to the project, it becomes necessary to compare benefits and costs with and without protection. This type of analysis is referred to as "with and without" analysis, and it attempts to measure the changes in profits and land values as a result of the project. Identification of these project benefits under a variety of situations forms the basis of this chapter.

In the process of demonstrating the application of with and without analysis, it is shown that in the cases where there is no project-induced growth, total benefits are equivalent to damages reduced. The application of with and without analysis in this case consists of identifying the difference in damages with and without the project. In the case where there is project-induced growth, the relation between damages reduced and total benefits is not so simple. While this chapter focuses on <u>what</u> should be measured rather than <u>how</u> it should be measured, the two questions are closely related and results of the analysis of this chapter form the basis for later chapters on measurement.

B. "With and Without" Analysis and Definition of Terms

There is general agreement that with and without analysis is required for a sound evaluation of a project. However, the application of this procedure may result in practical and conceptual difficulties. These difficulties are mostly associated with project-induced growth which takes place whenever the land use or its rate of development in and around the flood plain is affected by the introduction of flood control measures. Thus, various economic activities will develop and locate differently with and without the project. In addition to the problem of actually forecasting future conditions with and without protection, the determination of the correct measure for the net benefits due to the project can become quite involved. The question in regard to with and without analysis is not whether it should be applied but how it should be applied.

Before discussing the applications we will define several terms which will facilitate the understanding of some basic concepts involved.

p — is the level of protection provided by a project which is measured by the percentage chance of having a flood smaller than or equal to the largest flood against which the project provides protection. For example, if a project design is based on the Standard Project Flood (SPF), the degree of protection is given by the probability that a flood will be smaller than or equal to the SPF. For the purposes of our discussion, p will vary between 0 and 1, where zero represents no protection and 1 represents full protection.

D(p) — measures the expected average annual damages that would occur without protection given the level of development that corresponds to a protection level p. That is, it is assumed that for any level of protection there corresponds a level of development, and the damages D(p) would occur if this level of protection were eliminated; e.g. zoning regulations affect the level of development. In the case where the development of the flood plain is independent of the degree of protection, D(p) is a constant denoted by D.

R(p) — is the total reduction in expected damages when a project provides for a level of protection p. Obviously $R(1) = D(1)$ and $R(0) = 0$.

r(p) — is the residual expected damage that will occur when a project does not provide for complete protection. Obviously, $r(0) = D(0)$ and $r(1) = 0$. It is clear then that for all levels of protection, $D(p) = R(p) + r(p)$.

C(p) — is the average annual cost of a project providing a level of protection p.

R'(p) is the marginal or incremental reduction in damages due to a small increase in the level of protection,

$$R'(p) = \frac{\Delta R(p)}{\Delta p} = \frac{\Delta R(p+\Delta p) - R(p)}{\Delta p}$$

C'(p) is the marginal or incremental cost of the project as a result of a small increase in the protection level and is given by

$$C'(p) = \frac{\Delta C(p)}{\Delta p} = \frac{C(p+\Delta p) - C(p)}{\Delta p}$$

The relationship between total possible damages D(p), reduction in damages R(p) and residual damages r(p) is given in Fig. 2.1a for the case where there is no project induced growth or D(p) = D. The case where D(p) is increasing with the degree of protection is shown in Fig. 2.1b and as indicated in the figure, r(p) may actually increase over some range of p. This will actually occur when the total damages to project induced growth exceed the reduction in damages to property previously located in the plain. If not properly understood, this phenomenon can cause concern as to the effectiveness of a flood control project. Figure 2.1c shows the relationship between D(p), R(p) and r(p) for a particular level of protection, p_0.

Fig. 2.2 shows the marginal damage reduction and marginal cost curves for varying level of protection p. In the case where all benefits from flood control are due to damage reduction, these curves are used to determine the size of the project that maximizes the annualized net benefits. Thus, R'(p) is the marginal of R(p) in Fig.2.1a, which will initially increase with the level of protection; for higher levels of protection the marginal curve will start decreasing. The marginal cost is expected to continuously increase with the level of protection. The total benefits and costs for a certain level of protection p_0 are given by the area under the corresponding marginal curves to the left of p_0. The residual damages are shown as the area under the R'(p) to the right of p_0; obviously, $D = r(p_0) + R(p_0)$ and D is the total area under P'(p). The maximum benefits occur when R'(p) = C'(p) as shown and p_0 is the optimal level of protection. This is the classical case in benefit-cost analysis and the <u>conceptual</u> objective in applying the with and without procedure to project

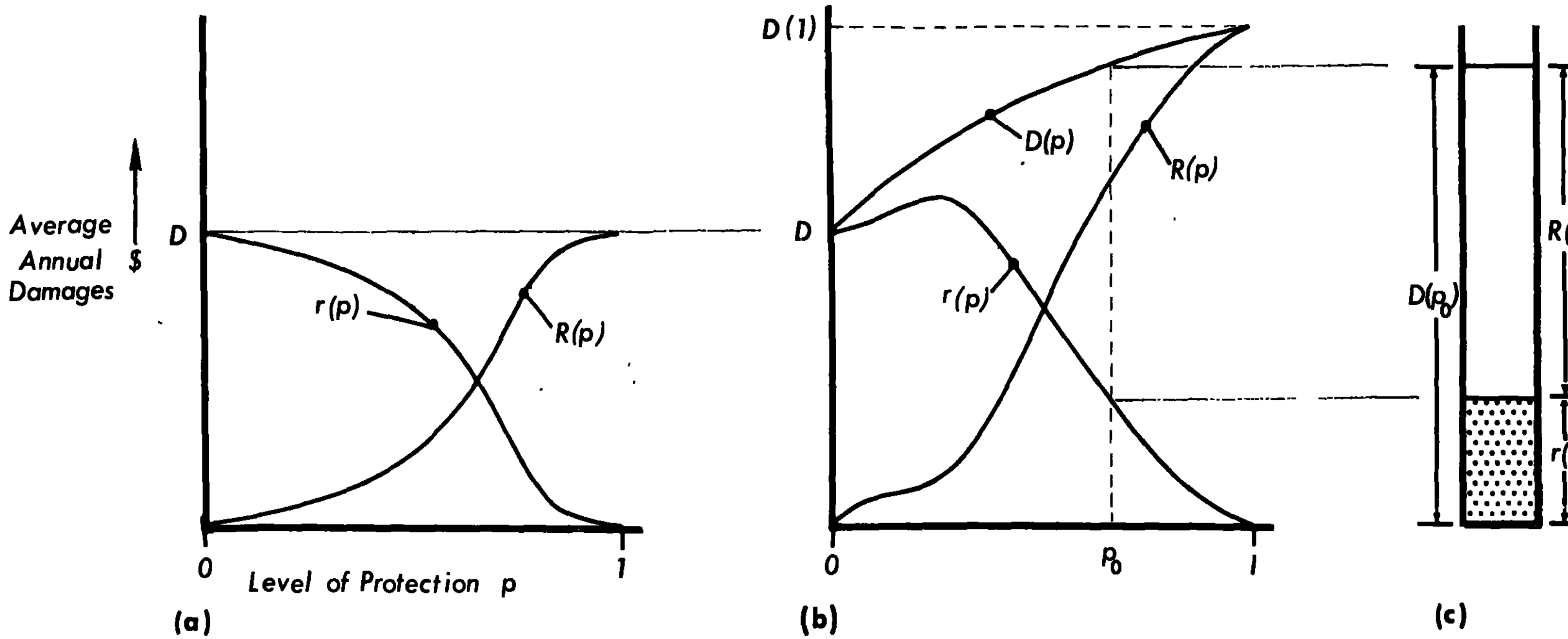

Figure 2.1

TOTAL, REDUCED AND RESIDUAL DAMAGES

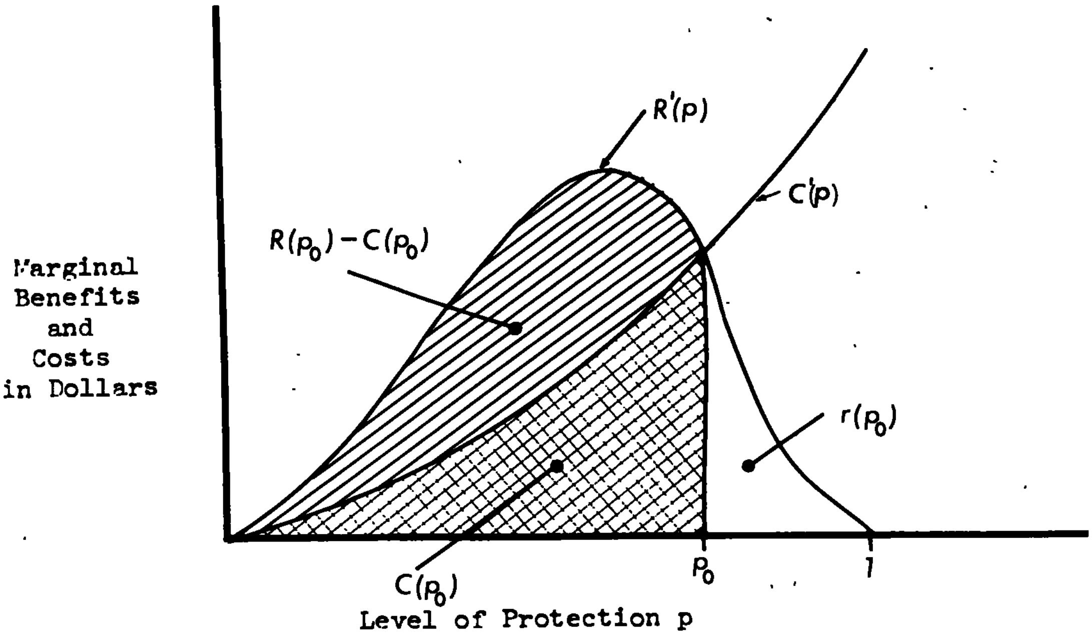

Figure 2.2

MARGINAL COST AND BENEFIT CURVES

evaluation is to determine the correct benefit curves so that application of benefit -cost analysis is straightforward.

In the remaining sections of this chapter with and without analysis is used to determine the appropriate benefits from flood control. In each case considered these benefits should reflect the increase in the net productivity of the economy that should be attributed to the flood control project. Projects with the following characteristics will be considered.

- No project induced growth
  1. flood plain fully developed
  2. flood plain not fully developed
- Project induced growth
- Ignorance concerning potential flood damages
  1. no project induced growth
  2. project induced growth

C. No Project Induced Growth

In case there is no project induced growth, the land use and its rate of development will not be affected by the introduction of the project. Two cases can be distinguished: (1) the flood plain is already fully developed and (2) the flood plain is not fully developed but will develop the same way independently of the presence of the project. In both cases we assume that location in the flood plain is based on sound economic reasoning and not the result of ignorance concerning potential flood damages. The objective in both cases is to determine the best protection against potential flood damages, considering all engineering and economic aspects of the problem.

1. Flood Plain Fully Developed

This is the simplest case of net benefit evaluation due to the project. In terms of the variables previously defined, the damages that would occur without protection are the total damages D and the associated cost is zero. With a project providing a level of protection p the expected damages are given by the residual r(p) while the cost is C(p). Applying the with and without concept the difference in damages with and without the project is $R(p) = D - r(p)$; these are the benefits from the project. The cost for this increase in benefits is given by C(p).

It should be noted that in this example, total benefits from the project correspond to damage reduction R(p) and as a result, the marginal benefit curve is precisely analogous to R'(p). The situation is as indicated in Fig. 2.2 and the optimal level of protection is defined as the level at which marginal cost equals marginal benefits. The net benefits from the project providing level of protection p_0 are given by $NB(p_0) = R(p_0) - C(p_0)$, the area between the two curves to the left of p_0. It should be noted that in this case where damage reduction accounts for the total benefits shared by the landowners and the activities occupying the land, residual damages do not explicitly enter into the measurement of net benefits. The reason for this is that the activities in the plain will experience those damages with or without the project; the difference being that with the project they will experience R(p) less damages than without it.

2. Flood Plain not Fully Developed

In the case where the flood plain is not fully developed but will develop in the same manner independently of the project, and assuming full awareness of the potential flood damages, economic activities will move into the flood plain because it is profitable to do so even with the flood hazard. Application of with and without analysis in this situation results that total benefits attributable to the project can again be evaluated by measuring total reduction in damages.

Because of the explicit assumption that the flood plain will develop in the same manner with or without protection, there is no relocation of activities outside the flood plain due to the project. The total net benefits due to the project will therefore accrue to the activities and the landowners in the flood plain through increased profits and increased wealth, respectively. The division of the benefits between these two will be determined by the price of land after protection has been provided, where any changes in land prices will be offset by corresponding changes in activity profits.

From the forecast of flood plain development, we can determine the total reduced and residual damages, D, $F(p)$, $r(p)$, that these activities will incur for each level of protection p. In addition, let $\pi_a(p)$ be the increase in the profitability of these activities, excluding flood damages, due to their location in the flood plain rather than outside. Since the activities find it profitable to move into the flood plain without protection, $\pi_a(0) \geq D$ as shown in Fig. 2.3. In addition, for a level of protection p_0, the increase in profitability, $\pi_a(p_0)$, should be larger than the residual damages, $r(p_0)$, because otherwise activities would move out of the plain. Thus, in general we can say

$$\pi_a(p) \geq r(p) \qquad (2.1)$$

where

$$r(0) = D \text{ and } r(1) = 0$$

With no protection, the net increase in profit of these activities by being in the flood plain is given by

$$\bar{\pi}_a(0) = \pi_a(0) - D \qquad (2.2)$$

With protection p_0, the net increase in profit becomes

$$\bar{\pi}_a(p_0) = \pi_a(p_0) - r(p_0) \qquad (2.3)$$

The difference with and without the project is

$$\hat{\pi}_a(p_0) = \bar{\pi}_a(p_o) - \bar{\pi}_a(0) = [\pi_a(p_0) - \pi_a(0)] + [D - r(p_0)] \qquad (2.4)$$

where

$[\pi_a(p_0) - \pi_a(0)]$ is the reduction in profit due to increases in the land values,

$[D - r(p_0)] = R(p_0)$ is the increase in profits due to damage reduction.

Because of the assumed economic equilibrium outside the flood plain, inside the flood plain the decrease in profits to the activities, excluding damages, is exactly equal to the increase in wealth of landowners. That is, if $\hat{\pi}_\ell(p_0)$ is the increase in the wealth of the landowners due to the project,

$$\hat{\pi}_\ell(p_0) = \pi_a(0) - \pi_a(p_0) \qquad (2.5)$$

and the total change in land values and activity profits is given by

$$\hat{\pi}_a(p_0) + \hat{\pi}_\ell(p_0) = [D - r(p_0)] = R(p_0) \qquad (2.6)$$

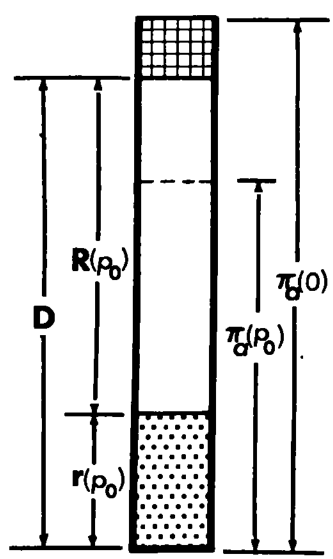

Figure 2.3

NO PROJECT INDUCED GROWTH; FULL AWARENESS OF FLOOD HAZARD

The relationship between the increased profitability of the activities and the increase in land values in the flood plain can be seen from Fig. 2.3. Therefore, under the assumptions of:

(1) competitive equilibrium outside the flood plain and

(2) complete awareness of the flood hazard,

the net increase in the productivity of the economy due to the project is given by the total reduction in damages. This increase in the productivity is allocated to increased activity profits and increased wealth due to enhanced land but their sum must be equal to total damage reduction.

D. Project Induced Growth

In the case where there is project induced growth, activities will move into the flood plain as a result of the project that would not find it profitable to do so without the project. This leads to a relocation of activities both inside and outside the flood plain as a result of the project. It is assumed again that the choice between a location in or outside the flood plain is based on sound economic reasoning and not on ignorance. The proper application of with and without analysis under these conditions presents two basic problems: (1) the forecasting of the development of the flood plain for different levels of protection and (2) identification of the appropriate benefits resulting from the project. For the purposes of this discussion we will assume only two levels of protection, 0 and p_0, each of which will result in a different development of the flood plain. We will demonstrate that total damage reduction is then not any longer an appropriate measure for flood control benefits.

The discussion of this case requires a careful distinction between the various activities in the flood plain with and without the project. Some of the old activities that will be in the plain without the project will remain there with the project; others will be displaced by new activities that will move into the plain. Using the same notation D, R and r for the total, reduced and residual damages, respectively, we define the following terms:

$D_n(p_0)$, $R_n(p_0)$, $r_n(p_0)$; The corresponding damages associated with the sum total of all new activities that find it profitable to move into the flood plain with protection p_0 but not without protection.

$D_o(p_0)$, $R_o(p_0)$, $r_o(p_0)$	The damages associated with all the activities that would locate in the flood plain with or without the project, and that would remain there after protection is provided.
D, $R(p_0)$, $r(p_0)$	The damages associated with all the activities that would be in the flood plain without protection.
$D_t(p_0)$, $R_t(p_0)$, $r_t(p_0)$	The damages associated with all the activities in the flood plain with protection p_0; they are the sum of the first two categories so that for example $D_t(p_0) = D_o(p_0) + D_n(p_0)$.

In addition we define:

$\pi_n(p_0)$	is the increase in profitability, excluding flood damages, to all new activities due to their location in the flood plain with protection p_0 rather than outside
$\pi_o(p)$	is the increase in profitability, excluding flood damages, to all old activities due to remaining in the flood plain with protection p rather than outside, where p may be 0 or p_0
$\pi_t(p_0)$	is the sum of the above terms, or $\pi_o(p_0) + \pi_n(p_0)$
$\Pi(p_0)$	is the increase, excluding damages, in profits and land values to all activities and parcels of land in and outside which are involved in <u>relocation</u> as a result of the project.

Application of with and without analysis for this case will be demonstrated through the use of Fig. 2.4, where (a) considers the activities that locate in the flood plain with and without the project, (b) the new activities that move in the flood plain, and (c) the resulting sum of these two.

For activities that would be located in the flood plain with or without protection and which are not displaced by new ones, the analysis is exactly the same as in the previous section and a graphic representation is depicted in Fig. 2.4a. For these activities and the corresponding parcels of land, the net increase in profits plus the increase in land values are due to the project and are measured in terms of total damage reduction $R_o(p_0)$. Note that these activities are not involved in relocation due to protection.

For the new activities that find it profitable to move into the plain, their increase in net profits over the next best alternative - outside the plain - must be greater than the residual damages $r_n(p_0)$ as shown in Fig. 2.4b. At the same time, this increase must be smaller than the total damages $D_n(p_0)$ without the protection or else the activities would locate in the flood plain without the project. Therefore, $r_n(p_0) \leq \pi_n(p_0) \leq D_n(p_0)$. The net increase in profits accruing to the new activities is given by

$$\hat{\pi}_n(p_0) = \pi_n(p_0) - r_n(p_0) \tag{2.7}$$

The increase in land values is given in Fig. 2.4b by the difference between $\pi_n(0)$ and $\pi_n(p_0)$, where $\pi_n(0)$ is based on land values assuming no protection. The reduction in damages $D_n(p_0) - \pi_n(0)$ do not constitute a benefit due to the project because the activity would be indifferent locating in or outside the flood plain if damages were reduced by this amount.

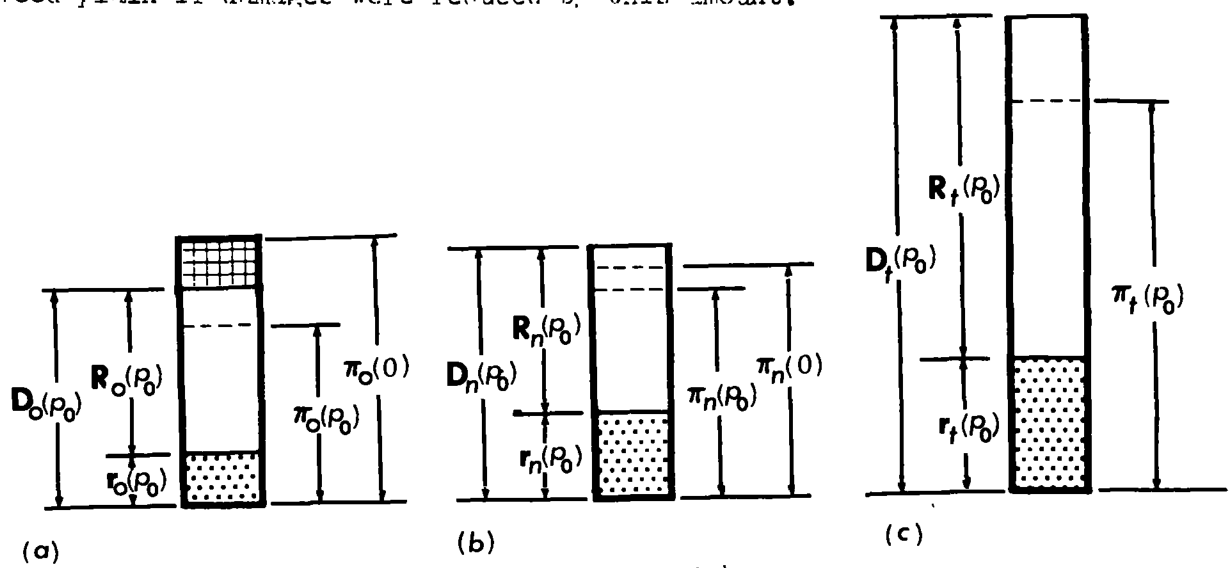

Figure 2.4

PROJECT INDUCED GROWTH; FULL AWARENESS OF FLOOD HAZARD

The old activities that are displaced find that given the protection and the accompanying increase in land prices, it is either more profitable to locate elsewhere or not to operate at all. The relocation of the old activities will also affect profits and land values outside the flood plain. This we include in the term $[\Pi(p_0) - \pi_n(p_0)]$ which also includes changes in land values in the flood plain that are affected by the relocation. This rather artifical term has been created in order to isolate those parts that are most important for the analysis.

The protection p_0 provided by the project results in the following increases in benefits to the economy of the region:

1. $R_o(p_0)$, the reduction in damages to activities that will remain in the flood plain, or would move into the flood plain without protection. The term includes increased profits to the activities and increased wealth to the landowners who do not relocate because of the project.
2. $\pi_n(p_0) - r_n(p_0)$, the increase in profits to the new activities which locate in the flood plain after protection has been provided.
3. $\Pi(p_0) - \pi_n(p_0)$, the increase in profits to the activities outside the plain affected by the project, and the increase in land values to all land affected by relocation.

The total benefits accrued are then given by

$$B(p_0) = [\Pi(p_0) - \pi_n(p_0)] + [\pi_n(p_0) - r_n(p_0)] + R_o(p_0) \qquad (2.8)$$

or

$$= \Pi(p_0) - r_n(p_0) + R_o(p_0)$$

The proper application of the with and without concept in the case of project-induced growth under complete awareness of the flood hazard results in an expression for the benefits as given in Eq. (2.8). Even though this expression is intuitively obvious, it is convenient in identifying the part of the <u>net increase in the productivity of the economy</u> that can be directly measured as flood damages, reduced or residual. That is, if the definition $\Pi(p_0)$ was changed to include increases in profits and land values to activities in the flood plain whose location is not affected by the project, $R_0(p_0)$ would be included in the new definition of $\Pi(p_0)$, and the only damage term left in expression (2.8) would be residual damages to the new activities. In addition, lifting the "excluding the flood damages" from the definition of $\Pi(p_0)$, would eliminate $r_n(p_0)$ from expression (2.8) and $\Pi(p_0)$ would become the net increase in the productivity of the economy due to the flood control project.

