A COMPUTER SIMULATION MODEL FOR FLOOD PLAIN DEVELOPMENT

PART II: MODEL DESCRIPTION AND APPLICATIONS

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A COMPUTER SIMULATION MODEL FOR FLOOD PLAIN DEVELOPMENT
Part II: Model Description and Applications

A Report Submitted to the

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FOREWORD

A. Purpose

This research by INTASA, a private consulting firm specializing in planning and analysis of large-scale systems, has been directed toward improving the Corps' approach to planning and benefit measurement procedures, and toward providing practical analysis methods for Flood Plain Management (FPM) programs. The entire effort has been orientated toward development of a computer simulation model (SIMULATOR) encompassing improvements in planning and evaluation concepts, and constituting a practical tool to aid in the analysis of FPM alternatives. Part I of this effort, IWR Report 72-1, concentrated on improving benefit measurement concepts and on investigating techniques appropriate for land use analysis as needed by the Corps to perform FPM studies. This report describes the entire simulation method developed and offers a case study demonstrating the computer program's ability to address practical situations. This case study deals with the analysis of Reach 13 in the Connecticut River Basin.

B. The SIMULATOR in Perspective

1. Flood Plain Management

Flood Plain Management refers to the overall task of initiating, recommending and implementing programs that will assure wise use of flood plain lands. Present Corps procedures require National Economic Efficiency (NEE) criteria for determining FPM alternatives with the greatest potential. These criteria are comprised of two components: NEE benefits and costs associated with realizing these benefits. For a particular FPM alternative, the benefits are determined as the difference between benefits derived from the impact of the alternative on existing and likely future land utilization and benefits derived from the FPM alternative that is likely to prevail without the Corps involvement. This latter alternative is referred to as the "without" condition. Similarly, the cost associated with these benefits refers to the difference in cost between a particular FPM alternative and cost of the "without" condition. One NEE criterion for measuring an alternative's economic efficiency is the ratio of the above benefits and costs. Another, used for selecting among alternatives, is the net NEE benefits—given by the difference of the above benefits and costs.

FPM alternatives include a wide range of actions that can be taken to improve the utilization of flood plain lands: alternative structural flood control projects is one example, while flood plain regulation through zoning, flood proofing, and flood warning are others historically used less frequently. One or a combination of such alternative actions are normally referred to as elements of a FPM program or plan. The above actions have one characteristic in common: they include benefits that result as a direct consequence of differences in land use with and without the specific FPM alternative.

2. Role of the SIMULATOR in Program Analysis

The primary goal guiding this research has been the development of a practical tool that can be used to evaluate NEE benefits resulting from the simulation of alternative levels of flood protection accomplished through structural flood control. Realization that key to proper evaluation is the ability to analyze the effect of various land use plans on these benefits led to the present version of the SIMULATOR; a model that performs benefit evaluations through the simulation of alternatives consisting of: (1) a level of flood protection, and (2) a land use plan corresponding to that level of protection.

These land use plans are normally difficult to specify without some type of analysis of the flood hazard. Thus, land use plans, as provided by local planning agencies, are often incomplete and may require modifications in order to cover the range of flood protection alternatives considered; or they are inadequately specified in terms of location of economic activities over available land and in terms of the rates at which development is forecasted. In the first case, the Corps planner, through interaction with the local planner, assists in modifying land use plans which better correspond to the levels of flood protection under consideration; performed properly, this modification will result in a better estimate of NEE benefits. Similarly, in the second case, the Corps planner provides assistance in adequately determining activity locations and rates of future growth. Thus, the SIMULATOR has been designed to guide the planner in both: modification of land use plans to better correspond to the levels of flood protection analyzed; and specification of plans so that they can be properly evaluated.

The capability of the SIMULATOR to rapidly analyze alternative land uses is the key feature for accomplishing the above, thus making it a useful FPM tool. In its present form, the program analyzes FPM plans encompassing structural flood control and zoning regulations, while it has the inherent capability for analyzing other programs as they influence present and future land utilization.

The basic land use pattern that the SIMULATOR is designed to analyze is: changing vacant or agricultural land to more intense use through the occupancy of this land by higher order activities such as residential, industrial and commercial.

C. Main Parts and Key Attributes

The SIMULATOR is an integrated computer model consisting of three major parts:

1. Calculation of flood damages and economic rent components. Economic rent components include fixed area development cost, site development cost, transportation cost, amenity value and social effect. These calculations are performed either on the basis of specifying economic activities in an aggregate manner (residential housing, local commercial, etc.) or in a detailed manner (single family dwellings, apartments, etc.).