E. Complete or Partial Ignorance of the Potential Flood Damages

A flood plain may develop in the same manner with or without the project because of ignorance of the flood hazard. This may happen either when flooding occurs infrequently or when the landscape is such that people do not realize the existence of the flood plain. In the absence of zoning laws or proper management of the flood plain, acitivities may occupy the plain without being aware that they are subject to flood damages.

Another situation arises when people mistake partial protection for complete protection. As a result they do not account for residual damages in making the decision to move into the flood plain. Even though only a certain level of protection is provided, activities may move in with the impression that they are fully protected. In the present subsection we apply with and without analysis to these two situations.

1. <u>The Same Development With and Without the Project</u>

The development of the flood plain is the same with or without the project. Although this development may not be based on sound economic judgment, but could be the result of ignorance of the potential flood damages, the with and without analysis only asks what is expected to happen with the project and without the project. The reasons behind the expected land uses are not questioned. As a result, based on with and without analysis, the benefits can again be measured as the reduction in damages similar to those in Section C. In the following we will consider the three cases that may result due to ignorance of the flood hazard.

The total expected damages without the project, the reduction in damages due to the project, the residual damages and the increase in profitability, excluding damages, are defined by D, R(p), r(p) and $\pi_a(p)$ precisely as in Subsection 1 of the previous section. Depending on the size of $\pi_a(0)$ and $\pi_a(p_0)$ the location of these activities in the flood plain

(a) is not economically justified either without or with protection p_0

(b) is not economically justified without but justified with protection

(c) is economically justified without but not with protection

(d) is economically justified both with and without protection

Cases (a), (b) and (c) are shown in Fig. 2.5. Case (d) is identical to the one discussed in Subsection 1 of the previous section. The ignorance of flood hazards does not in this case result in incorrect decisions, and precisely the same situation exists as described in Sections C and D of this chapter.

Case (a) is illustrated in Fig. 2.5a. The location of the activity in the flood plain without protection would result in an economic loss of $[D - \pi_a(0)]$. With the project providing protection p_0, $\pi_a(p_0)$ is smaller than the residual damages resulting in a net economic loss to the activity. Applying the with and without procedure to these activities, we write the net increase in profits of

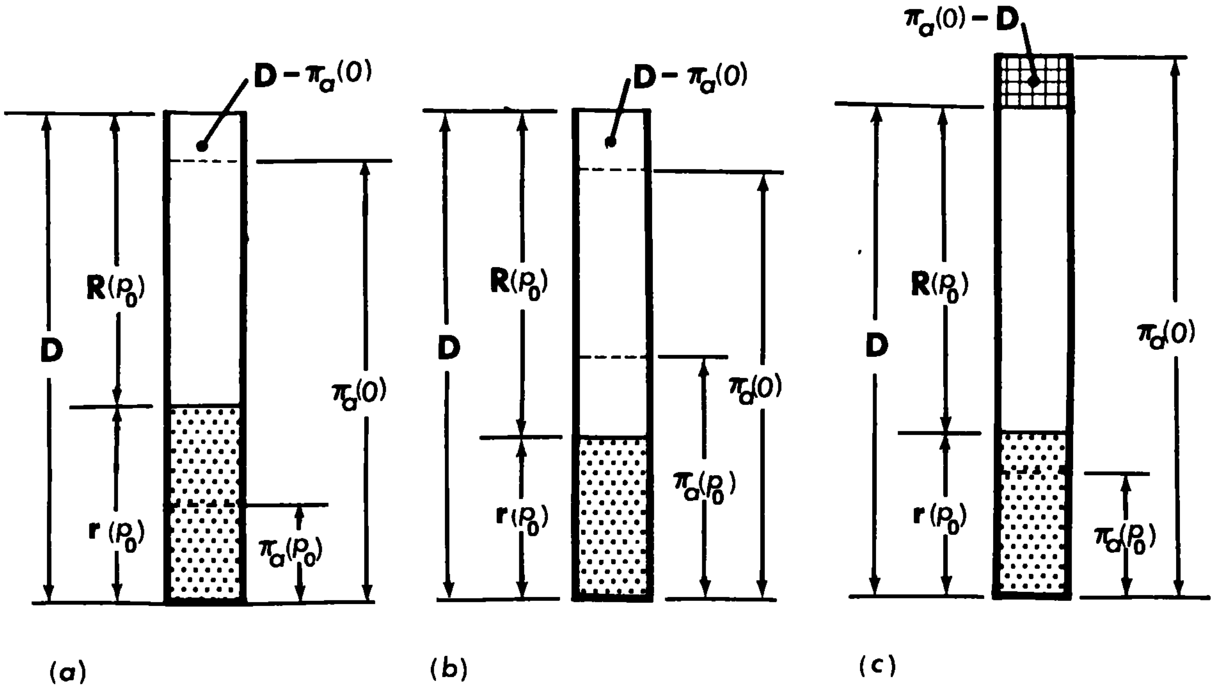

Figure 2.5

NO PROJECT INDUCED GROWTH; IGNORANCE OF FLOOD HAZARD

the activities due to the project as

$$\hat{\pi}_a(p_0) = [\pi_a(p_0) - r(p_0)] - [\pi_a(0) - D]$$

which reduces to equation (2.4). Thus

$$\hat{\pi}_a(p_0) = [\pi_a(p_0) - \pi_a(0)] + R(p_0) \qquad (2.9)$$

In Fig. 2.5a, this corresponds to a negative change in benefits and thus presents the net decrease in profits to the activity due to the project. Assuming, however, an economic equilibrium outside the plain, $[\pi_a(p_0) - \pi_a(0)]$ is the negative of the increase to the wealth of the landowners in the flood plain and, therefore, the decrease in the profits to the activities, $\pi_a(p_0) - \pi_a(0)$, is offset by the increase in the value of the land. Hence, the total benefits due to the project are evaluated again through total damage reduction $R(p_0)$. Application of with and without analysis in cases (b) and (c) will result in the same conclusion.

In case (a) the activities experience a net economic loss with or without protection because of their ignorance of the flood hazards. Before protection their loss is $D - \pi_a(0)$ and after protection $r(p_0) - \pi_a(p_0)$. Obviously, $\pi_a(0) - \pi_a(p_0) > P(p_0)$ and the landowners not only accrue all the benefits from the project, but they also cause the activities to operate at a greater loss. This is clearly a case of bad bargaining or decision making through ignorance. Similar interpretations are possible for cases (b) and (c) and the conclusion follows that it is difficult to measure flood control benefits through prices or profits because of the irrational decisions that people make. Damage reduction should, therefore, always be used as a measure of benefits in cases where there is no project induced growth.

2. <u>Different Development With and Without the Project Due to Induced Growth.</u>

In this situation the development of the flood plain will be different with and without the project. We will only consider the analysis of the new activities moving into the flood plain, because for the activities that remain there or would have moved in without the project, the analysis is the same as in the previous section. The decision of a new activity to move into the flood plain may not be based on complete knowledge of the degree of protection provided. An example is the case where zoning regulations do not permit the location of activities in the plain unless a specific level of protection is satisfied. Once this level is provided, activities may understand this as meaning complete protection.

An oversimplified version of this situation is depicted in Fig. 2.6, where all the symbols are defined as previously. For simplicity we assume that p_0 is the level of protection required by zoning regulation, and we assume that protection at that level will be provided. In Fig. 2.6 $\pi_n(p_0)$ is smaller than $r_n(p_0)$ which means the location of the new activities in the flood plain will result in a decrease in benefit of $[r_n(p_0) - \pi_n(p_0)]$. Thus, with a level of protection p_0 and with the associated land prices, the location in the plain results in a decrease in the net profits to the new activities. The total benefits of the project will be given as before by Eq. 2.8; however, the activities induced into the flood plain will have a decrease in benefits and this will be subtracted in obtaining the total.

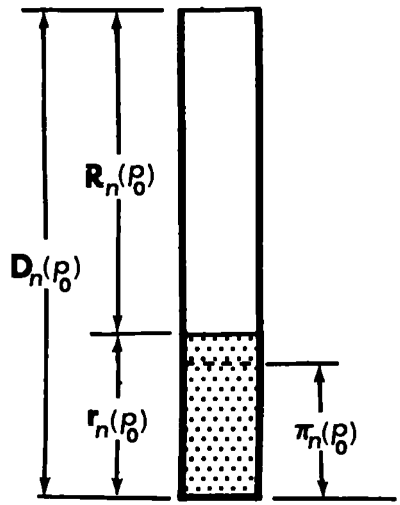

Figure 2.6

PROJECT INDUCED GROWTH; IGNORANCE OF FLOOD HAZARD

Analysis of the case where the location of activities in the flood plain is irrational because of ignorance shows that application of the with and without principle results in the same evaluation procedures as in the case of rational behavior. What should be measured is the same in both cases, although the actual numbers in general differ. This does not mean, however, that projects should necessarily be undertaken based on the prevention of damages to activities whose location in the flood plain is irrational. Some form of flood zoning or other form of flood plain management may be far superior. When activities locate in the flood plain irrationally, a net loss in productivity is created. This loss can be prevented or reduced either by preventing the irrational location or by providing flood protection.

A second issue which is directly related, and which is the source of much confusion, is the question of whether damages reduced to property which is irrationally located in flood plain should ever be counted as a benefit in the evaluation of a project. The argument against counting such benefits is that it will encourage more irrational behavior. Thus, if non-economic choices of location result from policies for benefit measurement, one may choose not to include such benefits. This position in no way conflicts with the results of this chapter, which is set out to demonstrate the application of with and without analysis to project evaluation and it does not examine the problem of flood plain management.

F. Summary

In this section we have applied the with and without analysis to a number of situations under different assumptions. We have done that without concern for what these benefits are called or how they are to be actually measured. We have examined enough situations under rational and irrational behavior to demonstrate that proper application of the concept reduces all cases to two basic classes:

1. Under the general assumption of no project induced growth the benefits attributable to the project resulting from the proper application of with and without analysis can be measured by the reduction in damages. The actual net increase in productivity of the economy, however, may vary depending on the rationality of the decision making process of the economic activities and on the degree of protection provided.

2. Under the general assumption that the project induces the economic growth in the flood plain, the benefits attributable to the project and resulting from the proper application of the with and without analysis is given by

$$B(p_0) = \Pi(p_0) - r_n(p_0) + R_o(p_0)$$

Even though the formula is the same in all cases, its value may vary again depending on the rationality of the decision making process of the various activities. A negative value may result when the project induces activities to move into the plain when this is not profitable for them.

III. NATURE AND DEFINITION OF BENEFITS FROM FLOOD CONTROL

A. Introduction

In the previous chapter we have demonstrated the application of with and without analysis to a number of situations. In each case examined, the increase in productivity attributable to the project and accruing to all users in or outside the flood plain was measured as the difference in profits with and without protection. This was done without special regard to the several sources from which flood control benefits arise and based on a generalized definition similar to that of General W. M. Glasgow, Jr. in his statement at the California Senate Committee on Water Resources [Ref.2].

"Flood control benefits are the sum of all dollar value increases accruing to the users of flood plains measured as the difference in the values to flood plain users (whether present or projected) with protection and without protection".

In the present chapter we attempt to identify the sources from which flood control benefits are derived, to define these benefits, and to clarify the distinction between "land enhancement" and "damage reduction". Chapters IV and V address the problems of actual measurement.

B. Benefits from Damage Reduction

Damage reduction benefits are the traditional benefits considered by the Corps in evaluating flood control projects. This was appropriate in the past where the Corps was faced with highly developed flood plains, and it had to determine whether physical protection was economically feasible. Since the plain was already developed, economic justification was based on a comparison between the reduction in damages and the cost of the project.

However, as the Corps began to consider projects to protect relatively undeveloped flood plains which would develop as a result of protection, it was clear that damages to existing property in the flood plain would not measure all of the benefits. At the same time there was uneasiness as to whether damages prevented to new activities presented a correct measure of additional benefits. Thus, the distinction between past and present use of damage reduction is that in the past, damage reduction measured all the benefits from flood control whereas at the present, they may only be part of the benefits. To clarify this question we consider two cases.

1. Damage Reduction Equivalent to Total Benefits

Under the assumption that the flood plain will develop in the same way with or without the project, it was shown in the previous chapter that the annualized expected reduction in damages over the lifetime of the project is the appropriate measure for benefits from flood control attributable to the project. It follows then, that damage reduction is equivalent to all benefits from flood control if a flood plain is expected to develop in the same way with or without the project. This statement is independent of the rational or irrational basis on which economic activities are expected to move into the plain.

When damage reduction is the appropriate measure for all benefit evaluation attributable to the project, the marginal benefit curve is the same as the marginal damage-reduction curve, and traditional benefit-cost analysis can be applied to determine the optimal size of the project that maximizes the net benefits.

Even in this case, however, it should be remembered that total damage reduction actually measures the increase in profits to the activities in the flood plain, and the increase in the wealth to the landowners due to the enhanced value of the land. In this sense, land enhancement benefits are part of total damages reduced.

2. Damage Reduction is not Equivalent to Total Benefits.

In the case where there is project induced growth, total benefits attributable to the project are given by $\Pi(p_0) - r_n(p_0) + R_o(p_0)$. In this expression, $R_o(p_0)$ is the reduction in damages to activities that are or would be located in the flood plain with and without protection. The question here is whether $R_n(p_0)$, the reduction in damages to the new activities, equals $\Pi(p_0) - r_n(p_0)$. This is not the case; $R_n(p_0)$ is larger as will be demonstrated in Chapter IV.

We, therefore, see that in the case of project induced growth damage reduction is only applied to the economic activities that remain or that would move into the flood plain with or without the project. This part of the benefits is identical to the previous case and is used to measure increased profits to these activities and enhanced land values due to the project.

C. Land Enhancement Benefits

Land enhancement benefits from flood control have created much controversy both in terms of their definition as well as their measurement. The issue arises in the case of project-induced growth where the actual pattern of land use is affected by the project. In this case there are benefits accruing to landowners and to activities due to relocation and it is clear from the discussion in Chapter II that these benefits are represented by $\Pi(p_0) - r_n(p_0)$. These benefits are referred to as "Land Enhancement" Benefits.

We can use this discussion to clarify the Corps' use of the concept of land enhancement. Referring to the statement of General W. M. Glasgow, Jr., the Corps of Engineers currently defines land enhancement as "these benefits resulting from development potentials created by the flood control project normally resulting from changes or intensification in land use made possible by the project and measured in terms of increases in net returns." This definition has several key expressions. The "development potentials created by the project" may be interpreted as a basis for distinguishing between benefits derived from project-induced growth and benefits from reduction in damages resulting in case the flood plain will develop the same way with or without the project. As a result the definition appears to be applicable only to the case of project-induced growth. A similar interpretation can be given for the expression "changes or intensification in land use made possible by the project."

A second definition used by General Glasgow is slightly more inclusive and it states that "land enhancement benefits may be defined as the additional economic gains accruing to agricultural, industrial and commercial firms and to households that find it profitable to use the flood plain once protection has been provided versus what these firms and households would earn either in the flood plain or elsewhere in the absence of flood control protection.". This definition can again be interpreted as restricting land enhancement benefits to cases of project-induced growth. The key word is once which excludes the activities that find it profitable to move into the plain even without protection.

The clarification of these definitions is given in a subsequent discussion by General Glasgow where he states that "land enhancement benefits as currently defined and used are differentiated from two other types of flood control benefits. One is the prevention of damage to existing development that can be expected to persist in the future. The second is the prevention of damage to future development in the flood plain that can reasonably be expected to take place even if flood protection is not provided.". Using the two definitions and the above clarification, we may proceed to identify land enhancement benefits as currently defined and used by the Corps in terms of our discussion in the previous chapter.

In the case of no project-induced growth, it was demonstrated that all benefits were due to reduction in damages to present or future property in the flood plain. These benefits are identified by $R(p_0)$. It then follows that according to the current definition and use of land enhancement benefits by the Corps of Engineers, these benefits are zero in the case for which development of a flood plain will take place the same way with or without the project. We should note that as stated earlier, part of this reduction in the damages goes to increase the value of the land in the flood plain, and in this sense, "land enhancement" benefits are measured by damage reduction.

In the case of project-induced growth, it was demonstrated that net benefits were given by

$$B(p_0) = [\Pi(p_0) - r_n(p_0)] + R_o(p_0) \tag{3.1}$$

where $R_o(p_0)$ defines the reduction in damages to existing property that would remain after protection is provided, or to property that would move in with or without the project. As a result, it follows that according to the current use of land enhancement benefits, they may be defined as the net benefits resulting in the case of project-induced growth which are due to the relocation of economic activities as a result of the project. The net benefits in the case of project-induced growth can thus be written as

$$B(p_0) = (\text{land enhancement benefits}) + (\text{damage reduction})$$

D. Generalized Definition of Benefits from Flood Control

The classification of flood control benefits given above is useful in the sense that it isolates the several sources from which flood control benefits arise, and as such, may facilitate the measurement of these benefits. However, it does obscure a more generalized definition which embraces all sources and perhaps, would eliminate confusion. We therefore propose the following definition for flood control benefits which is only slightly different from the generalized definition quoted earlier: Flood control benefits are the sum of all dollar value increases accruing to the users and non-users of flood plains measured as the difference in the productivity with protection and without protection. These benefits are given by Eq. (3.1).

This definition reduces to the proper benefits under different situations that may arise. For example, in the case of no project-induced growth, we will have $r_n(p_0) = 0$, $\Pi(p_0) = 0$ and $B(p_0) = R(p_0)$. Therefore, benefits are equal to total damage reduction. Under the assumption that these benefits correspond to the actual increase in the value of the land, in which case all the benefits go to landowners, they can also be called land enhancement benefits. This certainly presupposes that all benefits from flood control enhance the land values, which may or may not be the case depending on the bargaining between economic activities and landowners.

In the case of project-induced growth the generalized definition evaluates the benefits by the sources from which they are derived. One component is given by reduction in damages, and the other by increase in productivity due to the relocation of the economic activities as a result of the project. Following the discussion in the previous paragraph, land enhancement benefits could also be defined as the total benefits from flood control.

We can hence conclude that land enhancement benefits may be defined either as the total benefits from flood control, in which case the reduction in damages may be interpreted as an enhancement of the value of the property, or it can be defined on the basis of its current use by the Corps. Whatever the definition may be, however, the generalized definition holds and should be used appropriately in each particular situation.

IV. MEASUREMENT OF FLOOD CONTROL BENEFITS

A. Introduction

Benefits from flood control have been defined in the previous chapter and sources for these benefits have been identified. In addition, the distinction between land enhancement benefits and benefits from damage reduction has been clarified and a generalized formula has been derived which, with the proper definition of the variables, is applicable to all situations one may encounter in practice. The present chapter addresses some of the problems of benefit-measurement.

The conceptual classification of benefits presented in the two previous chapters is always simpler than the measurement of these benefits. This is particularly true in the case where there is project-induced growth for which benefits due to relocation of the activities must be taken into account. A basic requirement in that case is the forecast of land use patterns with and without the project. The problem of land use forecasting will not be addressed here but some of the basic difficulties will be summarized. These involve forecasting methodology and data availability. Problems in methodology are associated with the identification of variables and parameters that affect land use patterns as well as the relationships that characterize the manner in which these patterns are affected. It will include among others the modeling of human behavior. Data problems are normally classified in two categories: (1) hard data, and (2) soft data. Hard data refers to historical records providing information on the past growth pattern of the region. This may be all that is needed in cases where there are reasons to suspect that future growth will be an extrapolation of the past. Soft data is needed in situations where growth characteristics will not be an extrapolation of the past but will follow different trends. Forecasts of land use patterns must then be based on subjective evaluations and examination of the enviromental, economic and political factors that are expected to influence growth.

In this chapter we explore a number of indirect measures for evaluating land enhancement benefits; in addition, upper and lower bounds for land enhancement benefits are established. Although some indirect measures can be appropriately used under certain conditions, in general they do not appear very practical. The one that deserves closer examination is where the difference in the value of the land outside and inside the plain without protection may be used. The reason is that speculation may be eliminated by extrapolations of historical values and using normal economic pressures for land availability in the region. This may provide a good approximation and should be further investigated.

B. Measurement of Damages

Thus far evaluation of the annual expected damages, reduced or residual, has been taken for granted. First, it should be realized that evaluation of damages is really an estimation rather than a measurement problem. The process of arriving at annual damages involves a variety of uncertainties and probabilistic events. Therefore the mean or expected value of damages alone does not provide sufficient information for project justification. The variance of this estimate is very important because it can provide the probability that the actual damages will remain within certain bounds. As a result one can distinguish between reliable and unreliable estimates which can be used accordingly. When a series of probabilistic events is jointly used to arrive at a particular estimate, such as in the process of estimating damages from flood control, and the associated uncertainties are not taken into account, the error could vary anywhere from 0 to 100% or more. Therefore the decisions based on these estimates could prove not to be the best. Simply stated, the estimate of annual damages for a given level of protection can be given by a probability distribution which should be identified by at least two parameters, its mean and variance.

In estimating damages uncertainty is present in the value of property, in the hydrological considerations used to derive the standard project flood, in the analysis used to derive the frequency of the standard project flood and other floods, and in the discharge-damage relationships. All these aspects involve either events of chance (rainfall) or insufficient information (value of future property), and as a result the damage estimates are uncertain. Without a consistent procedure and sound statistical methods for dealing with these uncertain events, the results are difficult to interpret. In the present section we shall not attempt to resolve these problems, but rather we will sketch an outline of the procedure that is required to arrive at an estimate of flood control damages. The sections on Hydrology, Frequency Analysis and Benefits Due to the Project in Appendices B and C review presently-used Corps procedures and identify some of the sources which could cause errors in estimating damages.

The process of annual damage estimation requires the following steps:

1. A forecast of land use and of the value of property over the next one hundred years. This forecast includes the increase in the value of property of the existing activities due to the real increase in the productivity of the economy as a whole, as well as that of new activities that find it profitable to locate in the flood plain with or without the project. The reason for forecasting this increase in value is the assumption that as the economy grows each

activity will have more property exposed to flood losses. The Corps procedure is based on the assumption that flood damages increase proportionally with the value of property; this assumption is questionable. In addition, total property subject to flood damages must be classified into a number of categories such as residential, commercial, industrial and agricultural because the flood-damage relationships for these will not be the same. Forecasting different land use categories is more complicated than forecasting the total. These forecasts, however, greatly influence the estimated damages, since uncertainty in the measurement of benefits through damage reduction is at least as large as the uncertainty in these forecasts. It is therefore important that different growth patterns be tested and their effect on damages investigated.

2. A study of the hydrological characteristics of the region to determine the magnitudes of the standard project flood, the maximum probable flood, and the debris storage requirements and spillway capacities at selected concentration points in the basin. This analysis requires examination of storm patterns and whether simultaneous events included to produce a particular flood are statistically independent.

3. Determination of the discharge-frequency curve. This curve forms the basis for much of the subsequent analysis and therefore its accuracy is quite important. For regional frequency analysis a number of statistical tests are needed to determine the homogeneity of the region and to generate consistent streamflow records. Frequency analysis of specific streams runs into the problem of short historical records and therefore must be correlated with streams with longer records for which the hydrological properties are similar. Determining the frequencies of the maximum probable and standard project floods by merely extrapolating the curve fitted to a small statistical sample is incorrect and over-estimates the frequency of these floods. This is because the sample points correspond in general to single historical events and the above floods require a number of events to occur simultaneously. A more extensive discussion of this is given in Section IV of Appendix B.

4. Damage-discharge curves must be determined for the different levels of protection considered in the analysis. They require that flood depths for different overflow areas be determined for various peak discharges and levels of protection. In addition the damage to property must be estimated for different flood depths.

5. Combining the discharge-frequency and the damage-discharge curves for a particular level of protection results in the damage-frequency curve. This process must be repeated for each level of protection that provides a possible alternative. The expected annual damages are given as the area under the curve.

6. For each year and each level of protection the damage reduction is calculated by subtracting the damages for this particular level of protection from the total damages with no protection. The future damages must then be discounted to obtain their present value which can then be annualized to determine the average annual damages.

The procedure outlined above is summarized in Equation C-2 of Appendix C. The formula shows that annualized damages are quite sensitive to a number of uncertain variables such as value of property in the future, annual increase in productivity, the assumed ratio between damages and property value for each land use category, the probability of floods and the annual discount rate. Since the logical procedures for damage estimation are well-established, the process could be computerized and the sensitivities explicitly determined. Such a simulation model of damage estimation is essential for the effective analysis of flood control projects.

C. Indirect Measurement of Land Enhancement Benefits

This section considers situations where land enhancement benefits can be reasonably estimated by indirect measures. Two topics of particular interest are discussed: (1) the case where the land enhancement benefits are measured as the difference in the market value of land in the flood plain before and after protection; and, (2) the upper and lower bounds for land enhancement benefits based on the reduced damages to the new and displaced activities in the flood plain.

Land enhancement benefits for a level of protection p_0 are given by

$$LEB(p_0) = \Pi(p_0) - r_n(p_0) \tag{4.1}$$

where $\Pi(p_0)$ and $r_n(p_0)$ have been previously defined. Thus, in addition to the residual damages to the activities that move into the flood plain, we must find ways to measure the change in profits to all activities which relocate as a result of the project, plus the changes in land values in and outside the plain. The situation is considerably simplified by assuming that competitive conditions hold outside the flood plain. Under this assumption Lind [Ref.5] has shown that the sum of the changes in activity profits and property values outside the flood plain sum to zero. As a result we need only consider the changes of activity profits and land values in the flood plain. With this result we proceed to consider alternative measures of land enhancement benefits.

1. The Basic Formulas for Land Enhancement Benefits

Let us define for each new activity x the following quantities:

S_x^f is the profit of activity x in the flood plain exclusive of the cost of land and expected flood damages.

S_x^o is the profit of activity x outside the flood plain exclusive of the cost of land.

$q_x^f(p)$ is the price of land paid by activity x to move into the flood plain when the level of protection p is provided.

$q_x^o(0)$ is the price of land outside the plain which is occupied by activity x when no protection is provided.

$r_x(p)$ is residual damages to activity x when it moves into the flood plain with protection p; $r_n(p)$ equals the sum of $r_x(p)$ over all the activities x.

$\gamma_x^f(p)$ is the net profit of activity x in the flood plain with level of protection p.

$\gamma_x^o(0)$ is the net profit of activity x outside the flood plain at the next best alternative location in case of no protection.

The following relationshps hold between these variables.

$$\gamma_x^f(p) = S_x^f - q_x^f(p) - r_x(p)$$

$$\gamma_x^o(0) = S_x^o - q_x^o(0) \tag{4.2}$$

Thus by moving into the flood plain the increase in profit of activity x is given by

$$\hat{\pi}_x(p) = [S_x^f - q_x^f(p)] - [S_x^o - q_x^o(0)] - r_x(p)$$

$$= \pi_x(p) - r_x(p) \tag{4.3}$$

where $\pi_x(p)$ and $\hat{\pi}_x(p)$ are defined analogous to $\pi_n(p)$ and $\hat{\pi}_n(p)$ in Chapter II; these correspond to the sum of $\pi_x(p)$ and $\hat{\pi}_x(p)$ over all x. From Eq. (4.3) it is clear that activity x will locate in the flood plain if

$$\pi_x(p) - r_x(p) \geq 0 \tag{4.4}$$

For the sum total of the new activities this condition was explained in Chapter II and illustrated in Fig. 2.4b.

Assuming that the above condition is met, we can use the following argument to arrive at the maximum price that the landowner of the property can hope to receive from activity x. With complete information concerning the flood hazard as well as the profitability opportunities of activity x, this price corresponds to a zero increase in the net profits to the activity. From Eq. (4.3) we then obtain

$$\bar{q}_x^f(p) = \left[S_x^f - r_x(p)\right] - \left[S_x^o - q_x^o(0)\right] \tag{4.5}$$

If the landowner could actually obtain this price, all benefits from the project as a result of relocation of activity x would equal the difference in the price of the land with and without protection. Therefore, subtracting the value of the land in the flood plain without protection, $q_x^f(0)$, from both sides of Eq. (4.5), we would obtain the net benefits

$$\bar{q}_x^f(p) - q_x^f(0) = \left[S_x^f - q_x^f(0)\right] - \left[S_x^o - q_x^o(0)\right] - r_x(p) \tag{4.6}$$

Thus, the difference in market value of the land with and without the project is an appropriate measure for the land enhancement benefits if all benefits accrue to the landowner and nothing to the activity that moves into the flood plain. This may be the case when a number of equally profitable activities compete for the land and bid up the price to a point where they are indifferent to a location on or off the flood plain.

In general not all activities will find it equally profitable to move into the flood plain. Thus, the righthand side of Eq. (4.6) would differ for different activities. If there is no price discrimination, so that the landowners charge a uniform price for the land, they may only extract the maximum payment from the activity for which the increase in profits is the lowest among all new activities that move into the flood plain. In this case the other activities will receive some of the benefits due to the flood protection. That is, if activity $\underline{x}$ has the lowest increase in profit then

$$\bar{q}_{\underline{x}}^{f}(p) - q_{\underline{x}}^{f}(0) = \min_{x} \left\{ \left[S_x^f - q_x(0)\right] - \left[S_x^o - q_x^o(0)\right] - r_x(p) \right\} \qquad (4.7)$$

The total land enhancement benefits to the landowners are given by

$$LEB_L(p_o) = n\left[\bar{q}_{\underline{x}}^{f}(p) - q_{\underline{x}}^{f}(0)\right] \leq \sum_{x=1}^{n} \left[\bar{q}_x^f(p) - q_x^f(0)\right] \qquad (4.8)$$

where the left side of inequality Eq. (4.8) is derived by summing Eq. (4.7) over all x and the right hand side by summing Eq. (4.6). The difference between the right and left hand sides of inequality Eq. (4.8) gives the land enhancement benefits received by the activities as a result of the uniform price of land. That is,

$$LEB_n(p) = \sum_{x=1}^{n} \left\{ \left[\bar{q}_x^f(p) - q_x^f(0)\right] - n\left[\bar{q}_{\underline{x}}^{f}(p) - q_{\underline{x}}^{f}(0)\right] \right\} \qquad (4.9)$$

Under more general conditions prices for different pieces of land will be different, in other words there will be price discrimination. The price of land occupied by activity x will be established somewhere between the original price, $q_x^f(0)$, and the maximum price that the land owner can ask for, $\bar{q}_x^f(p)$. This price will depend on the amount of information available to the parties, on their respective bargaining strengths and on their competitive positions. Thus,

$$q_x^f(0) \leq q_x^f(p) \leq \bar{q}_x^f(p) = \left[S_x^f - r_x(p)\right] - \left[S_x^o - q_x^o(0)\right] \qquad (4.10)$$

Under these conditions the land enhancement benefits that accrue to the owner of the land occupied by activity x are given by

$$LEB_\ell(p) = q_x^f(p) - q_x^f(0) \qquad (4.11)$$

and the part that goes to the activities by

$$LEB_x(p) = \left[S_x^f - q_x^f(p) - r_x(p)\right] - \left[S_x^o - q_x^o(0)\right] \qquad (4.12)$$

The total benefit accruing to activity x and the landowner of lot ℓ is obtained by summing Eqs. (4.11) and (4.12), the result of which is identical to Eq. (4.6). Summing over all activities x, the total is obtained as the sum of the benefits to land owners in the flood plain and activities which move into the flood plain, and is given by

$$LEB(p) = \sum_{\ell} LEB_{\ell}(p) + \sum_{x} LEB_x(p) \qquad (4.13)$$

or

$$LEB(p) = \bar{q}(p) - r_n(p) = [S^f - q^f(0)] - [S^o - q^o(0)] - r_n(p) \qquad (4.14)$$

where S^f, $q^f(0)$, S^o, $q^o(0)$ and $r_n(p)$ are defined as the corresponding sums over all activities x.

2. Approximate Methods for Measuring Land Enhancement Benefits

Certain conclusions concerning approximate methods for measuring land enhancement benefits can be drawn from the previous section, especially from the single activity equations (4.6), (4.7) and (4.13), and the aggregate equations (4.8) and (4.14).

a. Land enhancement benefits can be measured by the difference in the market value of the land in the flood plain before and after protection if and only if Eq. (4.6) individually holds for each activity and parcel of land so that the landowner accrues all the benefits from land enhancement by charging the maximum allowable price for each piece of land, $\bar{q}_x^f(p)$. The two basic conditions required for this are:

(1) Each landowner has complete information in regard to the flood hazards and profit potential of the activities.

(2) Perfect price discrimination is possible.

Therefore, the aggregate of Eq. (4.6) will hold and land enhancement benefits can be measured by the change in the market price before and after protection.

From the above remarks it follows that approximating the land enhancement benefits by measuring the difference in the market value of the land in the flood plain before and after protection may lead to an <u>understatement</u> of the benefits if

(1) each landowner cannot receive the maximum price for his land due to a weak bargaining position and/or

(2) the assumption of perfect price discrimination does not hold. Under these conditions additional land enhancement benefits will accrue to the owners of the activities and the difference in the market value of land will only partially reflect the land enhancement benefits. On the other hand, it should be pointed out that land values before and after the project are not necessarily the same as land values with and without. Land values after the project may rise because of any number of factors unrelated to flood control. In this case, the increase in land values might greatly overstate land enhancement benefits. Similarly, speculation caused by the anticipated flood control may result in actual land prices being very different from the idealized prices used in the model.

To summarize, approximating land enhancement benefits with changes in market values with and without the project has the following shortcoming: (1) speculation may distort the prices, particularly in areas undergoing rapid development, now or in the near future, (2) forecasting price changes with and without the project is difficult in the sense that it is difficult to differentiate between changes in land values that will occur as a result of the project and those that will result from other activities or natural economic pressures for land, and (3) the prices of land will depend on the discount rate each individual uses for the future uncertain returns on land; these may or may not be appropriate for evaluating returns to land as a result of public investments.

b. Under certain conditions the flood plain with protection will provide the same economic opportunities as the land outside. In this case S_x^o is the same as S_x^f and Eq. (4.13) reduces to

$$LEB_x(p) + LEB_\ell(p) = \left[q_x^o(0) - q_x^f(0)\right] - r_x(p) \tag{4.15}$$

This may be the case where the flood plain is located in an already developed environment. Eq. (4.15) then states that land enhancement benefits can be measured by the difference in market prices between the land outside the flood plain with protection p and the land inside the plain before protection, less the residual damages to activity x. This situation appears to be applicable to a number of situations. The difficulty lies in forecasting the value of land in the flood plain without including speculation on the future construction of a flood control project.

This case does not have several of the shortcomings of the previous situations. First, in an already developed environment the value of land outside the flood plain is not expected to change with and without protection and therefore $q_x^o(p) \approx q_x^o(0)$. Thus the value of land in the flood plain would increase from its price without protection to the equilibrium price established outside the flood plain. As a first approximation, the land prices can be assumed to follow a historical trend and projections can be based on past records. Second, this difference in price is independent of the bargaining positions of the activities and the landowners in the flood plain, and, as a result, it can actually reflect the total benefits, excluding residual damages, independently of speculation in the flood plain land and the manner in which the benefits from the project are divided between landowners and activities. Finally, in situations where the above approach appears applicable, a closer examination of historical land values in the area would help to identify the changes in land value trends in order to determine if Eq. (4.15) actually applies.

3. Upper and Lower Bounds of Land Enhancement Benefits

Using Eqs. (4.13) and (4.14) we can arrive at a lower and an upper bound of the land enhancement benefits based on reduced damages.

a. Upper Bound of Land Enhancement Benefits

Eq. (4.13) expresses the total land enhancement benefits accruing to activity x and to the landowner ℓ. Thus

$$LEB_{x+\ell}(p) = \left[S_x^f - q_x^f(0)\right] - \left[S_x^o - q_x^o(0)\right] - r_x(p) \qquad (4.13)$$

From Eq. (4.3) we have that for no protection

$$\hat{\pi}_x(0) = \left[S_x^f - q_x^f(0)\right] - \left[S_x^o - q_x^o(0)\right] - r_x(0) \qquad (4.16)$$

and since activity x will not move into the flood plain unless protection p is provided

$$\left[S_x^f - q_x^f(0)\right] - \left[S_x^o - q_x^o(0)\right] \leq r_x(0) = D_x \tag{4.17}$$

where D_x is total damages to activity x if it would move into the flood plain without protection. Using the inequality in Eq. (4.17) we conclude that

$$LEB_{x+\ell}(p) \leq D_x - r_x(p) - R_x(p) \tag{4.18}$$

Summing over all activities x we conclude that the total land enhancement benefits due to projects are bounded above by the reduction in damages to all activities that would find it profitable to move into the flood plain once protection is provided. Therefore,

$$LEB(p) \leq R_n(p) \tag{4.19}$$

Put differently, if one were to calculate the damages prevented by the project to those activities which move into the flood plain as a result of the project, the number obtained should be greater than the value of land enhancement benefits. For this reason, land enhancement benefits must be overstated if they are larger than the damages reduced in the case of project-induced growth. It is possible, however, as will be demonstrated in the next chapter, to use a part of damages reduced to measure land enhancement benefits.

b. Lower Bound of Land Enhancement Benefits

Let us assume that when activity x locates in the flood plain it will displace another activity y which had found it profitable to move into the flood plain without protection. Activity y could be a household, agricultural land, or any business activity that would be in the flood plain without protection p. With protection p the profit of activity y excluding the cost of land will increase by the reduction in its damages, $R_y(p)$. Therefore, it would be willing to pay at least that much in higher rent. In order for activity x to locate on that parcel of land the benefits to x of a flood plain location must be sufficient to bid up the price by more than $R_y(p)$. Therefore, it follows, by summing over all activities y, that

$$R_m(p) \leq LEB(p) \qquad (4.20)$$

where $R_m(p)$ is the potential damage reduction to the displaced activities. Thus, if one were to calculate the damages reduced to property which would be in the flood plain in the absence of protection, the resulting figure would be less than the full value of the land enhancement benefits.

Combining inequalities Eqs. (4.19) and (4.20) we have

$$R_m(p) \leq LEB(p) \leq R_n(p) \qquad (4.21)$$

Therefore, total land enhancement benefits due to the flood control project must be greater than the total damage reduction that the displaced activities would incur had they remained in the flood plain with level of protection p, and less than the total damage reduction to the new activities when they move in with the protection. These bounds can be effectively used to determine whether land enhancement benefits are either overestimated or underestimated independently of the actual method of measurement used.

V. MEASUREMENT OF LAND ENHANCEMENT BENEFITS THROUGH DAMAGES REDUCED

A. Introduction

Land enhancement benefits have been defined and identified in Eq. (4.14) as

$$LEB(p) = \left[S^f - q^f(0)\right] - \left[S^o - q^o(0)\right] - r_n(p) \tag{5.1}$$

It was demonstrated that these benefits are divided between the economic activities that locate in the flood plain and the landowners according to their respective bargaining strengths and their competitive positions. Indirect methods for measuring these benefits were investigated and it was concluded that such methods present a number of difficulties. An upper and lower bound were established through damage reduction and this appears to be useful in detecting excessive overestimation or underestimation of land enhancement benefits. The direct approach of actually measuring the quantities in brackets in Eq. (5.1) appears to be the most difficult of all since it requires knowledge of the best alternative location outside the flood plain.

In the present chapter we investigate an approach where land enhancement benefits could be measured by reduced damages at different levels of protection. This approach requires that we know the level of protection at which economic activities are indifferent to a flood plain location and some alternative locations. Therefore, this level of protection does not represent an increase in the profitability of the activities or in the value of the flood plain lands. This principle will be demonstrated in the next section by applying it to a single activity. The construction of the total benefit curve through damage reduction is then presented and finally the determination of the <u>no-land-enhancement</u> levels is briefly discussed. It is pointed out that this is an area where future investigation may prove effective.

B. The Single Activity Case

We consider a single activity x that contemplates its location in the flood plain. The assumption is made that this activity does not find it profitable to locate in the flood plain with no protection and therefore some protection must be provided in order to induce the relocation of the activity into the flood plain. Let us indicate by p_x the minimum level of protection required to induce activity x to locate in the flood plain. That is, p_x is such that activity x is indifferent between locating in the flood plain or somewhere else. It then follows that

(1) the increase in profit to activity x due to locating in the flood plain is zero, and

(2) the price of the flood plain land with protection p_x must be the same as without protection.

These statements follow from the fact that p_x is the <u>minimum</u> level and therefore there are no benefits to divide between the activity and the landowner.

From the definition of p_x we can write Eq. (4.3) as

$$\hat{\pi}_x(p_x) = \left[S_x^f - q_x^f(0)\right] - \left[S_x^o - q_x^o(0)\right] - r_x(p_x) = 0$$

or (5.2)

$$\hat{\pi}_x(p_x) = \pi_x(0) - r_x(p_x) = 0$$

Equivalently, Eq. (5.2) expresses the land enhancement benefits accruing to the activity x and landowner of lot ℓ at the level of protection p_x. Thus,

$$LEB_{x+\ell}(p_x) = \pi_x(0) - r_x(p_x) = 0 \quad , \tag{5.3}$$

which is shown in Fig. 5a. For a new level of protection $p = p_x + \Delta p_x$ or $p > p_x$ the situation is shown in Fig. 5.1b. From this we see that for the increased level of protection $p > p_x$, the land enhancement benefits are given by

$$LEB_{x+\ell}(p) = \Pi_x(0) - r_x(p) = R_x(p) - R_x(p_x) \tag{5.4}$$

or by the difference between the reduction in damages to activity x at level of protection p and the reduction in damages required to induce the activity into the flood plain. As previously, these benefits are divided between the activity and the landowner. An interesting and useful observation from Eq. (5.4) is that change in the land enhancement benefits caused by an incremental change

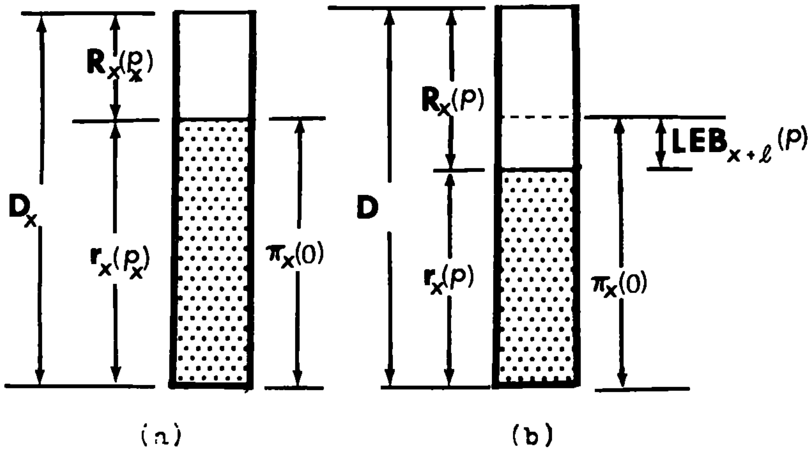

Figure 5.1

MEASUREMENT OF LAND ENHANCEMENT BENEFITS THROUGH DAMAGES REDUCED

in the level of protection is equal to the incremental change of the reduction in damages to activity x. That is, $LEB_{x+\ell}(p)$ and $R_x(p)$ have the same slope for all p's that are greater than p_x; or

$$\frac{\Delta[LEB_{x+\ell}(p)]}{\Delta p} = \frac{\Delta R_x(p)}{\Delta p} \quad \text{for all} \quad p > p_x \tag{5.5}$$

The single activity case explains the basic concept for measuring land enhancement benefits through reduced damages. That is, there exists a level of protection p_x such that land enhancement benefits due to relocation of activity x into the flood plain with protection $p > p_x$ are measured by the reduction in damages over and above the reduction in damages required to induce the activity into the flood plain.

C. Construction of the Total Benefit Curve

The results of the previous section are now used to construct the total benefit curve resulting from project-induced growth. For this we start with the basic formula that total benefits from flood control providing protection p_0 are given by

$$B(p_0) = LEB(p_0) + R_o(p_0) \tag{5.6}$$

where $R_o(p_0)$ has been previously defined as the damages reduced to activities that are in the flood plain with protection p_0 and would be there without protection. Thus, we attempt to measure the total benefits due to the project providing protection p_0.

For simplicity we divide the total of n project-induced activities into two groups: the first group consists of n_1 activities that require a minimum level of protection p_1 in order to relocate in the flood plain; similarly, we define n_2 and p_2 for the second group of activities, where $n_1 + n_2 = n$ and $p_1 < p_2 < p_0$. The situation is depicted in Fig. 5.2. First, the damage reduction curve is constructed for the activities that are in the flood plain with protection p_0 and would be there without protection. It should be noted that in general this curve would depend on p_0, the level of development under consideration, since it includes activities that are not displaced by new ones and the displacement process depends on the level of protection. At $p = p_1$, n_1 of the activities are induced to locate in the flood plain and the land enhancement benefits accruing to the n_1 activities and the landowners of the associated lots at that point are zero as in the single activity case considered in the previous section. That is at $p = p_1$,

$$LEB_{n_1+\ell_1}(p_1) = \pi_{n_1}(0) - r_{n_1}(p_1) = 0 \tag{5.7}$$

For $p > p_1$,

$$LEB_{n_1+\ell_1}(p) = \pi_{n_1}(0) - r_{n_1}(p) = R_{n_1}(p) - R_{n_1}(p_1) \tag{5.8}$$

It should be noted here that the sum of $R_o(p)$ and $LEB_{n1+\ell 1}(p)$ do not form the total benefits at level of protection p, because it does not include the damages to property that will be displaced at a higher level of protection p_2 by the n_2 activities. At this higher level, the land enhancement benefits due to the location of activities n_2 in the flood plain are zero as was the case for the n_1 activities at level p_1. For $p > p_2$ all new activities are located in the flood plain and

$$LEB(p) = R_n(p) - R_{n_1}(p_1) - R_{n_2}(p_2) \tag{5.9}$$

while in this case

$$B(p) = B_o(p) + LEB(p), \quad \text{where} \quad p_2 \leq p \leq p_0$$

This is indicated graphically in Fig. 5.2 for levels of protection between p_2 and p_0.

If the number of activities remaining in the flood plain is sensitive to the levels of protection considered, the function $B_o(p)$ has to be reevaluated for each of these levels p_0^1, $p_0^2, \ldots,$ p_0^k and the above procedures must be continued until all new activities are located in the plain. The corresponding total benefits $B(p_0)$, $B(p_0^1)$, $B(p_0^2), \ldots,$ $B(p_0^k)$ then define the total benefit curve as a function of the level of protection.

The above procedure demonstrates that damage reduction can be used to measure land enhancement benefits. The procedure requires a forecast of the protection levels at which activities are indifferent between a flood plain location or a location somewhere else. This forecast is equivalent to projecting land development under different levels of protection which is also required in all previous measurement techniques discussed. The procedure allows us to measure land enhancement benefits as damages reduced above the level of protection required to make the flood plain a profitable location for the activities that move in. At this level of protection, activities are indifferent between moving into the flood plain and locating at the best alternative outside of the flood plain. The land enhancement benefits in that case are zero; for protection above this level, the land enhancement benefits are equal to the additional reduction in damages.

To see how this might be applied, consider a hypothetical case of a flood plain which will remain in agricultural use as long as it is unprotected. First, the minimal level of protection is determined that would convert the agricultural land into residential use. To calculate the land enhancement benefits from providing protection against the standard project flood, one would calculate the reduction in damages to the residential property for the standard project and subtract from this the damages prevented at the minimum level of protection required for residential use to be economically justifiable.