2. Allocation of land use requirements over time based on:

- Land use plans at some future point in time within or beyond the social planning horizon.
- A sequence of development provided as input for parts of the study area that have fixed development cost.
- Present values of net economic rents.

3. Calculation of NEE benefits based on locational advantage and damage reduction. Locational advantage is estimated using three different methods:

- Difference in economic rents net of flood damages.
- Difference in land values and flood damages.
- A combination of the above methods.

The SIMULATOR is characterized by the following key attributes:

1. Rapidly investigates land use development patterns and the effect of such patterns on NEE benefits. Alternative land use patterns are easily generated by changing the sequence of subarea development, by changing ultimate land use plans, and by imposing zoning regulations.

2. Calculates NEE benefits using three methods, each having different data requirements. NEE benefits based on net economic rent differences is the conceptually proper measure but requires more data than the other two. Using differences in land values as a proxy for differences in economic rent requires the least data but the market imperfections can be substantial. Combining the above is a compromise between amount of data required and desired accuracy.

3. Uses varying data requirements depending on desired accuracy. The first two main parts of the program can be performed at two levels of detail: the first level uses limited data and aggregate land use information; and the second level uses more detailed data and specific land use information. The goal of the first level is to limit the scope of the analysis to aspects that affect NEE benefits. Thus, the second level normally encompasses a much narrower scope than the first, addressing only aspects of the study that affect benefits.

4. Easily performs sensitivity studies by changing assumptions on key parameters or forecasts. These can be used to aid the planner in data collection efforts and to facilitate review procedures when key parameters are in doubt.

5. Is designed to diagnose inconsistencies in input data, to enable easy changes in data, to enable access to printout that provides useful information other than final evaluations, and, most important, to facilitate extensions of the program in order to accomodate specific situations.

D. Assessment

The present version of the SIMULATOR is a practical analysis tool that can significantly aid the Corps of Engineers in improving the quality of evaluations of FPM programs encompassing flood plain zoning and structural measures. Due to the influence of different land use patterns in water resource development in general, and FPM in particular, as is now widely recognized, the most significant aspect of the program for the Corps planner is its ability to delineate the effect of these patterns on NEE benefits.

There are several major areas where additional research is needed:

1. Development of a set of models for the assessment of amenity values and social effects. The present version of the SIMULATOR does not contain such models.

2. Extensions to account for a wider range of FPM alternatives: flood proofing, flood insurance, flood warning, etc.

3. Development of more detailed subroutines to account for a variety of local situations. Examples are: detailed agricultural models for rural areas; and a wider range of economic activities for urban areas.

4. Extension of the transportation model to represent: modal split, public transport, and multiple destination networks.

5. Interface of the SIMULATOR with other Corps programs in such areas as hydrology and land use.

6. Development of programming support for maintaining and updating the SIMULATOR.

7. Development of simplified cost estimating procedures for various FPM programs.

E. Status

The SIMULATOR has been tested in Reach 13 of the Connecticut River Basin and the results are shown in this report. The program is operational and is currently being applied to the Papillion Creek in Omaha, Nebraska.

INTASA is presently working on small program modifications and documentation. This effort will be completed by the end of February 1973 and will produce the following documents:

1. Planner's Manual describing how to effectively apply the SIMULATOR.

2. Input Data Collection Guide describing procedures to be followed in collecting field data for the two different levels of analysis. Standard data sources will also be documented.

3. Basic User's Manual describing the procedures to be followed in executing the program and preparation of input data cards.

4. Program Manual describing the program and its logic in detail. This document will be addressed to computer programmers.

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ACKNOWLEDGEMENTS

In the course of the project staff members of the Army Corps of Engineers participated in the study by critically reviewing and commenting on the structure and results of the flood plain management SIMULATOR. Mr. Ed Cohn of the Plan Formulation and Evaluation Branch, Planning Division of the Office of the Chief of Engineers, continued his active participation by providing valuable suggestions in finalizing and implementing the program. Mr. William J. Donovan, Chief of Plan Formulation and Evaluation Branch of the Planning Division, Office of the Chief of Engineers was most cooperative in contractual and administrative matters. Messrs. Larry Bergen, Mike McArdle and Steve Rubin of the New England Division carried much of the responsibility for data gathering during the testing of the program. Their experience with flood control projects was very valuable in setting up the study and in interpreting the results. We express our appreciation and thanks to them all and to many others that we have not mentioned by name but whose contributions and cooperation we received.