The results presented in this section can be developed in a complete and rigorous manner so that they can form the basis for operational precedures for measuring all benefits in terms of damages reduced. This will require considerable effort in determining fast and approximate models to identify the protection levels at which activities find it just profitable enough to locate in the flood plain. It is anticipated that this effort will also provide better understanding of the problems in flood plain management such as zoning regulations which presently determine to a large extent the land enhancement benefits.

Legend for Fig. 5.2

$P_o(p)$	is the total reduction in expected damages to all activities that would locate or remain in the flood plain with or without protection when a level of protection p is provided.
$LEB(p)$	is the total land enhancement at protection level p.
$B(p)$	is total benefits of project at protection level p.
$R_{n_i}(p)$	is total reduction in expected damages at protection level p to activities that require, in order to locate in flood plain, a minimum level of protection p_i, $i=1,2$.

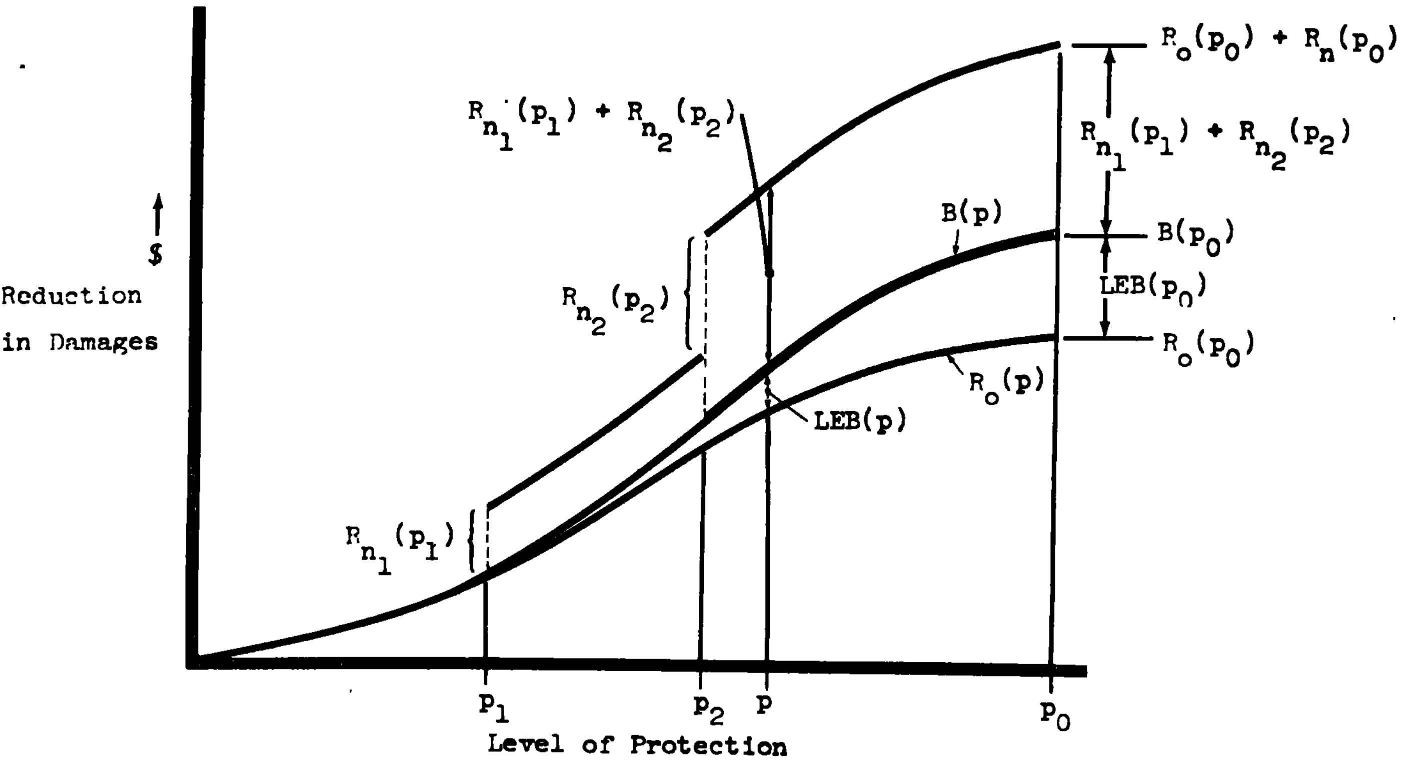

Figure 5.2

TOTAL BENEFIT CURVE FOR PROTECTION p_0.

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Part Two

ANALYSIS OF SPECIFIC PROJECTS

I. SUMMARY OF PART TWO

A. Introduction

Part Two of this report analyzes two specific flood control projects in Southern California. For the purpose of this analysis, INTASA reviewed two Interim Review Reports prepared by the U.S. Army Engineer District in Los Angeles and subsequently, with the assistance of Messrs. A. Potter and S. Light of the Los Angeles District, and J. Tang of the Institute of Water Resources, visited the two project areas. The reports describing the two projects are:

1. NEWHALL, SAUGUS, AND VICINITY
   Los Angeles County
   U. S. Army Engineer District,
   Los Angeles (June 1969)

2. DAY, EAST ETIWANDA, AND SAN SEVAINE CREEKS
   San Bernardino and Riverside Counties
   U. S. Army Engineer District, Los Angeles (undated)

These reports were reviewed with the objective of studying the basic principles that the Corps is using for evaluating flood control projects. In the process, all aspects of the evaluation procedure were considered but emphasis was placed on the application of economic concepts to project evaluation. That is on

- the application of "with and without" analysis
- the reasons for using damage reduction as the major measure of benefits for one of the projects but not for the other
- the measurement of land enhancement benefits

These aspects were examined and the validity of the procedures used were critically analyzed. In addition, hydrology, frequency analysis and other aspects of the projects were examined to the extent that they affect the benefit evaluation. Part Two of the report presents a brief summary of each project, it questions and analyzes the conceptual aspects of the procedures used and, when appropriate, suggests alternative courses of action or topics for further investigation.

The environment in which a flood control project is constructed is an important consideration in obtaining an understanding of the benefit evaluation procedures. Hence, a brief overview of the total Southern California area is presented in Appendix A. This review summarizes the geography of the area and provides basic information on population growth and land use development patterns. Population and land use projections are given for the South Coastal Hydrologic Subregion and for Los Angeles, San Bernardino and Riverside Counties. These are of primary concern in the study of the two projects. The Newhall, Saugus and Vicinity project is described and analyzed in Appendix B. The economic justification for this project is provided mostly by land enhancement benefits and therefore much of the analysis is oriented toward identifying the important aspects of the land enhancement benefit measurement problems. The Day, East Etiwanda and San Sevaine Creeks project is discussed in Appendix C. Here almost all benefits are attributed to damage reduction and therefore the damage measurement problem is addressed in more detail than in the previous case. An overview and comparison of the two projects is given in the following section whereas conclusions and recommendations drawn from this review are given in the project summary.

B. A Comparative Summary of the Two Projects

The main difference in the economic evaluation of the two projects is that Newhall, Saugus and Vicinity derives almost all benefits from land enhancement while benefits for the Day, East Etiwanda and San Sevaine are derived from expected damage reduction. This section points out the similarities of the two projects and some of the important differences which provide the reasons for the different sources of benefits. Analysis of the procedures for obtaining these benefits are described in the corresponding appendices.

The similarities are that both projects

a. are within the Los Angeles metropolitan area.

b. are in areas with adequate infrastructure for development

c. are exposed to similar weather conditions.

d. are in sub-basins contained wholly within larger river basins.

e. use channels and debris basins as main features for the project.

f. have the same project life and same construction period.

g. use the same method for cost estimating and the same discount rates.

h. use the same general methods for estimating damage reduction.

i. do not explicity account for intangible benefits.

A Comparative summary of the differences between the two projects is given in the accompanying table. This table indicates that the main reason for using land enhancement benefits in one case but not in the other is the rigid enforcement of flood zoning regulations in one of the counties. This difference is further explored in the appendices.

The data used in the two project reports and reviewed by INTASA is preliminary in nature. This does not necessarily reflect the data used or judgments made with respect to the final project reports.

COMPARATIVE SUMMARY OF THE TWO PROJECTS

Aspect Considered	Newhall, Saugus and Vicinity	Day, East Etiwanda, and San Sevaine Creeks
1. Geographic characteristics of the area	Large mountainous area drained by narrow river valley	Small mountainous area drained by large alluvial cone
2. Main River Basin	Santa Clara	Santa Ana
3. Size of total drainage area (square miles)	421	90
4. Developable land in drainage area		
(a) percentage of total	10%	82%
(b) acres	30,000±	48,000±
5. Developable land in overflow area (acres)	5,970	34,680
6. Present development	Extension of existing suburban community	Relatively undeveloped

COMPARATIVE SUMMARY OF THE TWO PROJECTS (Cont'd.)

Aspect Considered	Newhall, Saugus and Vicinity	Day, East Etiwanda, and San Sevaine Creeks
7. Density projections in persons per acre used as a basis for analysis		
(a) Assumed metropolitan saturation density	14.5	13.1
(b) Density forecast in year 2020 for		
. Coastal Los Angeles	14.5	13.1
. Coastal San Bernardino	12.2	8.8
. Coastal Riverside	11.6	5.4
8. Estimated time to full development (year)	10	50
9. Zoning regulations in effect for overflow area	Prevents development of 2,560 acres	Does not prohibit development
10. Development with and without the project	Different	Same
11. Standard project storm	Thunderstorm, March 1943 and winterstorm, January 1943	Thunderstorm, March 1943

COMPARATIVE SUMMARY OF THE TWO PROJECTS (Cont'd.)

	Aspect Considered	Newhall, Saugus and Vicinity	Day, East Etiwanda, and San Sevaine Creeks
12.	Basis for frequency-discharge relationship	Regional frequency analysis	Analysis of single stream flow record
13.	Frequency of standard project flood	500-year flood	200-year flood
14.	Major features of the project		
	(a) Channels in miles	27.1	31.3
	(b) Debris basins	3	7
15.	Cost estimate of project		
	(a) First cost	$44.8 million	$50.9 million
	(b) Annual O & M	270,000	233,000
	(c) Average annual costs	2,413,000	2,689,000
16.	Annual benefits from protection		
	(a) Damage reduction	938,000	9,233,000
	(b) Land enhancement	6,679,000	
	(c) Effect on water supply	-37,000	
	(d) Elimination current cost		43,000
	(e) Area employment benefits		206,000
	(f) Average annual benefits	7,580,000	9,482,000
17.	Benefit:Cost Ratio	3.1:1	3.5:1

APPENDIX A

OVERVIEW OF SOUTHERN CALIFORNIA

Appendix A

OVERVIEW OF SOUTHERN CALIFORNIA

1. Introduction

The part of the Southern California region that is of interest in this report includes the six counties: Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura. These counties all fall within three hydrologic subregions: the South Lahontan, the South Coastal and the Colorado Desert, except for a small part of Ventura County which falls in the Central Coastal hydrologic subregion. Rather than attempt to describe these areas in verbal terms, a schematic representation is presented in Fig. A.1. The large square in this figure represents the total area of 38,416 square miles, which is subdivided into rectangles that represent the six counties. The area of each rectangle indicates the relative size of the respective county. Diagonal broken lines are drawn to show the bounds of the three hydrologic subregions. The area of each rectangle that is within the boundary of a subregion indicates the proportion of the county within the subregion. The actual areas that were used to construct the symbolic representation of Fig. A.1. are given in Table A.1.

The projects discussed in this report should be evaluated from a perspective that recognizes the development conditions, geography and urban characteristics of Southern California. Urban growth in the last thirty years has been extraordinary in this area, yet the development has been limited to a rather narrow strip of land in close proximity to the Pacific Ocean. It is assumed in the reports that the population of the area will continue to grow and that the population of the coastal region will continue its outward movement. The stated reasons for this assumption are:

a. the demonstrated tendency of young families to seek single-family dwelling units.

b. the existence of large tracts of vacant undeveloped acreage.

c. the motor-oriented transportation system of Southern California.

Although such bases for the assumed growth are recognized to have existed in the Southern California Region, there are emerging manifestations that these trends may not continue with the vigor of the past. Recent declines in the proportion that single-family housing starts make in the nation's housing stock as compared with multi-family starts and mobile home sales; the continued

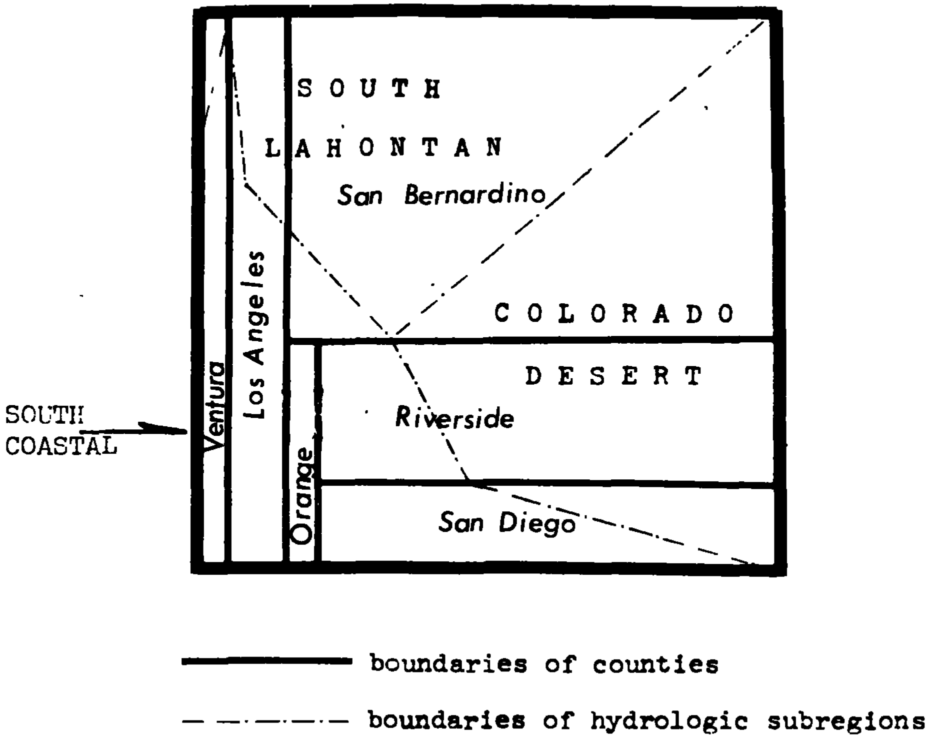


Figure A.1

SCHEMATIC DESCRIPTION OF COUNTIES AND HYDROLOGIC SUBREGIONS IN THE SOUTHERN CALIFORNIA REGION

Table A.1.

LAND AREA BY COUNTY AND HYDROLOGIC SUBREGION (SQ. MILES)

County	County Total	South Coastal	Colorado Desert	South Lahontan	Central Coastal
Los Angeles	4,079	2,748	-	1,331	-
Orange	785	785	-	-	-
Riverside	7,243	1,896	5,347	-	-
San Bernardino	20,164	982	8,173	11,009	-
San Diego	4,281	2,987	1,294	-	-
Ventura	1,864	1,584	-	-	280
TOTAL	38,416	10,982	14,814	12,340	280
% of TOTAL	100	29	38	32	1

decrease in family size; rising national and local concern about preservation of open space and wilderness areas; and the growing public awareness of the dangers of the automobile as a major cause of air pollution with consequent resistance to proliferation of this means of transportation, provide evidence of significant countercurrents to the assumed trends. It would therefore seem prudent to assess the impact of other sets of assumptions that are at least conceivable for the development of the Southern California region. This is expecially so when these projections are used to evaluate projects that are designed to last for a long time. Changing the fundamental growth assumptions in a meaningful way is beyond the scope of the present study, but we believe that this is an important area for future research. The present study will therefore accept the stated assumptions as valid for the time being, and descriptions that follow will be so founded.

The two reports analyzed in this study concern specific locations in Los Angeles County (Newhall, Saugus and Vicinity) and in the counties of San Bernardino and Riverside (Day, East Etiwanda and San Sevaine Creeks). Both of the projects are located within the South Coastal Hydrologic Subregion. The following discussion will describe appropriate characteristics of the South Coastal Subregion and of the counties within which the projects are located.

2. South Coastal Hydrologic Subregion

This subregion contains 11,000 square miles and its subdivision by county is as indicated in Table A.1. and Fig. A.1. The importance of the South Coastal Subregion results from geographic and climatic advantages. It is contiguous to the Pacific Ocean and its mild, year-round, climate makes it a desirable place to live. In addition, the subregion also possesses the major infrastructure necessary for urban growth. The population in the subregion has experienced an annual growth of 2.9% from 1960 to 1968, and all counties or portions of counties physically within the subregion have exhibited large population increases during this period. Coastal Los Angeles County had the largest absolute population increase. Its percentage gain was, however, exceeded by all five other counties. The population of the South Coastal Hydrologic Subregion is the most dense in metropolitan Los Angeles, and has exhibited an outward growth. By the year 2020 densities for each county in the South Coastal Subregion are forecast to be as indicated in Table A.2. The table also shows the percent of saturation that each county will have attained by year

2020, where density of 14.5 persons per acre was assumed as the saturation density.[1] Projected densities for each county in the South Coastal Subregion are shown in Fig. A.2. and projections of land use, population and density in Fig. A.3.

Table A.2.

POPULATION DENSITY IN YEAR 2020

County	Density	% Saturation
Coastal Los Angeles	14.5	100
Orange	13.0	90
Ventura	12.3	85
Coastal San Bernardino	12.2	84
Coastal Riverside	11.6	80
Coastal San Diego	7.1	49

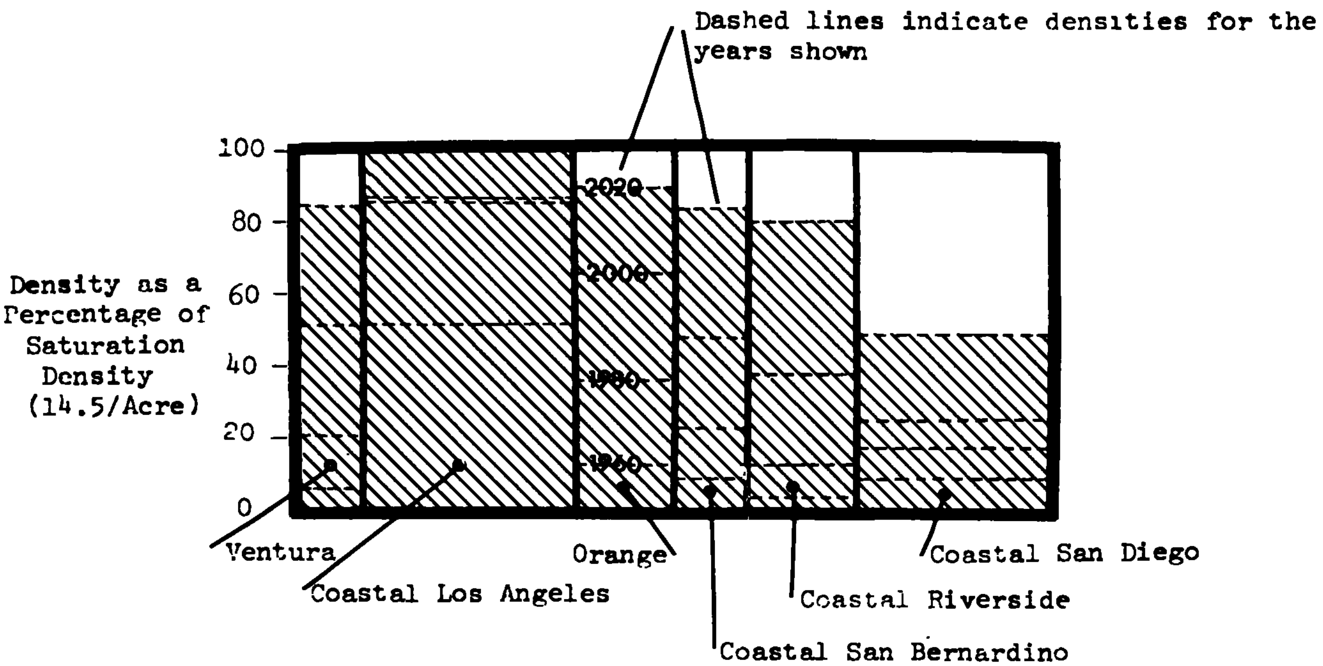


Figure A.2

PROJECTED DENSITIES SOUTH COASTAL SUBREGION

1. There is an inconsistency between the Day and Newhall reports as to the projected county densities and the metropolitan saturation density (e.g., the Day report indicates a saturation density of 13.1 instead of 14.5).

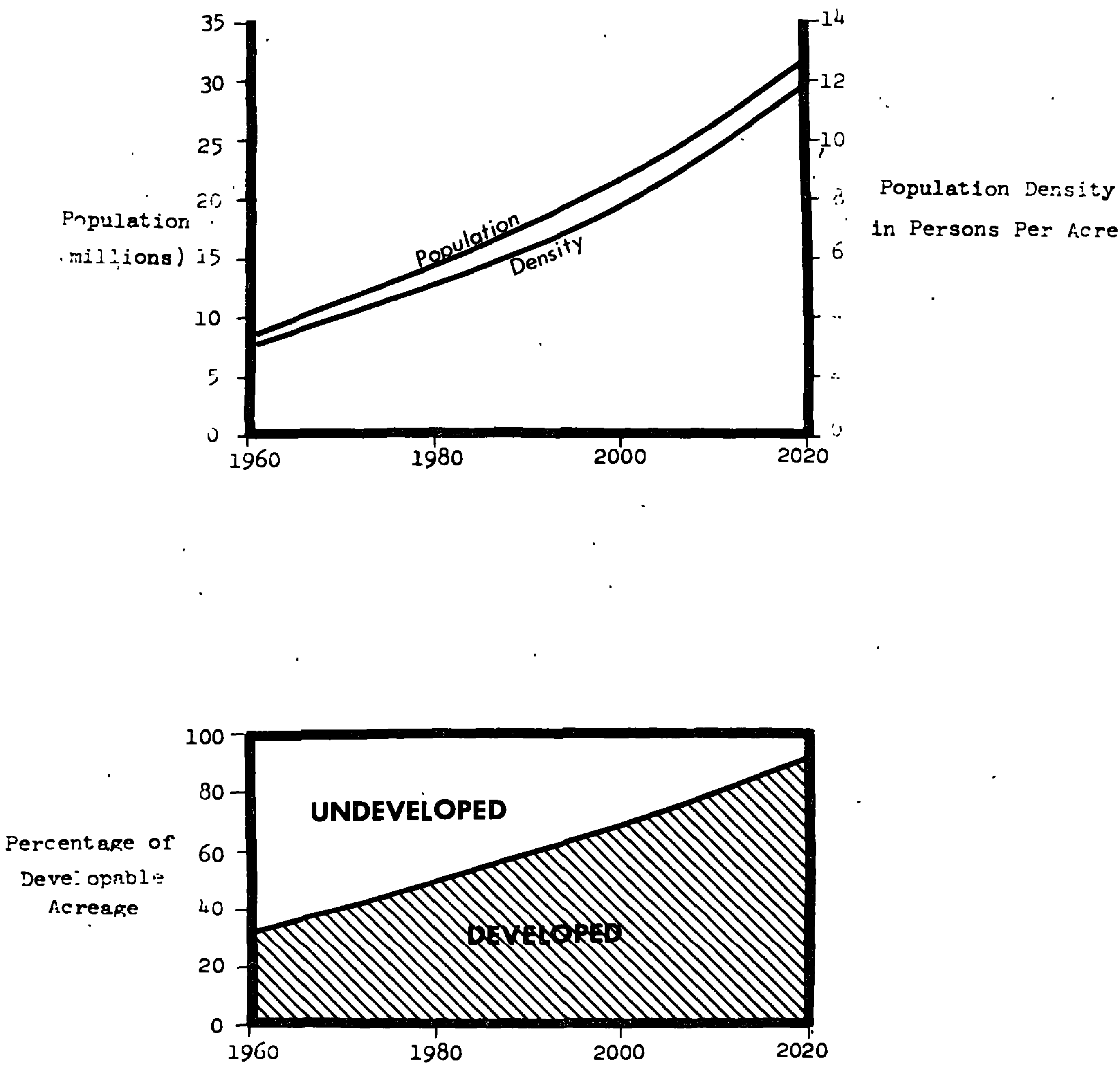


Figure A.3

POPULATION, DENSITY AND URBAN DEVELOPMENT IN SOUTH COASTAL HYDROLOGIC SUBREGION

3. Los Angeles County

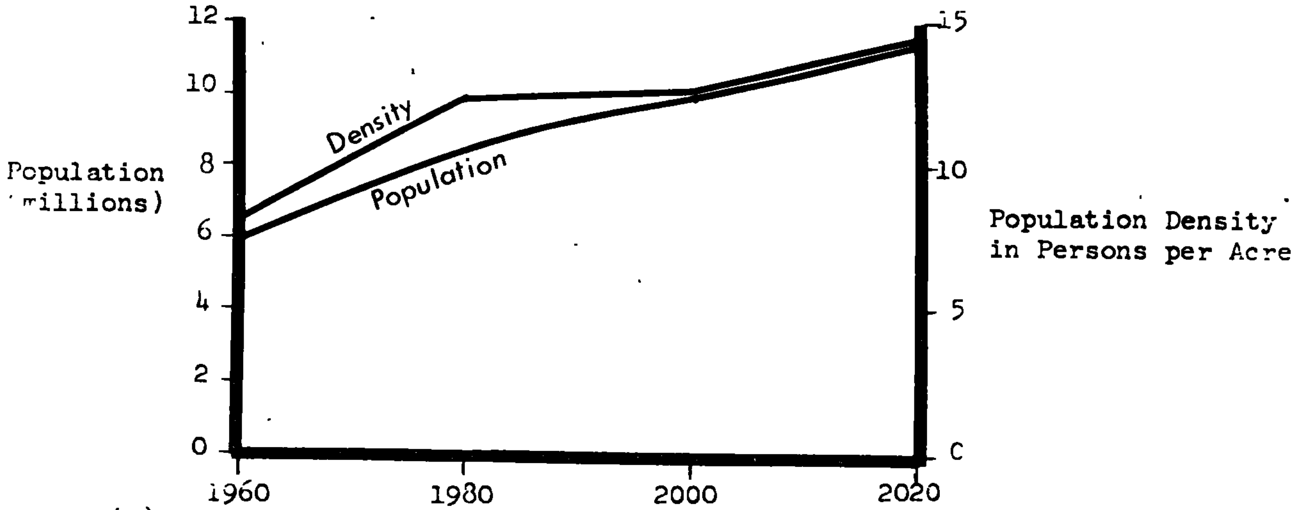
The County of Los Angeles may be divided into two distinct areas for the purpose of future planning - the coastal area and the north county area. The coastal area comprises 980,000 acres. Subtracting the vacant areas that are over 25% in slope, the forest preserves, and other areas that are generally unsuitable for urban development, the net developable area in the coastal region amounts to about 790,000 acres, of which 640,000 were developed by 1968. The density of this developed area at that time was eleven persons per acre. Projections of population, density and urban development are shown in Fig. A.4.

The Newhall-Saugus area is classified by Los Angeles County as part of the north county area; in fact it is within the mountain area along the connecting link between the coastal area and the north county. A more detailed description of the Newhall-Saugus area is given in Appendix B.

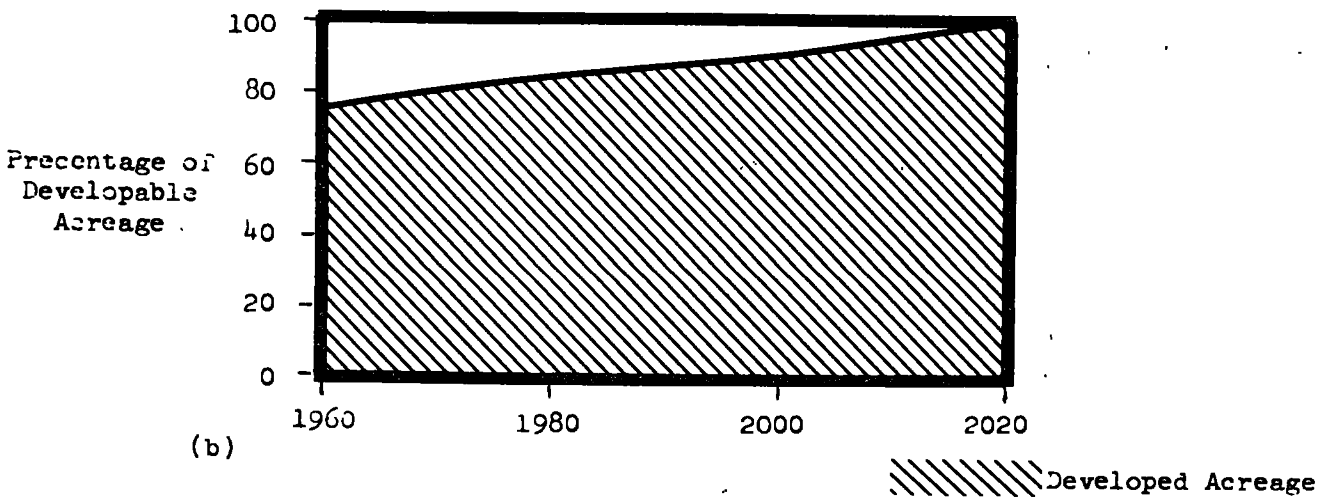
4. San Bernardino and Riverside Counties

San Bernardino County is the largest of the six counties in the Southern California region with an area of 20,164 square miles while Riverside County has a total area of 7,243 square miles. The portions of these counties that are in the South Coastal Subregion are only small fractions of their total areas. There are 1896 square miles of Riverside County within the South Coastal Subregion while San Bernardino County accounts for only 982 square miles. In 1960 Coastal San Bernardino County had 55,000 developed acres out of a total developable acreage of 268,000 acres. Coastal Riverside County had 46,000 developed out of 407,000 developable acres. The area is relatively lightly populated with a 1960 population of 645,000 for the combined coastal areas of both counties. Projected population and density of each county's coastal area are shown in Fig. A.5a. The projected development in San Bernardino and Riverside County's is shown in Fig. A.5b and c, respectively.

The Day, East Etiwanda, San Sevaine area overlaps the coastal counties of San Bernardino and Riverside. A more detailed description of the area is given in Appendix C.



(a)



(b)

Figure A.4

POPULATION, DENSITY AND URBAN DEVELOPMENT IN LOS ANGELES COUNTY

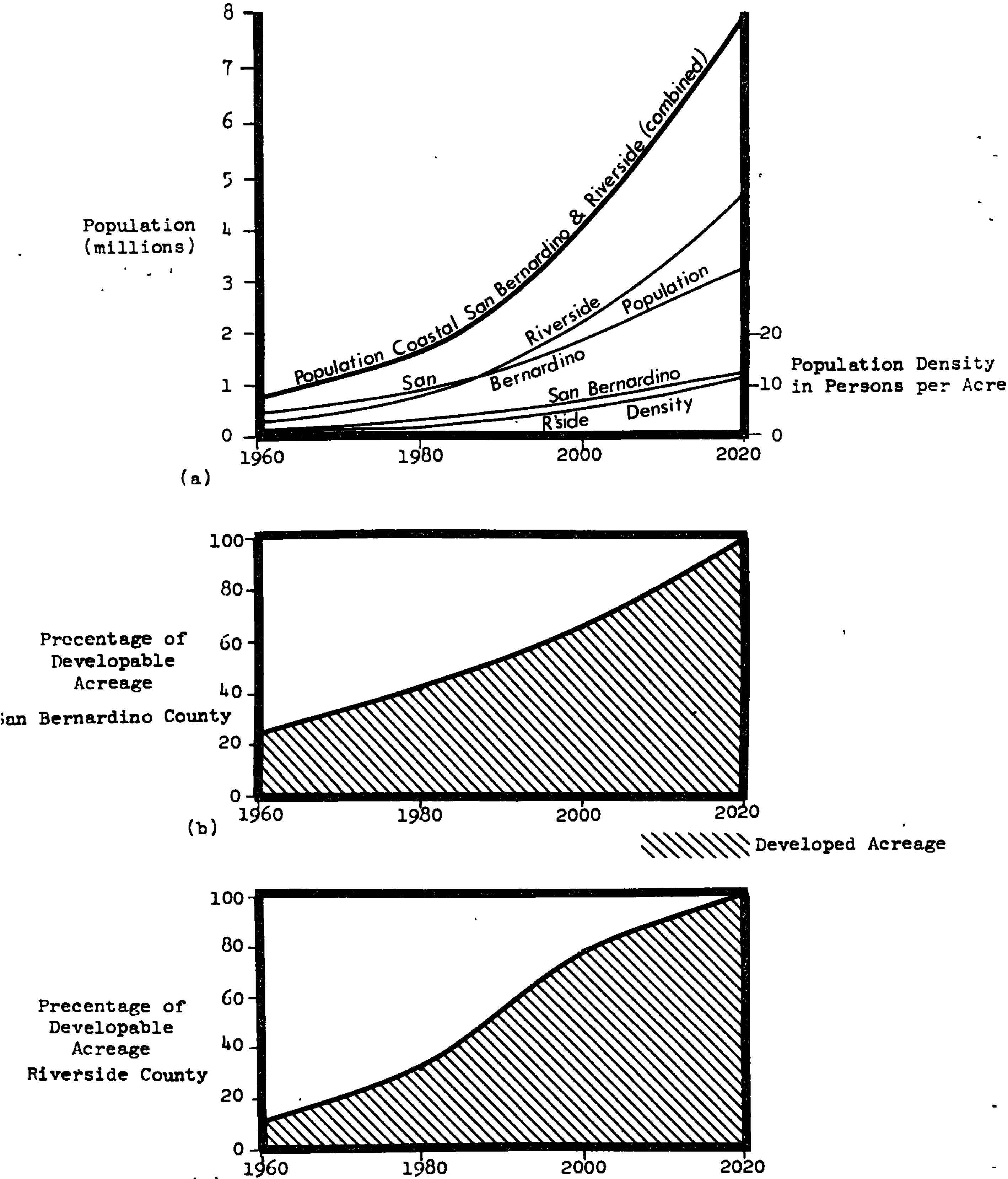


Figure A.5

POPULATION, DENSITY AND URBAN DEVELOPMENT IN SAN BERNARDINO AND RIVERSIDE COUNTY

APPENDIX B

DESCRIPTION AND ANALYSIS OF NEWHALL, SAUGUS AND VICINITY

I. DESCRIPTION OF THE PROJECT AREA

The project considers specific streams in the Los Angeles County part of the Santa Clara River basin which is located in the South Coastal Hydrologic Subregion. A location map of the vicinity of the drainage area covered by this study is presented in Fig. B.1. The Santa Clara River basin is an elongated area with a maximum east-west length of about 66 miles and a maximum north-south width of about 37 miles with an area of 1629 square miles. The Los Angeles - Ventura County line divides the basin into two parts; the part within Los Angeles County is 772 square miles. The project analyzed here concerns an area of 421 square miles of the eastern end of the Los Angeles portion of which 10 percent is alluvial valley and 90 percent mountains and foothills.

The area is in a generally narrow valley surrounded by steep hillsides, most of which are in the Angeles National Forest. The bordering steep slopes are extremely expensive to subdivide, and have a very high fire hazard during the summer months when left with natural vegetation to prevent the erosion and mudslides that may occur during the winter rains. In and adjacent to the Newhall-Saugus area there are 10,500 acres suitable for urban development, of which 5970 are in the overflow areas considered in this report. A symbolic representation of the relative sizes of the

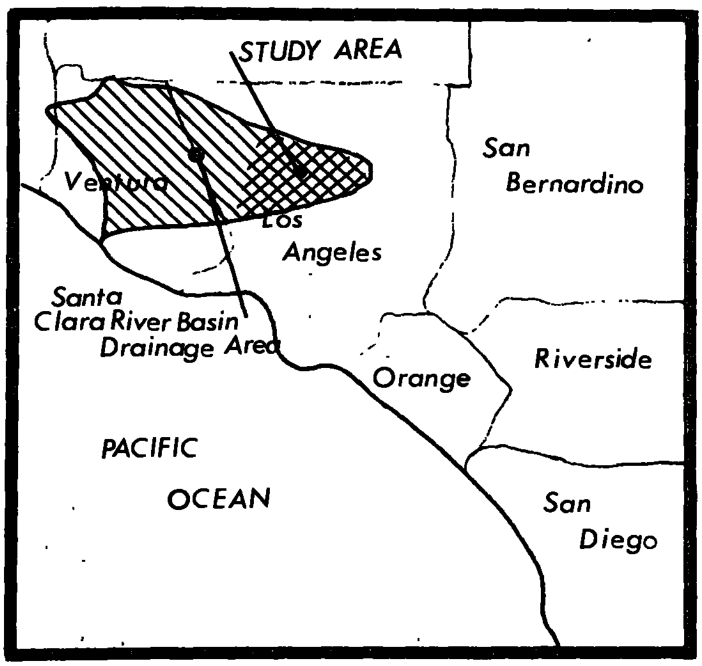


Figure B.1 LOCATION MAP NEWHALL-SAUGUS STUDY AREA different areas is presented in Fig. B.2.

The present (1968) and projected land uses are listed in Table B.1 and graphically presented in Fig. B.3 according to the general categories of developed, agricultural and undeveloped land. The presently developed land amounts to 1655 acres and with no further flood control, it is assumed that 786 acres of additional land will ultimately be developed; this is shown in the third column of Table B.1 which gives the expected net change in land use without flood control measures. The fourth column in Table B.1 shows the acres that will develop in addition to the 786 acres if flood control will be provided. The development of these 2653 acres is prohibited by zoning regulations without a minimum level of flood protection; this land is referred to as "enhanced" land. The last two columns of Table B.1 show the ultimate land use pattern with and without the project. Thus, with the project 5094 acres will ultimately be developed which is the sum of the original 1655 acres, the 786 acres that will develop with or without the project and the 2653 acres of the enhanced land. The expected rate of land development is graphically presented in Fig. B.4.

The area is served by three major highways - Interstate 5 and California Routes 14 and 26. These highways are now, or soon will be, improved to freeway standards and provide highway access to the continental U. S. markets. The Burbank Airport is 20 miles from the area and the Los Angeles International Airport 40 miles. Rail transport service is available from the main line of Southern Pacific Company and the harbors of Los Angeles and Long Beach are 50 miles away with freeway access. Water for anticipated future growth is available from local sources supplemented by water from units of the California Water Plan.

A close examination of the Newhall, Saugus and Vicinity overflow area raises an interesting observation in regard to the measurement of land enhancement benefits. It appears that the difference in the market value of the flood plain land before and after protection could lead to an overstatement of the actual economic benefits due to the flood control project. This is because there are many other development activities, such as the transportation system which provides easy access to the surrounding industrial centers, to which part of the difference in the market prices could be attributed. Under these circumstances, the analyst should examine whether the land enhancement benefits are greater than their upper bound which is total damages reduced, and if they are, he should conclude that they have been overestimated (See Chapter IV of Part One).

a. Distribution of Land in Eastern end of Santa Clara River Basin.

b. Distribution of Developable Alluvial Valley Land in Santa Clara River Basin.

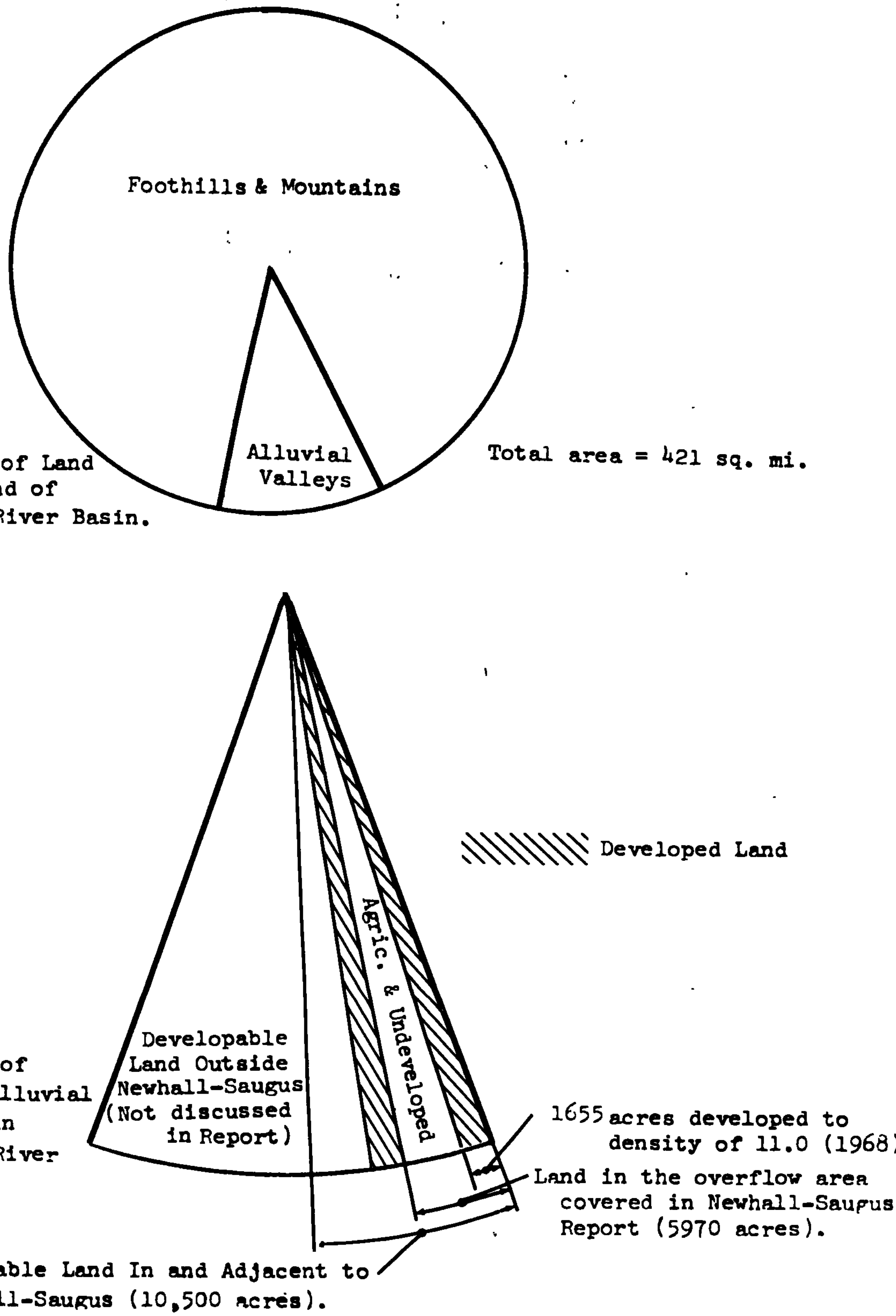
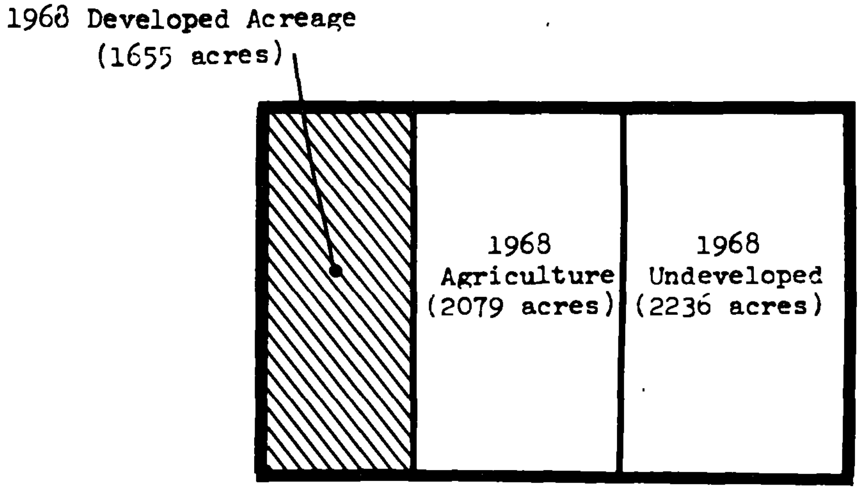


Fig. B.2. SYMBOLIC REPRESENTATION OF LAND AREAS DISCUSSED IN NEWHALL-SAUGUS REPORT. (1968)

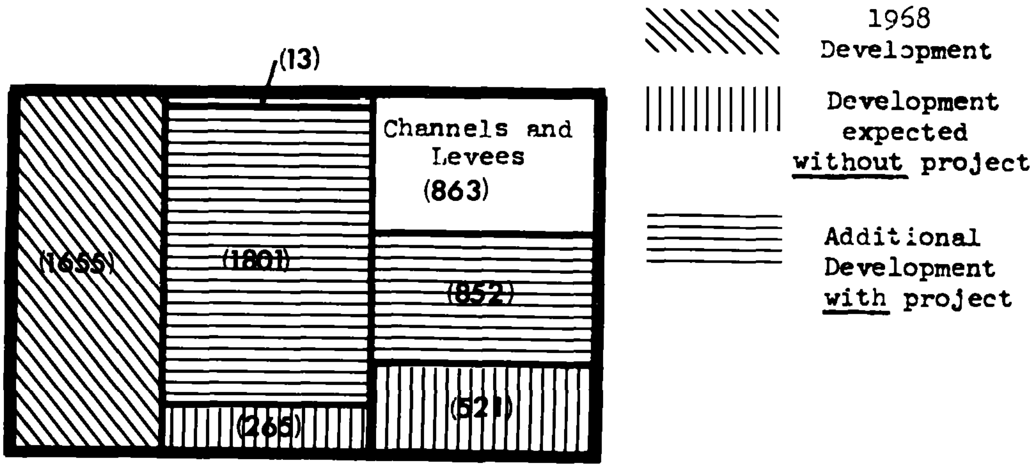
Table B.1.

PRESENT AND PROJECTED LAND USE IN NEWHALL-SAUGUS AND VICINITY

Land Use Category	1968	Net Change Without the Project	Net Change Due To the Project	Ultimate Future Development: Without the Project	Ultimate Future Development: With the Project
Residential	880	+159	+1,498	1,039	2,537
Other urban use	775	+627	+1.155	1,402	2,557
Total Urban	1,655	+786	+2,653	2,441	5,094
Agricultural	2,079	-265	-1,801	1,814	13
Other undeveloped	2,236	-521	- 852	1,715	863
Total Rural	4,315	-786	-2,653	3,529	876
Total Land	5,970	0	0	5,970	5.970



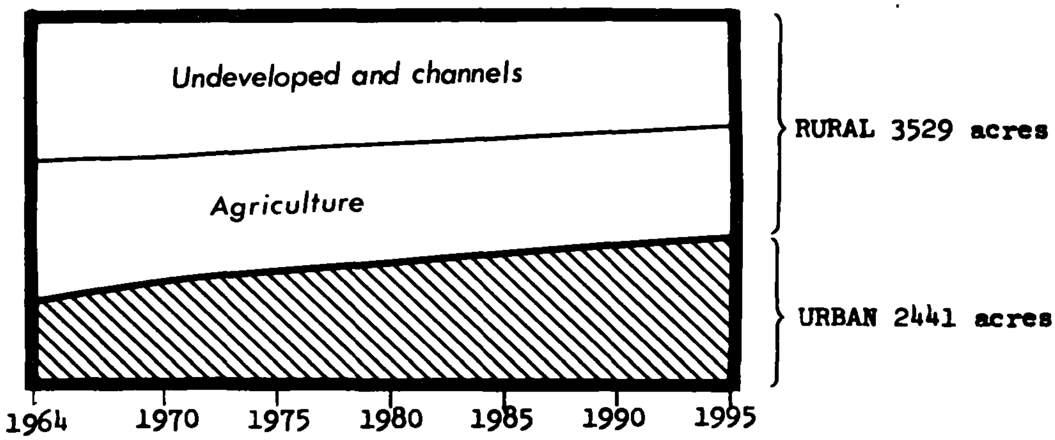
a. 1968 Land Development of Newhall-Saugus Area.