CONTRIBUTIONS OF INTASA STAFF

This is the third and final report documenting INTASA's efforts to develop a flood plain management tool over a three year period. The two previous reports dealt with conceptual benefit measurement issues and with the design of the simulation program. This report addresses the program and its implementation. Contributions were made by many of INTASA's staff members throughout the development of concepts, computer programs and testing of the SIMULATOR.

Dr. J. Rosing led the project team during this last phase with the responsibility of developing a program consistent with the conceptual framework previously developed. Drs. J. Rosing and D.P. Petropoulos jointly carried the responsibility for integrating the various subroutines and for computerization of the land use, transportation and social environment models. Drs. C.H. Jolissaint and J.L. Poage were responsible for the site development cost and flood damage subroutines. Dr. N.V. Arvanitidis' supervisory role consisted of interfacing the current effort with the conceptual framework developed under his leadership. Key concepts and ideas in the model are also due to a number of other INTASA associates: Prof. R.C. Lind made significant contributions in relation to benefit measurement; Prof. D.G. Luenberger contributed toward the definition of the affected area and theoretical issues related to the uniqueness of optimally allocating economic activities; Prof. L. Ortolano contributed to the delineation of issues related to the social environment and physical amenity models. It has taken the individual and collective contributions of all these professionals to complete and implement a tool that should prove to be of great value to the Corps planner.

INTASA, Inc.

Nicolaos V. Arvanitidis

N.V. Arvanitidis, President

GLOSSARY OF TERMS

Term	Definition
Activity Intensification	Results when FPM increases the economic rent of an activity without a change in the activity's location.
Aggregate Activity Type	A group of detailed activities that traditionally locate together in the same vicinity: residential housing, local commercial, public buildings, etc.
Allocation at Level 1	Locates aggregate activities to subareas at the end of each allocation period. This location is based on preferences established by economic rents and is constrained by land uses reserved in each subarea through the ultimate land utilization.
Allocation at Level 2	Locates detailed activities to parcels at the end of each evaluation period. This location is performed on the basis of a pre-established sequence of parcel development and is restrained by Allocation at Level 1.
Allocation Periods	Divide the planning horizon into time intervals. At the end of these intervals, additional land use requirements are specified.
Amenity Value	Measures the value of physical amenities of a site excluding project related improvements.

Damage Reduction — Measures the benefits accruing to existing activities and future activities which locate the same with and without protection.

Detailed Activity Type — An economic activity specified at the level of detail necessary for desired accuracy in the evaluation of benefits: single family dwellings, apartments, two-story with basement, etc.

Dummy Locations — Represent areas outside the study area that are affected but are excluded from analysis because they are far away, widely dispersed, difficult to identify, or because data is difficult to collect.

Economic Growth Areas — Are formed by dividing the study area into areas which are expected to develop as integrated units, quite independently from the rest of the area. When two economic growth areas are assumed to develop independently from one another, alternative locations for an activity are only considered within the same economic growth area.

Economic Rent — Is associated with a combination of economic activity and location. It represents annual net earnings to both economic activities and land owners excluding average annual flood damages. According to this definition, economic rent is always larger than or equal to net earnings.

Evaluation Periods — Divide the planning horizon into time intervals for the purpose of evaluating annual benefits resulting from different rates of development.

Flood Plain Management (FPM) — Refers to development of programs for improving present and future utilization of flood plain lands. These programs generally include structural alternatives, flood plain warning, flood proofing, flood insurance and regulation through zoning. In this report, FPM is limited to analysis of structural alternatives and flood plain zoning.

Land Use Requirements — Exogenously derived acreage requirements by aggregate activity type at the end of each allocation period. These are given separately for each economic growth area.

Locational Advantage — Measures the difference in annual net earnings for an activity-land owner combination at two different locations.

Market Horizon — The time over which private decision makers discount future costs and earnings.

Net Earnings — Income minus costs. For activities such as housing and public buildings, income is represented by willingness to pay.

Net Economic Rent — Economic rent minus flood damages. Thus, net economic rent is a proxy for net earnings.