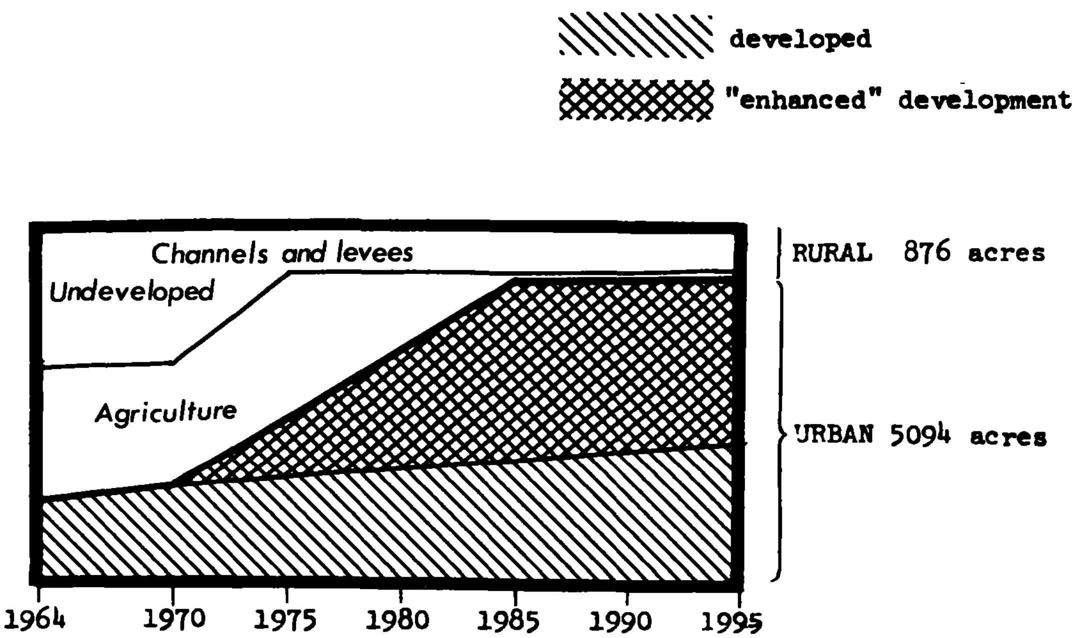
b. Expected Land Development With and Without Flood Control Project.

Figure B.3

SYMBOLIC REPRESENTATION OF THE OVERFLOW ZONE IN NEWHALL-SAUGUS



a. <u>Without</u> major flood control



b. <u>With</u> major flood control.

Figure B.4

PAST, PRESENT AND PROJECTED LAND USE:
NEWHALL, SAUGUS AND VICINITY 1964-1995

II. ALTERNATIVE FLOOD CONTROL MEASURES

1. Non-Structural Alternatives

Los Angeles County is currently zoning 2653 acres of land from urban use unless the provision of county required level of protection is met. This level of protection is lower than that provided by the project as recommended in the report. As stated in the previous section, 786 acres of land in the overflow area is available for development into urban use and will develop with or without the project. Most of it will be approved for industrial and commercial development on the condition that developers and tenants are aware of the flood hazard. Some of this land is no longer subject to subdivision control and will possibly develop into residential use. The project will provide protection to these 786 acres and will allow the relaxation of flood zoning regulations on the remaining 2653 acres.

One alternative, of course, is to accept the flood risk for the 786 acres and continue to restrain development of the 2653 acres. This alternative has two possible outcomes. First, since it is implicitly assumed in the report that the Los Angeles County will continue to enforce the flood zone regulation, it will prevent the development of the enhanced land and expose the already occupied 786 acres to the flood hazard. Second, if future pressures on land use remove the flood zone regulation, the total development of the enhanced land will become subject to the flood hazard. As a result, the consequences of this alternative have some serious implications which must be investigated before this alternative is seriously considered.

In regard to the alternative of flood proofing, the report states that it would require extensive filling of the valley floor and would not prevent damage to existing improvements and property. It is implied that the cost of such measures would exceed the net benefits. This seems reasonable for this means of flood proofing, since fill operations are expensive. However, there might be other alternatives to filling that could be technically feasible either now or in the future. Exploration of flood proofing methods in addition to filling could prove to be of significance.

It was also concluded that flood forecasting and temporary evacuation would be impracticable since floods in the area result from thunderstorms and winter storms. These storms have elapsed times between rainfall and runoff approximately one to six hours which are considered short.

In general it appears that a close examination of non-structural alternatives would require substantial effort and extensive investigation. The outcome of some of these is certainly obvious but others would require complete evaluation studies.

2. Structural Alternatives

The structural alternatives considered included (a) a reservoir, (b) channel improvements, and (c) a combination of reservoir and channel improvements. From preliminary studies made by the Corps of Engineers, it was determined that a reservoir would cost about 17 million more than all-channel-improvement. This is primarily due to the required relocation of the main line of the Southern Pacific Railroad. It was also concluded that some channel improvements would still be required. It was decided that the additional cost of the reservoir would not be justified by the additional benefits derived from water conservation and recreation. Economic studies were also made to determine the extent of the channel improvements as well as the difference between earth bottom or concrete bottom channels. It was determined that concrete bottom channels are more economical.

The recommended plan of improvement for the area comprises 27.1 miles of channel, 6790 feet of levee works, and three debris basins. Table B.2 lists the individual elements of the project with their proposed improvements. Separate plans and specifications will ultimately be provided for each of the six units listed in Table B.3. The recommended timing sequence of the six units is shown in Fig. B.5, where the total recommended construction time for the project is 45 months. Other than this, it is not explicitly indicated whether the timing or staging of project construction was analyzed in relation to its effect on net benefits.

Two degrees of protection were considered to determine the degree of channel improvement. Comparative studies were made for channel improvements to control the peak discharge from a standard project flood and from discharges set by the Los Angeles County Flood Control District. Consideration of additional levels of protection would have been useful in the determination of the best size of the project.

Table B.2

INDIVIDUAL STREAM ELEMENT IMPROVEMENTS FOR NEWHALL, SAUGUS AND VICINITY

Individual Stream Element		Channel length (miles)	Debris Basin	Inlet Levee In Feet
A.	Santa Clara	9.4		1300
B.	Bouquet	0.4		1540
C.	South Fork	4.3	1	
D.	Pico	0.7		1950
E.	Placerita	3.1		900
F.	Newhall	2.6		550
G.	Sand	3.4	1	
H.	Iron	1.2	1	
I.	Mint	2.0		550
	Total	27.1	3	6790

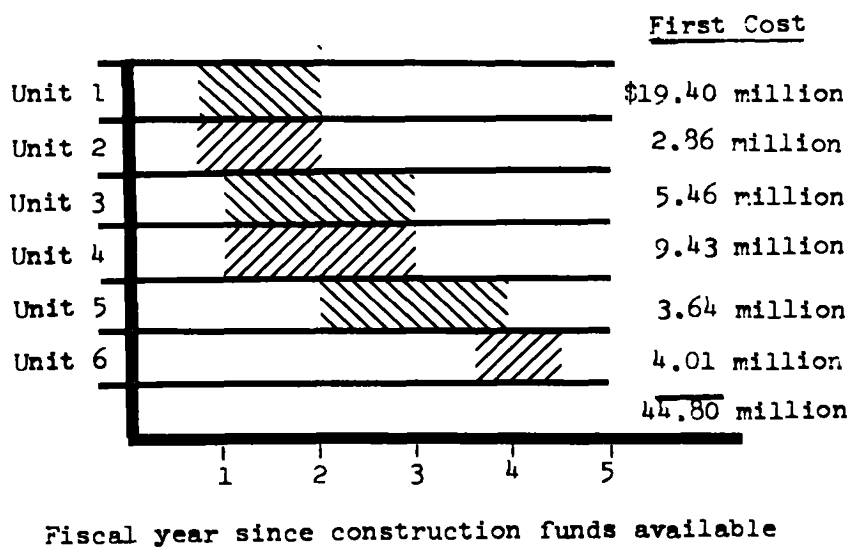


Figure B.5

RECOMMENDED CONSTRUCTION SCHEDULE FOR NEWHALL-SAUGUS FLOOD CONTROL WORKS

Table B.3.

ESTIMATED COSTS FOR IMPROVEMENTS UNDER RECOMMENDED PLAN FOR NEWHALL, SAUGUS AREA
(IN THOUSANDS OF DOLLARS)

Unit	Description	Federal Construction Cost*	Other Federal Costs**	Total Federal Cost	Non-Federal Costs	Total First Cost	Total Annual Operation and Maintenance Costs
1	Santa Clara River; Bouquet Canyon Channel and Inlet	13,961	2,239	16,200	3,200	19,400	67
2	Mint Canyon Channel	2,166	344	2,510	350	2,860	5
3	Sand Canyon Debris Basin and Channel; Iron Canyon Debris Basin and Channel	3,852	708	4,560	900	5,460	47
4	South Fork Santa Clara River Channel; Towsley Canyon Debris Basin	5,707	913	6,620	2,810	9,430	130
5	Newhall Creek Channel System	2,525	405	2,930	710	3,640	8
6	Placerita Creek Channel	2,742	438	3,180	830	4,010	13
	Total	30,953	5,047	36,000	8,800	44,800	270

* Does not include supervision, administration, engineering and design costs

** Federal costs for supervision, administration, engineering and design

III. COST ESTIMATES

A summary of the estimated costs associated with the construction of the six units for the project is shown in Table B.3 together with estimates of annual operation and maintenance costs. These estimates were computed by determining the quantities of various items of labor, material and equipment, multiplying the quantities by unit prices for each category and obtaining the sums of these products. The unit prices used were developed by using prevailing January 1969 labor, material and equipment costs typical of work of this nature in the vicinity of the construction site. The cost obtained was $25,900,000 and to this $5,100,000 which represents a contingency estimate, was added to obtain the total federal construction cost of $31,000,000. This figure does not, however, include either engineering and design costs or supervision and administration costs which were estimated at $5,000,000 thus making the total federal cost $36,000,000. Estimates for non-federal costs, representing rights of way and relocation expenses, were also made and these costs amounted to $8,300,000. Thus the overall first cost of the project comes to $44,800,000 and the annual maintenance and operation cost to $270,000.

While the procedure for estimating the cost is generally accepted practice, several points might be made. First, the contingency figure of about 20% of the calculated cost seems to indicate that the procedure may be deficient in accurately producing cost estimates. This possibility could be explored by analyzing past projects to determine the level of uncertainty that has historically been associated with projects of this nature. It is suggested that the accuracy of preliminary estimates may be improved by applying multivariate statistical analysis. Such an approach would not only be useful in cost estimation but would be of value in determining marginal costs curves which are needed in a proper benefit-cost analysis.

There is a question as to the use of 44.8 million as the estimate of the first cost of construction. Under the assumption that benefits begin to accrue to the project at the time that the entire project is completed, account should be taken of the 45-month construction period in arriving at the estimate of the first cost. Fig. B.5 shows the recommended time sequence for each of the six construction units. By assuming that payment is made in full for each construction unit at the end of its construction time, a series of cash flows would result as shown in Fg. B.6. Using a discount factor of 4 5/8% the equivalent lump sum cost that would occur at the completion of the total project would be approximately 48.6 million. This figure would be more representative of the first cost of the project provided that no benefits would accrue before the entire project is completed.

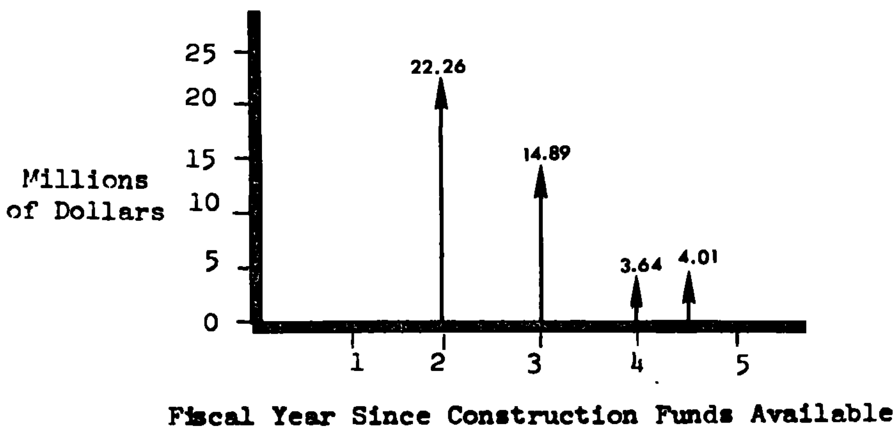


Figure B.6

CASH FLOWS FOR UNITS OF CONSTRUCTION

1. Design Floods

The hydrologic analysis was made to determine the following design parameters:

- the magnitude of the standard project flood,
- the magnitude of the maximum probable flood, and
- the debris storage requirements and spillway capacities at selected concentration points.

In general the standard project flood is determined by the standard project storm which is the most severe storm of record in the region. This storm is then critically centered over the area to produce the maximum runoff. Three types of storms produce precipitation in the area:

a. General winter storms. These occur from December through March. They originate over the Pacific Ocean as a result of the interaction between polar Pacific and tropical Pacific air masses. These storms move eastward over the basin and often last for several days. They are accompanied by widespread precipitation in the form of snow and rain - caused by orographic influences.

b. Thunderstorms. These can occur at any time of the year, but are infrequent along the coast in the summer. They can occur during other storms or as isolated phenomena. They cover a comparatively small area but result in high-intensity precipitation for durations of three hours or less. Winter thunderstorms are generally associated with frontal systems.

c. Tropical hurricanes. These storms have occurred in late summer and early fall and have not resulted in major floods during the past.

These different types of storms will be considered as independent events which means that the occurrence of one type does not depend upon either of the others occurring. This assumption is used later and may or may not critically affect the net benefits. It should, therefore, be studied and the sensitivity of the net benefits should be tested.

Historical records of storms in the vicinity were examined and both a thunderstorm and a general winter storm produced severe conditions. Therefore, two standard project storms were defined, one associated with a thunderstorm, and the other with a general winter storm. In determining the standard project floods from the standard project storms, it was assumed that either type storm could occur over the area, but both types were not assumed to occur simultaneously.

The standard project thunderstorm was used to determine the peak discharges for the smaller areas contributary to the main river channel. This thunderstorm was recorded on March 1943, and occurred while a general winter storm was in progress. For the larger areas the standard project winter storm was used and was based on the assumed occurrence of a storm equivalent in magnitude to that of January 1943 which in many respects was the most severe storm of record in Southern California

Using precipitation data for the standard project storms, the standard project flood peak discharges were computed. This procedure involves: (a) dividing the basin into appropriate subareas; (b) determining unit-time increments of precipitation for each subarea; (c) determing effective precipitation for each subarea by subtracting a loss rate and by applying an impervious factor where applicable; (d) determining the surface runoff hydrograph for each specific subarea by applying synthetic unit-hydrograph values to the effective unit-time period precipitation; (e) adding base flow and subtracting percolation losses to get a final subarea hydrograph; (f) combining appropriate subarea hydrographs to get a total flood hydrograph for each concentration point desired.

The maximum probable flood is defined as the flood that would result if the maximum precipitation for the drainage area were to occur at a time when ground conditions were conducive to a maximum runoff. The U.S. Weather Bureau has not made a determination of the probable maximum storm for the Newhall-Saugus drainage area. This storm was therefore developed based upon the probable maximum precipitation for the area, which was obtained by analyzing meteorological conditions and influences in the area, determining the quantities of precipitable water and transforming this into precipitation and intensity patterns.

Peak discharges at selected concentration points in the area for the standard project and maximum probable floods are listed in Table B.4. The peak discharges for the standard project flood are used to determine parameters for design of the channel systems while the maximum probable flood peak discharges determine the storage requirements and the spillway capacities for the debris basins. On the basis of the frequency-discharge relationships derived in the next section it follows that the standard project flood corresponds roughly to a 500-year flood.

Table B.4.

PEAK DISCHARGES AT SELECTED CONCENTRATION POINTS IN NEWHALL, SAUGUS DRAINAGE AREA

Concentration Point	Peak Discharge for Standard Project Flood (cfs)	Peak Discharge for Maximum Probable Flood (cfs)
Sand Canyon	5,000	14,000
Iron Canyon	2,500	7,000
Towsley Canyon	6,000	16,000
South Fork at Newhall Creek	25,000	NA*
Santa Clara River Downstream of Mint Canyon	44,000	NA
Bouquet Canyon	21,000	NA
Santa Clara River Downstream of Bouquet Canyon	56,000	NA

*NA means not-available.

2. Flood Frequency Analysis.

Economic analyses of flood-control projects require information in regard to the likelihood that any particular degree of flooding will occur. Hydrologic measurements are combined and statistically treated to provide this information. The procedure analyzes a series of flood records (measurements of peak discharges) and determines from these records the average time, in years between occurrences, of flood events of various magnitudes. The average time between similar events is termed the "return period" of the event. Thus if a record of flows for a given stream showed that a flood with a peak discharge of 50,000 cfs occurred five times in 100 years of record, the return period is 20 years, the flood is called a 20 year flood, and in terms of its chance of occurrence, it has a frequency of 5% or a probability of 0.05 per annum. In general the record of flows is short, and it is difficult to obtain good estimates for flood frequencies.

There are two general types of frequency analysis: a) frequency analysis for a specific stream with an individual streamflow record; b) regional analysis in which the records of several streams are combined to develop a set of areal measures that are applicable to all streams in the region. The second method is used for the Newhall-Saugus area and can be summarized as follows: The data available at each existing station in the area is used to develop a discharge-frequency relationship for the station. These are then adjusted for differences in record length among the stations to produce a set of comparable frequency-discharge relationships. Based on this uniform set of data, a generalized regional relationship is derived - using physical and meteorological measures together with calculated measures - that can be used to compute the frequency-discharge relationship for any point in the area.

From records of the U.S. Geological Survey, the Los Angeles Flood Control District and Ventura County Flood Control District, the annual maximum and secondary recorded peak discharges for all stream-gaging stations appropriate to the analysis were tabulated. Missing records were estimated using a procedure of graphical correlation by assuming that adjacent stations have similar hydrologic characteristics, while records from stations having upstream diversions or regulation were adjusted to natural flow conditions. Then all stations with 10 or more years of record were selected as the data base for the regional frequency analysis. The assumption was made that the peak discharges at each station follow the log-normal distribution. The mean and standard deviation, M and S, were then computed from the logarithm of the sample-maximum discharges. The frequency or cumulative probabilities for the sample were then plotted on probability paper and a straight line fit was used to test the hypothesis that the sample follows a log-normal distribution or as the goodness of fit test. Then, with the assumption that the straight line fit is sufficient, frequency points for any synthetic discharge can be generated by using the equation

$$\log Q = M + kS \qquad \text{(B.1)}$$

Where k is the magnitude in standard deviation from the mean for various exceedence percentages and is normally distributed with zero mean and standard deviation 1. The above procedure is valid for large samples, in which case the sum of the squared deviations from the straight line is used as a criterion which results in the well known χ^2 for goodness of fit test. For small samples, however, it is doubtful that valid conclusions can be drawn from the above approach and different methods may' be used to generate more sample points by statistical correlation with larger samples in the area.

The statistics from stations having records less than 30 years were extended based on the statistics of nearby hydrologically homogenous stations having records greater than 30 years. Having changed the data to comparable statistical samples, multiple regression was used to correlate peak discharges with the physiographic and meteorological characteristics of the drainage basin. In this multivariate analysis, the geometric mean flood, the antilogarithm of the mean M was the dependent variable for each station. The independent variables considered were:

A = drainage basin area in square miles

P = mean seasonal precipitation in inches

N = the slope of the main channels in feet per mile

L = length of main channel in miles

Sh = drainage basin shape factor define as L^2/A

A multiple regression analysis was performed, and the least significant independent variables were eliminated one at a time. The equation having the highest correlation coefficient was determined to be

$$Q_p = C_p A^{0.57} P^{2.95} \tag{B.2}$$

where Q_p is the geometric mean flow and C_p the anti-logarithm of the regression constant and is termed the peak discharge coefficient. Since the independent variables retained through this analysis were the same as those derived in a larger study done by the U.S. Army Engineer District, Sacramento in 1960, it was concluded that the equation developed through the latter study should be used. This was

$$Q_p = 0.001 C_p A^{.85} P^2 \tag{B.3}$$

where the factor 0.001 was introduced to enable the use of more convenient C_p values; it is observed that this is substantially different than Eq. (B.2).

The basis for the decision to reject the regression equation developed from actual data for the area, in favor of the published equation, is not entirely clear. It would appear that the stated reason - that the independent variables were the same - is not sufficient in itself. In order to investigate this point, INTASA performed a regression analysis on the data listed in Table 2 of Appendix 2 of the report, to calculate Eq. (B.2). The results showed that the index of multiple determination (R^2) for Eq. (B.2) was 0.53. This value of R^2 is quite small and the hypothesis of the multiple regression model for grouping the stations physiographically and meteorologically should be rejected; $R^2 = 0.53$ implies that the model represents only about 50% of the variation in the sample. However, the fact that this model was rejected does not necessarily imply that Eq. (B.3) will give a better fit on the sample. In fact, if R^2 is calculated using Eq. (B.3) and the actual sample for the stations, it would be smaller than 0.53 as expected since Eq. (B.2) was the best fit for that particular sample. Even though the fact that the same independent variables are retained in both equations does not alone justify the use of Eq. (B.3), a justification could be provided if the sample used to fit this equation was a much larger sample of a similar area and the area was found to be hydrologically homogeneous. In any case, this should be analyzed because of the obvious implications it has on the frequency-discharge relationships.

Regionalization of the data was obtained by plotting the standard deviation S of the logarithms of the flows for each station on a station-location map. Isograms were then drawn to provide smooth contours of S which give a measure of variability of the peak discharges for the area. The value of peak discharge coefficient C_p from Eq. (B.3) was calculated for each station by substituting known values of Q_p and A and P into the equation. These values were plotted similar to the standard deviations and the isograms drawn give a regional presentation of the peak discharge coefficient C_p from which we can then determine the geometric mean flow using Eq. (B.3). Statistical tables from "Statistical Methods in Hydrology", a 1962 report by the U.S. Army Corps of Engineers District in Sacramento, was used to develop a relationship between standard deviation values and the ratio of peak discharge to geometric mean discharge.

The frequency curve for any stream can now be obtained by determining the value of the standard deviation S from the isogram map and the stream in question. This value is used together with the size of the area, the mean seasonal precipitation and the relationship between S and the ratio of peak discharge to geometric mean discharge to compute the peak flow for various frequencies.

It should be pointed out that although the regional frequency analysis is conducted in accordance with generally accepted practice, judgment decisions were made that might have significant impact on the resulting frequency relationships. As the economic analysis is now structured for the Newhall project, the effect of different frequency relationships than those used would possibly have little impact on the net benefits since only a small proportion is due to damage reduction. However, given different procedures, such as the approach recommended in Chapter V of Part One, for measuring land enhancement benefits the hydrological issues raised in this section are of significance.

V. ECONOMIC FORECAST FOR THE AREA

Data for future development in the area was obtained from the land-use surveys conducted by the California Department of Water Resources for purposes of water use, from the Los Angeles Regional Transportation Study (LARTS) completed by the California Division of Highways, from the San Diego Planning Agency and from the Los Angeles County Planning Commission. On the basis of these data, estimates for land use were obtained with and without the project. This included acreage developed for each land use category in the years 1964 and 1968 as well as the ultimate levels of development. The year in which this level is reached for each case was estimated on the basis of growth in the area and land availability. A constant rate of development was assumed between 1968 and this year of ultimate development.

As an example the development of the residential acreage for the Santa Clara River is briefly discussed. In 1968 the number of acres developed was 351. Without the project, full development is expected in 1995 with a total number of acres developed equal to 398. With the project, full development is expected in 1985 with 871 acres. Thus, 473 acres of residential property develops as a result of the project. For the entire area the increase in developed land as a result of the project is 2653 acres as discussed in Chapter I of this Appendix. The full development of the land is expected to be achieved in ten years, except for Placerita Creek where full development will be achieved in five years, the development is assumed to be exactly the same for the two projects considered, one based on county regulation and the other on the standard project flood.

Estimates of the value of the property subject to flood damage based on 1969 development were made by (a) valuation data furnished by owners or managers of property and (b) field inspection and appraisals of the development. An average value of this property was used in order to account for the depreciation of existing property over time, and for residential, agricultural and vacant property, the value of land was also included to arrive at the total property value. Estimates of property developed in the future were obtained on the basis of (a) interviews with industrial, commercial and residential developers who have plans for future expansion in the area, (b) new construction of like facilities in the surrounding area, and (c) studies of overall southern California growth based on past experience in land utilization. The different information obtained through these sources must then be used to arrive at estimates of present and future values. The report does not indicate how these different sources of information are weighted in arriving at the estimates.

The property value will increase with time because of the increase in the productivity of the overall economy. For residential, commercial and public property an average annual rate of 2.6% was assumed for the first fifty years. This rate was reduced to 1.3% for the last fifty years because of the uncertainties associated with estimates so far in the future. For industrial property the rates used were 3% and 1.5% respectively. No increases were associated with channels, highways, railroads or agriculture, basically because it is difficult to predict their increase in productivity. We note, however, that the future development of the area depends heavily on an efficient transportation system, and it can be expected that with increases in population density, the productivity of transportation will also increase. Based on the above estimates an average future value of each piece of property can be obtained. This value will be quite sensitive to the increase in productivity used as will be illustrated in Appendix C on the Day project. For the Newhall project the accuracy of these estimates is not very crucial since it is used only in calculating damage reduction that makes up about 12% of the total benefits.

Estimates of the value of the 2653 acres of enhanced land are presented in Table B.5. Without the project, the land is expected to be used for agriculture or remain vacant. The price of the land in that case is given in the first column and no increase over time is assumed. With the project, the price of the land is expected to substantially increase during the lifetime of the project. Annual increases for different periods are given in the table. Fig. B.7 compares the increase in land values given in Table B.5 with the increase in the productivity of the economy using an exponential growth of 2.6% for the first fifty years and 1.3% for the last fifty years. This will be further discussed in the section on land enhancement benefits.

Table B.5

ESTIMATED VALUE OF LAND WITH AND WITHOUT THE PROJECT IN DOLLARS PER ACRE

	Price Without the Project	With Project			
		Price in 1975	Annual Increase in Value		
			1976-1995	1995-2005	2005-2075
Santa Clara River	1,000	14,000	1,500	1,000	500
Sand and Iron Canyon	1,000	11,000	1,500	1,000	500
South Fork of Santa Clara River	3,000	16,000	1,500	1,000	500
Placerita Creek	2,000	15,000	1,500	1,000	500
Newhall Creek	2,000	12,000	1,500	1,000	500

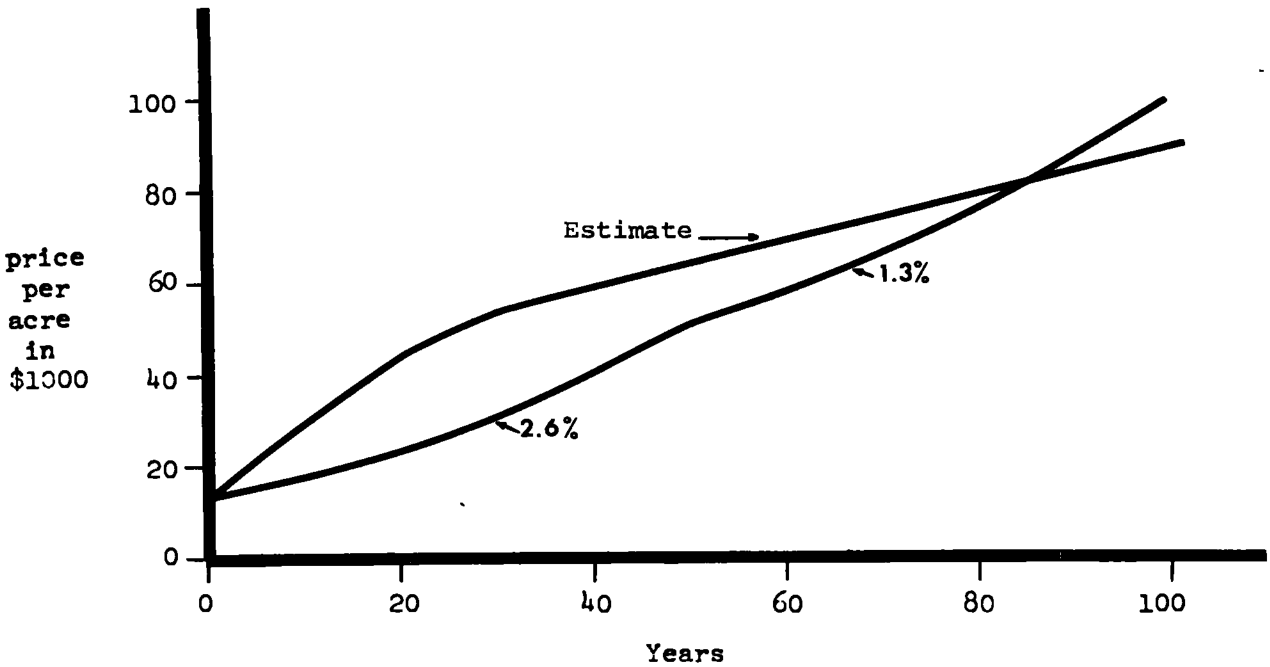


Figure B.7

INCREASE IN PRICE PER ACRE IN SANTA CLARA RIVER AREA

VI. THE BENEFITS DUE TO THE PROJECT

The benefits of the Newhall, Saugus and Vicinity project can be divided in three categories: (a) land enhancement benefits, (b) flood damage reduction and (c) adverse effect on water supply.

The estimates obtained for the annual benefits are:

Land Enhancement Benefits	$6,679,000
Flood Damage Reduction	938,000
Adverse Effect on Water Supply	-37,000
Total	$7,580,000

1. Land Enhancement Benefits.

The land enhancement benefits were obtained as the difference in the value of the land before and after protection. This was shown in Table B.5 where the land values for the different areas were estimated for 1975, project-year one, and an increase of $1500, $1000 and $500 per year was assumed for the indicated time periods. The enhanced land is expected to fully develop in 5 to 10 years, starting in 1975, and this newly developed land together with the increase in value results in a non-uniform stream of land value additions. The increases in value are obtained from Table B.5 and Fig. B.8 describes the total increase in value for the enhanced land in Santa Clara River. The total enhanced land of 800 acres will be fully developed in 10 years at a constant rate of 80 acres per year. Thus, the slope of the straight line in the first 10 years is $240,000 per year and this includes the increase in value plus the increase in total land developed. After year 10 the only annual increase is that of $1500 per acre; subsequently, this rate is reduced to $1000 and then to $500 per acre as indicated in Table B.5.

The average annual benefits due to land enhancement are obtained by transforming the non-uniform increases into an equivalent series of uniform increases. This uniform series can be determined by first obtaining the present worth and then multiplying it by the capital recovery factor.

In the report two interest rates were used. First, present worth was calculated using the interest rate of 4 5/8%, and then the capital recovery factor was obtained by using 7%. This capital recovery factor was applied to obtain

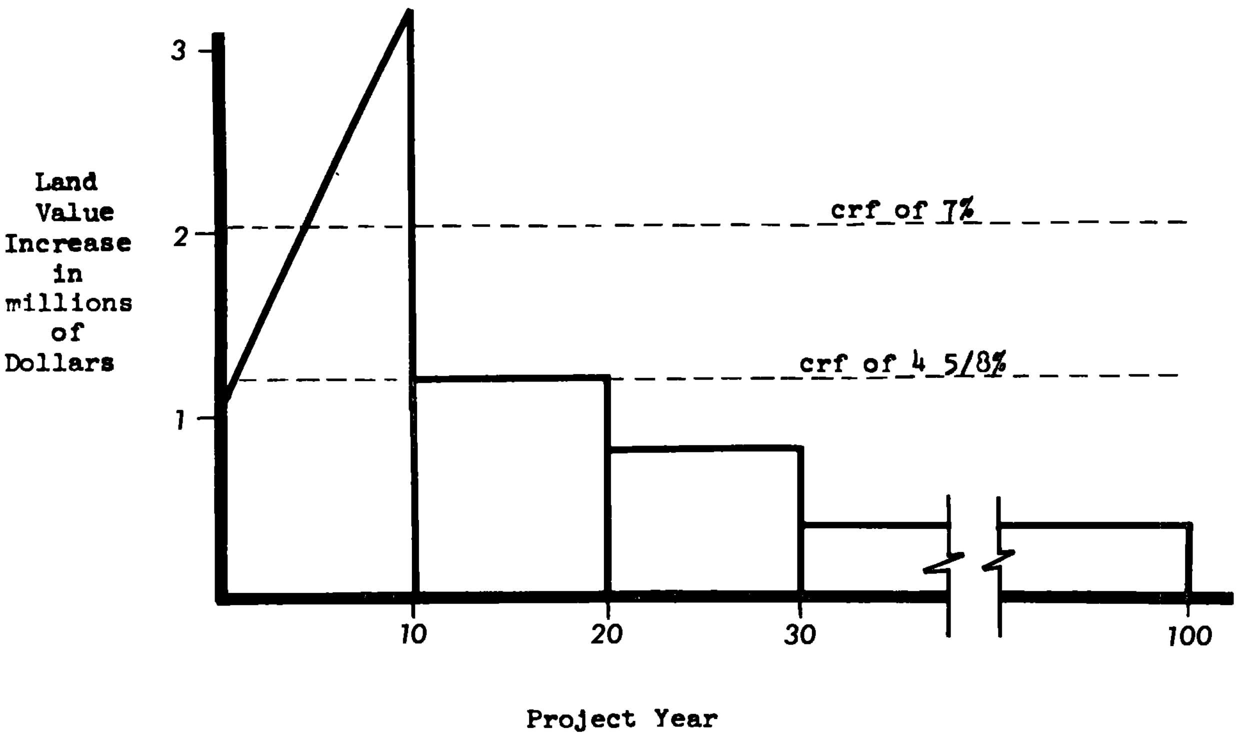


Figure B.8

BENEFITS FROM 800 ACRES OF ENHANCED LAND
AT SANTA CLARA RIVER

the equivalent uniform annual series. For Santa Clara, this results in average annual benefit of $2,040,000. Using a capital recovery factor based on 4 5/8% would have resulted in average annual benefits of $1,200,000. The land enhancement benefits for each overflow area are given in Table B.6. The total land enhancement benefits are 6.7 million. This number depends heavily on the use of a capital recovery factor based on 7%; using 4 5/8% instead to obtain the equivalent uniform annual series results in substantially lower benefits. Similarly, the average annual benefits per acre are expected to decrease from about $2,500 to $1,500 and the total benefits by about three million dollars for the two alternative interest rates discussed. Although the appropriate discount rate to be used in evaluating a project for flood control may be debatable, it appears logical to use the same discount rate for all aspects of that project. The reason for using at one point of the calculation one interest rate and at another point a second is not clear.

As was demonstrated in Chapter IV of Part One, the land enhancement benefits should be smaller than the total damages prevented in the enhanced area. This implies that the total damages prevented to the enhanced land should be greater than 6.7 million. For the Santa Clara River overflow area, this means that per acre the damages reduced should be greater than the land enhancement benefits of $2,550 per acre. Comparing this with the damage reduction of $270 per acre for land that would develop without the project (Table B.6), it can be concluded that the damage reduction in the enhanced land must be 9.5 times that of the non-enhanced land. Residual damages were not subtracted explicitly. Either they were included in estimating the price of the land, or they were neglected as being small. For the property that would develop without the project, the residual damages amounted to about 9% of the total. Assuming that the same percentage of 9% applies to the enhanced land, a lower limit to the residual damages would be $600,000. Data on the reduced and residual damages for the enhanced land was not directly available to check the above limits.

A detailed comparison of the estimated land enhancement benefits and the expected reduced and residual damages on the enhanced property is of significance. It may, for instance, help in determining if the benefits included in the total are actually land enhancement benefits due to the flood control project, or if they include benefits due to other economic and environmental considerations. This situation

Table B.6.

LAND ENHANCEMENT BENEFITS

	Number of Acres Enhanced	Years to full Development	Average Annual Benefits: Total-crf 7%	Average Annual Benefits: Per Acre-crf 7%	Average Annual Benefits: Per Acre-crf 4 5/8%	Average Damages Per Acre w/o Project
Santa Clara River	800	10	2,040,000	2,550	1,500	270
Sand and Iron Canyon	425	10	1,012,000	2,380	1,430	225
Mint Canyon	0	N.A	N.A	N.A	N.A	1370
South Fork of Santa Clara River	1245	10	3,170,000	2,550	1,560	355
Placerita Creek	160	10	407,000	2,550	1,560	350
Newhall Creek	23	5	50,000	2,170	1,560	670
Total	2653		6,679,000			

is explained in detail in Chapter IV of Part One. It is of special concern here because the choice between enhanced land and non-enhanced land is based on zoning regulations. If these zoning regulations are based on the same economic principles as those used in proper project evaluation, there should be no problem. This, however, may not be the case. Furthermore, the value of the enhanced land increases differently than the non-enhanced land as indicated in Fig. B.7 and if this difference is real, it may indicate the influence of other economic or environmental factors than those of flood control.

2. Damage Reduction.

The reduction in damages is determined by the difference between the total expected damages that would occur without the project, and the associated non-preventable damages with the project. The total expected damages without the project are obtained by determining the damage-frequency curve for each overflow area and by summing the total expected cost for each area. A typical damage-frequency curve is given in Fig. B.9, where the vertical axis gives the damage in millions of dollars for the average future development and the horizontal axis the percentage chance that the given damages are equaled or exceeded. The area between the two curves gives the expected annual reduction in damages for the particular overflow area. A more detailed description of the manner in which the damage-frequency curves are obtained is given in the Appendix C for the Day project.

The non-preventable damage-frequency curve is obtained by a downward shift of the part of the damage-frequency curve to the left of the frequency for which the project was designed. The extent of the downward shift depends on the type of flood protection. For the Santa Clara River, one side is protected by a levee which may break when the design flood is exceeded. As a result the downward shift is small and similar to the drawn non-preventable damage curve in Fig. B.9. In all the other overflow areas box channels are used and for these the downward shift is continued until the non-preventable damages for the design flood are equal to zero, as indicated by the broken curve in the figure.

Land that will be enhanced with the project should not be included in the above calculations because inclusion would result in double counting. A more detailed explanation of this case is given in Chapter II, Part One. It is not clear from reviewing the report whether this land is excluded or not. In any case, the error that would be introduced by including it is small because without the project, the land use will be for agriculture, or it will be vacant. The

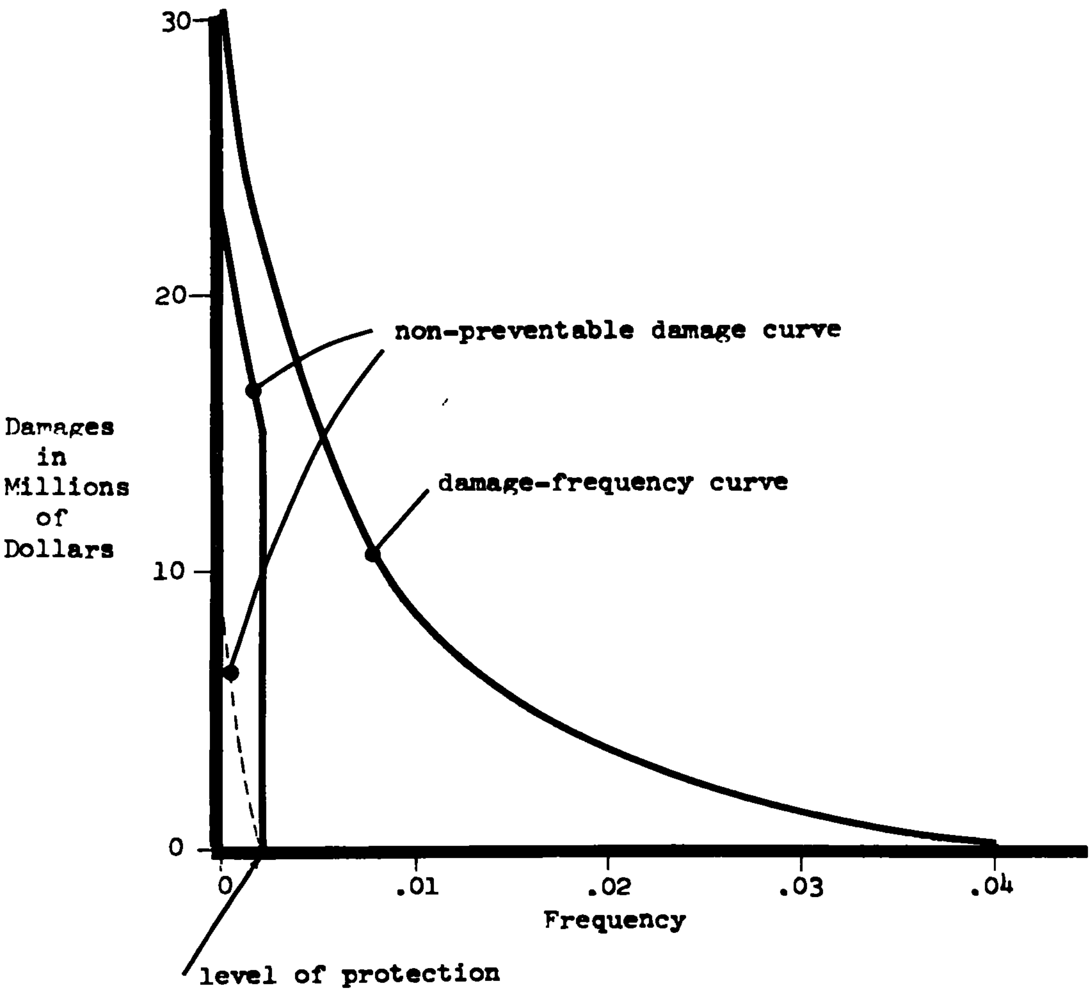


Figure B.9

THE DAMAGE FREQUENCY CURVES

expected damages are in both cases small. The reduction in average annual damages as a result of the recommended project for the Newhall, Saugus and Vicinity area is summarized in Table B.7. Without improvement the expected annual damages are $1,027,000, and with improvement $89,000 which equals an annual reduction of $938,000.

Table B.7

REDUCTIONS IN DAMAGES UNDER AVERAGE FUTURE CONDITIONS OF DEVELOPMENT

	Average Annual Damages		Average Annual Reduction in Damages
	Without Improvement	With Improvement	
Santa Clara River	242,000	42,000	200,000
Sand and Iron Canyons	9,000	1,000	8,000
Mint Canyon	206,000	6,000	200,000
South Fork of the Santa Clara River	190,000	20,000	170,000
Placerita River	198,000	8,000	190,000
Newhall Creek	182,000	12,000	170,000
Total	1,027,000	89,000	938,000

3. Adverse Effect on Water Supply

A concrete lined channel along Placerita Creek adversely affects the ground water supply. About 525 acre-feet, valued at $70 per acre-foot, will be lost resulting in a total disbenefit of $37,000. The additional cost of an earth-bottom channel is, however, larger than the loss.

APPENDIX C

DESCRIPTION AND ANALYSIS OF DAY, EAST ETIWANDA, SAN SEVAINE CREEKS

I. DESCRIPTION OF THE PROJECT AREA

The project considers the drainage area of the Day, East Etiwanda, and San Sevaine Creeks and their tributaries. These creeks are all tributaries to the Santa Ana River system which is within the South Coastal Hydrologic Subregion. A location map of the vicinity of the drainage area covered by this study is presented in Fig. C.1. The Day, East Etiwanda and San Sevaine Creeks drainage area comprises about 90 square miles of which almost 20% is mountainous terrain. The remaining area is in a valley formed by a broad alluvial cone along the base of the mountains. The area of the project analyzed is contained in the counties of San Bernardino and Riverside and is approximately rectangular in shape with a maximum north-south length of 16 miles and an east-west width of 9 miles. This area has a total developable acreage of about 48,000 acres, of which the 34,680 acres subject to inundation form the overflow area for the project. A symbolic representation of the land area is given in Fig. C.2.

The present (1968) and projected land uses are listed in Table C.1. according to the general categories of residential, other urban, agricultural and undeveloped land. The presently developed land amounts to 5,770 acres and an additional 21,510 acres is expected to develop with or without the project. This is shown in the second column of Table C.1. This level of full development is expected to be reached in 2026 and is given in the last column. The expected rate of

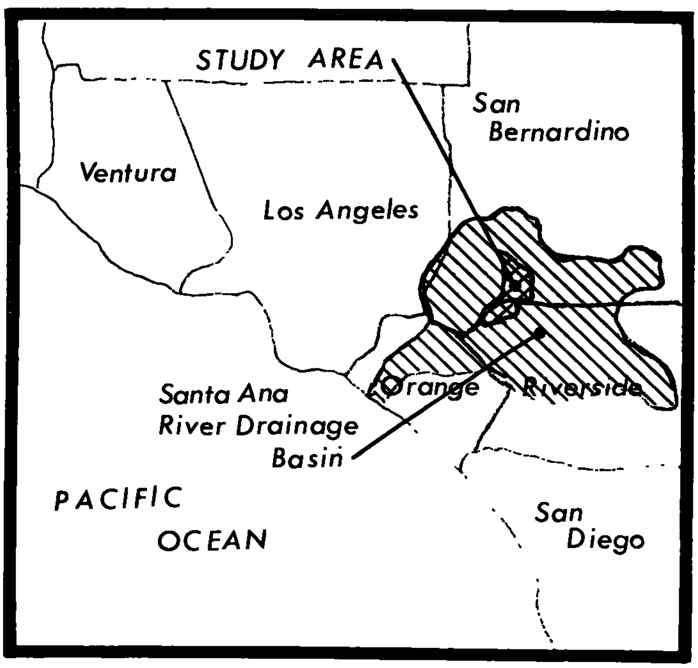


Figure C.1

LOCATION MAP DAY-EAST ETIWANDA STUDY AREA

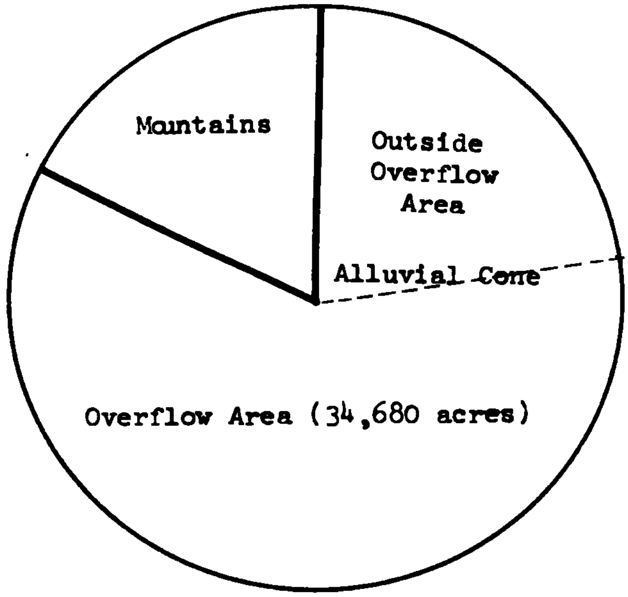


Figure C.2

SYMBOLIC REPRESENTATION OF LAND AREAS DISCUSSED IN DAY-EAST ETIWANDA REPORT (1968)

land development is graphically presented in Fig. C.3.

Both San Bernardino and Riverside Counties consider flood hazards in granting permits to construct residential tracts, but neither county requires flood protection beyond that of roughly a 10-year storm. It is assumed that developers can provide this level of flood protection and still remain competitive. Industrial and commercial firms are cautioned as to possible flood dangers in the area but are not prohibited from developing the area without providing protection.

Transportation facilities available to the area are excellent. Major rail, air and highway services are readily available. Three transcontinental railroads traverse the study area. Ontario Airport is three miles from the area and is being developed into a major component of the Los Angeles area air transport system. The area is crossed by Interstate 10 and U.S. Highway 60 in an east-west direction and is twelve miles from U.S. Highway 395, a north-south highway. In

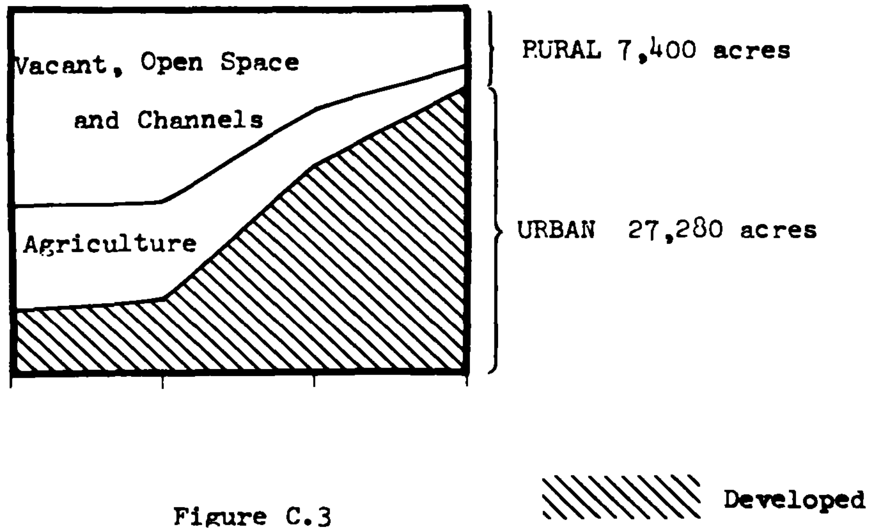


Figure C.3

PAST, PRESENT AND PROJECTED LAND USE:
DAY, EAST ETIWANDA AND VICINITY 1968-2026

Table C.1

PRESENT AND PROJECTED LAND USE IN DAY,
EAST ETIWANDA, SAN SEVAINE CREEKS OVERFLOW AREA

Land Use Category	1968	Additional Land to be Developed; both With and Without the Project	Ultimate Land Use (2026)
Residential	1,510	+ 8,810	10,320
Other Urban Use	4,260	+12,700	16,960
Total Urban	5,770	+21,510	27,280
Agricultural	10,180	- 8,150	2,030
Other Undeveloped	18,730	-13,360	5,370
Total Rural	28,910	-21,510	7,400
Total Land	34,680	0	34,680

addition three new freeways which have either been authorized or proposed will run through the area. Water now available together with water to be furnished from northern California is considered adequate to meet the needs of the area until about 1990. Similarly electric power will be available to meet power requirements under ultimate development.

II. ALTERNATIVE FLOOD CONTROL MEASURES

1. Non-Structural Alternatives

The nature of the overflow area is such that flood zoning would be of small value. The entire area would probably have to be zoned from development because of the wide areas subject to overflow and the erratic courses that the streams are capable of developing. The reason for this is the highly erosive soil conditions that subject streams to blockage by debris deposits. For similar reasons benefits from flood proofing are uncertain because of the erratic nature of the water courses. Elevation pads were considered as the cheapest method of flood proofing, and their annual cost was estimated at $1,450,000. The degree of protection from such measures is not indicated, but it was stated that the level of protection would be far below that of the proposed project, which would cost $2,689,000 per year.

2. Structural Alternatives

The nature of the terrain and flows indicates that consideration should be given to flood control measures consisting of channel improvements in combination with debris basins or barrier structures. Based on preliminary Corps of Engineers studies the plan to combine channel improvements and barrier dams was rejected because this solution would not provide positive control for collecting flows along the entire front and directing them to the single debris basin. Another plan which would use the individual stream basins as detention basins was rejected because the steep topography at the basin sites would require excessively high embankments to provide necessary storage.

In developing the recommended plan involving channel improvements and debris basins, consideration was given to various types and sizes of channels, ground water conditions and recharge areas, and debris potential and methods of its storage and removal. In general, rectangular concrete channels with debris basins were selected, and chosen so as to maintain depressed channels within existing grade limitations.

The recommended plan comprises 31.3 miles of channel improvement, seven debris basins, and two inlets and a levee in small canyons for diversion of flow into two debris basins. In general the alignment of the proposed channels will be along existing channels. The individual elements of the proposed project are listed in Table C.2. The construction is divided into eight units listed in Table C.3; these are not the same as the individual stream elements, but combine features of the project into packages that are logical to construct in a given time period. Separate plans and specifications will ultimately be provided for each of the recommended units. The timing sequence of the eight units is shown in Fig. C.4 together with the federal construction cost. Other than this, the report does not explicitly indicate that studies were made in regard to the timing or staging of the project.

Studies were also made of channel improvements that can control a 100-year, 50-year and 25-year flood.

Table C.2

INDIVIDUAL STREAM ELEMENT IMPROVEMENTS FOR
DAY, EAST ETIWANDA, SAN SEVAINE CREEKS

Individual Stream Elements	Channel Length (miles)	Debris Basin	Other Features
Day	6.0	1	
East Etiwanda	15.4	1	Inlet
Henderson	0.4	1	Diversion Levee
Morse	0.7	1	
San Sevaine	2.2	1	
Haruber	0.7	1	Inlet
Crawford	3.0	1	
Fontana	2.9		
Totals	31.3	7	2 Inlets 1 Levee

Table C.3

ESTIMATED FIRST COSTS OF IMPROVEMENTS UNDER RECOMMENDED PLAN
DAY, EAST ETIWANDA, AND SAN SEVAINE CREEKS

Individual Stream Element	Federal Costs	Non-Federal Costs	Total First Cost	Total Annual Operation and Maintenance Costs
Day	5,608,000	996,000	6,604,000	61,000
East Etiwanda	29,412,000	4,251,000	33,663,000	92,000
Henderson	358,000	53,000	411,000	6,700
Morse	527,000	113,000	640,000	11,400
San Sevaine	2,276,000	308,000	2,584,000	26,500
Hawker	708,000	88,000	796,000	10,000
Crawford	2,719,000	442,000	3,161,000	16,900
Fontana	2,658,000	400,000	3,058,000	8,500
Total	44,266,000	6,651,000	50,917,000	233,000

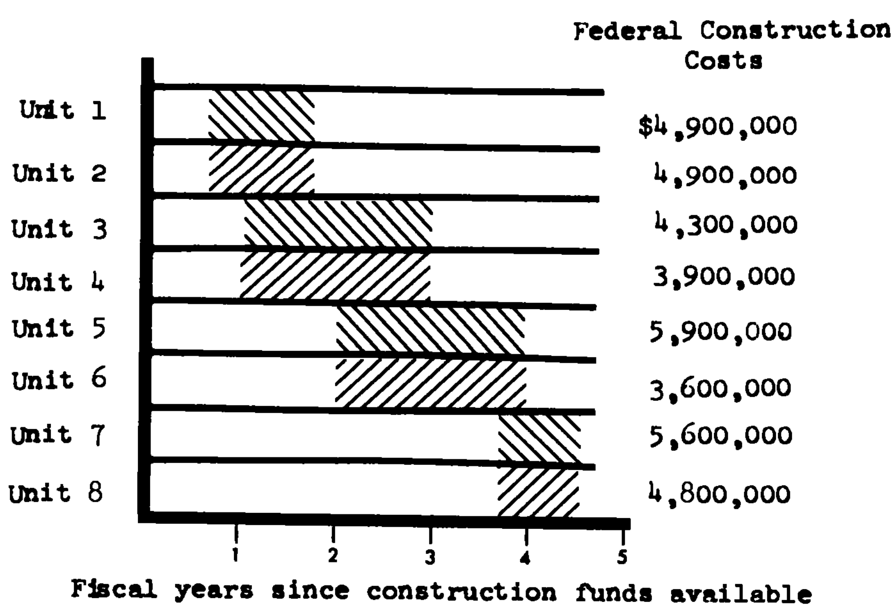


Figure C.4

RECOMMENDED CONSTRUCTION SCHEDULE FOR
DAY-EAST ETIWANDA FLOOD CONTROL WORKS

III. COST ESTIMATES

Detailed estimates were made of the costs of the recommended plan for construction as well as operation and maintenance. A summary of these estimates is given in Table C.3 for each stream element. It includes the federal, non-federal, the total first cost and the annual operation and maintenance cost. Remarks similar to the ones made in Appendix B apply here.

IV. HYDROLOGY

1. Design Floods

The general considerations in determining the standard project flood, the maximum probable flood and the debris storage requirements and spillway capacities are the same as the ones discussed in Appendix B, Section IV.

For the Day, East Etiwanda and San Sevaine area, the standard project storm was determined to be the thunderstorm of March 1943. The Hydrologic Engineering Center report, "Generalized Standard Project Rainfall Criteria for Southern California Coastal Streams" dated March, 1967 was used to compute the standard project flood (SPF) peak discharges. The maximum probable flood was determined using the U.S. Weather Bureau estimates of probable maximum precipitation. Adjustments were made for the size of individual drainage areas and precipitation-intensity patterns were selected to yield a maximum peak discharge. The peak discharges for the standard project flood and the maximum-probable flood at selected concentration points are listed in Table C.4.

Debris basins provide and maintain storage space to accomodate the debris expected in any single major flood. Their storage requirements were determined by (1) considering the information on debris inflow in the Los Angeles area, (2) comparing the debris-production characteristics of the drainage area with those of drainage areas producing a known quantity of debris, (3) the size of major floods, and (4) a field inspection of the area.

2. Frequency Analysis

The frequency analysis conducted in the Day, East Etiwanda, San Sevaine area is based on a 40 year record of stream flows near the mouth of Day Canyon. Assuming that the frequency-discharge relationship is log-normal in character, the data points for the peak discharges are plotted on log-normal probability paper using the formula

$$f = 100\,(n-0.3) / (t + 0.4)$$

Table C.4

PEAK DISCHARGES AT SELECTED CONCENTRATION POINTS IN DAY-EAST ETIWANDA DRAINAGE AREA

Concentration Points	Standard Project Flood (cfs)	Maximum Probable Flood (cfs)
Day Canyon	5500	15,500
East Etiwanda Canyon	3900	9,200
Morse Canyon	1600	4,100
Henderson Canyon	1400	3,500
San Sevaine Canyon	3000	7,700
Hawker Canyon	1100	3,300
Crawford Canyon	1400	3,700

where f is the plotted frequency, n is the rank of the flood in descending order and t is the number of years of record. The best fitting curve to these plotted positions was then drawn for the forty years of record for Day Creek, establishing its frequency-discharge relationship. Frequency-discharge relationships for East Etiwanda, San Sevaine and Crawford Creeks were then determined by using their standard project peak discharges and the frequency-discharge relationship established for Day Creek on the basis that (1) all standard project peak discharges have the same frequency, and (2) the frequency-discharge curves are parallel to one another. A composite curve was also obtained for East Etiwanda Creek at Foothill Boulevard by considering the network of streams above this point.

The basic assumption made here is that the different creeks and drainage basins are perfectly homogeneous. This assumption should be examined since the frequency relationships thus established form the basis for the economic analysis because in this case almost all benefits result from damage reduction.

As is clear from the above discussion, however, the accuracy of these discharge-frequency relationships is not necessarily very high. In case a more accurate relationship cannot be obtained, the sensitivity of the damage reduction to different estimates of the discharge-frequency curve should be determined in order to provide a basis for sound economic analysis.

V. ECONOMIC FORECAST FOR THE AREA

The forecast of land use in the area was again based to a large extent on the data obtained from the California Department of Water Resources and the Los Angeles Regional Transportation Study. No consistent data for land use over time exists for the area under consideration and county plans have not yet been completed. The area is expected to develop in the same way with or without the project. Land uses are estimated for the different areas and land use categories for years 1968, 1986, 2006 and 2026. Full development of the areas is reached in 2026 and therefore development here takes much longer than for the Newhall project. The growth rate between the years at which estimates are made is assumed to be constant.

The reason for anticipating the same development with and without the project is due to the low level of County-required protection and the need for land. Under these conditions it should be examined whether development of the flood plain without the project is economically justified, or if it is mostly due to ignorance of potential flood damages. In the latter case, justification must be provided for the investment of federal funds to protect against loss of property due to decisions based on ignorance, or a flood plain management plan should be developed which would prevent flood plain development based on irrational economic decision.

The value of the present property and that of property being developed at a future time is estimated in a manner similar to the one used for the Newhall project. The values are again increased based on the increased productivity of the economy after which an average future value is calculated. Because the damage reduction accounts for almost all benefits, and since these are roughly proportional to the average future value, it is of interest to show the sensitivity of the average future value to the assumed increase in productivity. Let d denote the rate of increase in productivity and α the discount rate. The variation of the average future value based on the rate d and discount rate α is given by

$$(\mathrm{crf};\alpha,\ 100)\ V_o \sum_{i=1}^{100} \left(\frac{1+d}{1+\alpha}\right)^{i-1} = (\mathrm{crf};\alpha,100)\ V_o \left(\frac{1+d}{\alpha-d}\right)\left\{1-\left(\frac{1+d}{1+\alpha}\right)^{100}\right\} \tag{C.1}$$

where V_o is the initial value of the land and crf(α;100) is the capital recovery factor for discount rate α and period of 100 years.

This is plotted in Fig. C.5 as a function of the increase in productivity and for discount rates of 4.5% and 7%. It is clear from this that the estimate of the damages will be quite sensitive to the choice of the rate of increase in productivity.

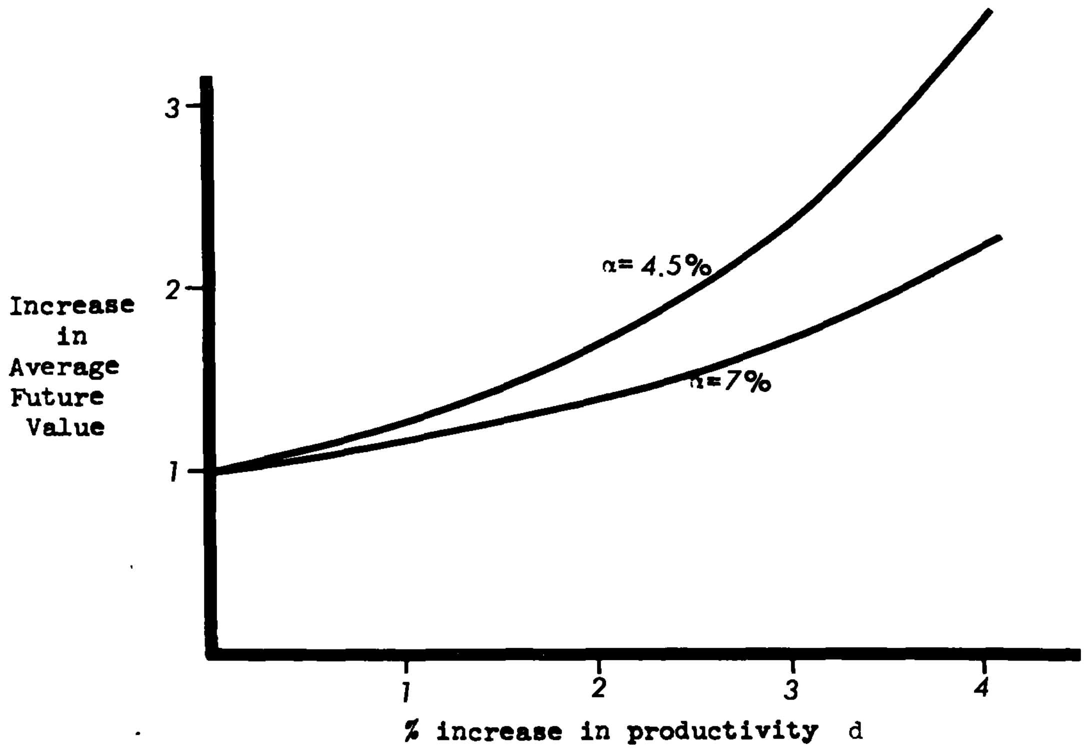


Figure C.5

VARIATION OF AVERAGE FUTURE VALUE WITH PRODUCTIVITY AND INTEREST RATE

VI. THE BENEFITS DUE TO THE PROJECT

The benefits from the Day project result from four different sources. The annual benefits for each of these are estimated as follows:

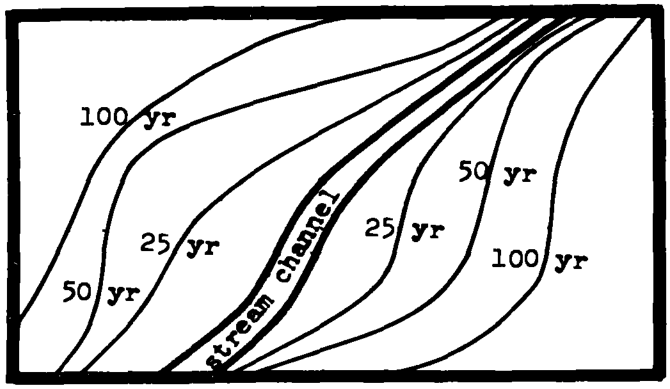
Reduced Flood Damages	$9,233,000
Area Employment Benefits	206,000
Savings from Maintenance and Operation	24,000
Advance Replacement of Bridges	19,000
Total	$9,482,000

Thus, more than 97% of the benefits are due to the reduction in flood damages.

1. Damage Reduction

A general description of the evaluation of the reduction in damages due to the project was given in Appendix B. Here we will describe in more detail the manner in which the damage-frequency curve for each overflow area is obtained. For a particular peak discharge, damages are estimated on the basis of the depth of the water in the different areas. This depth is determined by first drawing the flood level countour as given in Fig. C.6a and then deriving the depth of the water in the various parts from the profile of the flood plain as illustrated in Fig. C.6b. The relationships between estimated damages and depth of water are determined by the Local Corps District on the basis of historical data for each land use category and is given as a percentage of the property value. It is assumed that the depth of water at the time of the peak is sufficient to estimate the damages and that the time profile of the water depth is not needed. This assumption is a good approximation if the flood characteristics in the area under consideration are very similar to those in areas from which the data for the damage-depth relationship were obtained. It is not clear, however, if such a comparison between areas is normally undertaken. Furthermore, the assumption is made that the damages as a percentage of the property value will remain constant over the 100-year period. That is, the increase of damages over time is proportional to the increase of property value. This assumption should be further studied since cases can be conceived where this is not expected to be the case.

The expected annual damages are obtained by first calculating the average future value for property in the area that belongs to the same land use category and also has the same elevation. This average future value is obtained in



a. Overflow Area

b. Flood Depth

Figure C.6

OVERFLOW AREAS AND DEPTHS FOR HYPOTHETICAL FLOODS

order to account both for future land developments and for increases in value of the property over time. For a particular flood, the average future value is then multiplied by the ratio of damages to property value associated with the depth of water and the land use category.

The sum of all damages so obtained for property in the overflow area together with the frequency of the flood considered give one point on the damage-frequency curve. For the Day project, these damage estimates were made for the standard project flood which is a 200-year flood, the 100-year flood, 50-year and 25-year. In addition, the frequency of the no damage flood is obtained as well as an estimate of the damages for the maximum probable flood which has a frequency close to zero. Based on this, the damage-frequency curve is drawn as well as the curve for the non-preventable damages. The result for one of the overflow areas was presented in Fig. B.9. The area under the damage-frequency curve is equal to the expected annual damages for the overflow area.

The proper expression for the average future value can be derived by considering the following expression for the average annual damages,

$$D = (crf;\alpha,100)\sum_{\ell=1}^{L}\sum_{i=i_o}^{100}\sum_{k=1}^{K}\frac{1}{(1+\alpha)^{i-1}}\,p(k)r(\ell,k)(1+d)^{i-1}\,V(1,\ell) \qquad (C.2)$$

where

- $V(1,\ell)$ is the value of property ℓ in year 1
- i is the year and i_o the first year of development
- d is the annual increase in productivity
- L is the total number of properties considered
- $r(\ell,k)$ is the ratio between damages and property value for property ℓ and flood k
- $p(k)$ is the probability of flood k
- K is the maximum number of different floods considered
- α is the discount rate

In practice the calculation is performed differently by first of all interchanging the summation.

$$D = \sum_{k=1}^{K} p(k)\left\{\sum_{\ell=1}^{L} r(\ell,k)\left[(crf;\alpha,100)\sum_{i=i_o}^{I} V(1,\ell)\left(\frac{1+d}{1+\alpha}\right)^{i-1}\right]\right\} \qquad (C.3)$$

The expression in square brackets represents the average future value of property ℓ. To simplify its calculation, the exponential growth is approximated by a linear segment for each ten-year period and the value at the end of each ten-year period is multiplied by a factor obtained from a table specially prepared for this purpose. By summing the products, the average future value is obtained.

2. Other Benefits

Construction and maintenance labor costs that would relieve the unemployment rolls are allowed as benefits accruing to the project. Based on studies made by the San Francisco District, Corps of Engineers, it was assumed that 10% of the project construction cost is used for labor obtained from unemployment rolls. The average annual benefits are then $178,000. Studies made by the Los Angeles District indicate that 55% of maintenance and operation labor cost also comes from unemployment rolls. This benefit must be decreased to zero over a 20-year period and the resulting average annual equivalent value is estimated at $28,000.

The estimated average annual cost for maintenance and operation on the proposed replacements was not reduced by the existing average annual maintenance costs of $24,000. These are therefore included as benefits. Similarly, in calculating the cost of replacing bridges as required by the project, the longer lifetime of the new bridges was not accounted for, but it is included as a benefit of $19,000.

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY *(Corporate author)* INTASA 1030 Curtis Aaenue, Menlo Park, Calif. 94025	2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP

3 REPORT TITLE

Preliminary Review and Analysis of Flood Control Project Evaluation Procedures

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final

5 AUTHOR(S) *(Last name, first name, initial)*

Arvanitidis, N. V.; Lind, R. L.; Rosing, J.; Johnson, G. P.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
July 1969	123	

8a CONTRACT OR GRANT NO DACW07-70-C-0050 b PROJECT NO c d	9a ORIGINATOR'S REPORT NUMBER(S) IRR 70-01 9b OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* IWR 70-3

10 AVAILABILITY/LIMITATION NOTICES

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY Institute for Water Resources Dept. of the Army, Corps of Engineers 206 N. Wash. St., Alexandria, Va. 22314

13 ABSTRACT

This study clarifies the economic consequences and effects of programs designed to protect or otherwise manage flood plains. A firm basis is established to appropriately distinguish between the source of change of a flood plain development from its economic effects. Alternative techniques for the measurement of benefits is presented. The study makes the following major findings:

1. Where the development in the flood plain will be the same with and without the project, benefits attributable to the project will equal total damages reduced.

2. Where there is project induced growth, the benefits attributable to the project are equal to the net increase in productivity of the economy due to the relocation of activities both inside and outside the flood plain.

3. Benefits from project induced growth (so-called "land enhancement" benefits) can be measured by the difference between the net income (profits) of activities which move into the flood plain with protection and the net income they could earn outside the flood plain.

4. In the absence of direct observation of change in net income, benefits from project induced growth can be measured in terms of simulating damages reduced to new activities that would locate in the flood plain with protection.

DD FORM 1 JAN 64 1473

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Flood Control						
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Economic Rent						
Land Values						
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