Parcels	Land areas that have uniform net economic rent; several parcels make up a subarea.
Planning Period	The time over which benefits are evaluated.
Private Discount Rate	Used by private decision makers to discount future costs and earnings.
Reach	A stretch along the river where the flood profiles are assumed parallel to the riverbed; on each reach, a single depth-frequence curve is used to characterize floods.
Site Development Cost	Measures the cost associated with site preparation, roads, foundations and trenches in a particular location.
SIMULATOR	The mathematical models and associated computer programs combined in a consistent procedure capable of calculating FPM programs as previously defined.
Social Discount Rate	Used for discounting future benefits and costs when evaluating a public project.
Social Environmental Effect	Measures the effect of neighboring land uses on the economic rent of an activity-site combination.

Social Planning Horizon — The time over which future benefits and costs attributed to a public project are discounted.

Structural Type — Represents residential houses of same structure and for which the net economic rent is the same.

Study Area — Is composed by the flood plain, the area in the proximity where changes in economic rent can be reasonably expected, and sites in the general region that may constitute reasonable alternatives to flood plain location.

Subareas — Are areas projected to develop as units, reflect important differences related to the infrastructure of the region, and have an approximately uniform net economic rent. Subareas are usually composed of several parcels; they are generally either in or outside the flood plain.

Transportation Cost — Measures the operational transportation cost as affected by different locations.

Ultimate Land Use Plan — Gives for each subarea and aggregate activity type the land utilization at some point in time within or beyond the social planning horizon.

Zones — Areas where a component of economic rent or flood damage is uniform: site development zones, transportation zones, amenity zones, social environment zones, and flood damage zones. Thus, a parcel is also defined as an area given by the intersection of the above zones.

Chapter I

PROJECT SUMMARY

A. Background

In April 1970, INTASA submitted a final report, "Preliminary Review and Analysis of Flood Control Project Evaluation Procedures," to the Corps of Engineers under Contract No. DACW07-70-C-0050 (Ref. 1). That report described the results of a preliminary study dealing with important analytical issues related to the planning and evaluation of flood control projects. The study emphasized the use of analytical methods for evaluating flood protection benefits and recommended the development of a computerized model for project planning and evaluation. Specifically, it was recommended that the proposed model should be capable of performing sensitivity analysis with respect to crucial problem parameters and assumptions; should expedite the benefit evaluation part of project analysis; and should limit the data required for benefit estimation to the extent that such a limitation is possible.

In June 1970, a proposal was submitted to Mr. Robert M. Gidez, Assistant Chief, Planning Division, Civil Works Directorate, Office of Chief of Engineers, U.S. Army Corps of Engineers, to develop the computer simulation model in two major phases. The first phase, completed June 30, 1971 under Contract No. DACW07-71-C-0026, concentrated on establishing the analytical framework of the computer model. The findings and conclusions of that effort were presented in a report, "A Computer Simulation Model for Flood Plain Development, Part I: Land Use Planning and Benefit Evaluation" (Ref. 2). The second phase, completed June 30, 1972 under Contract No. DACW07-72-C-0012, concentrated on developing and testing the computer model. The description of that computer model, referred to as SIMULATOR, and the results obtained from implementation of the program on Reach 13 of the Connecticut River Basin are presented in this report, "A Computer Simulation Model for Flood Plain Development, Part II: Model Description and Applications."

B. Scope

The thrust of the initial scope of work was development of a computerized procedure for analysis of the effects resulting from different levels of flood protection. These levels of flood protection were to be achieved by structural flood control alternatives and the effects were to be measured in terms of National Economic Efficiency (NEE) benefits. Having recognized that these benefits are a direct consequence of land use patterns with and without protection, the scope was extended to allow for a closer examination of the impact of flood protection on present and future land utilization. Therefore, the present version of the SIMULATOR is designed to simulate the effects of levels of protection and corresponding land use plans on NEE benefits. Land use plans are often inadequately specified and, as a result, the scope was further extended to include additional features. With these additions, the program guides the planner in determining location of economic activities, and derives the allocation of these activities over time in cases where these are not specified. The basic land use environment simulated consists of replacing vacant and agricultural land by higher order activities such as residential, industrial, commercial, etc.

In addition, the initial scope of work included testing the program on three specific structural flood control projects. During analysis of Reach 13 of the Connecticut River Basin, it was mutually agreed to limit testing to a single project in order to perform a more comprehensive evaluation of the program's capabilities.

The tasks are divided into two major groups; (1) model and subroutine development, and (2) specific project analysis.

Model and subroutine development tasks:

(1) Development of mathematical models for measuring NEE benefits.

(2) Development of methods capable of delineating the study area so as to limit the geographic scope of the study and associated data requirements.

(3) Development of procedures for estimating land use requirements.

(4) Review and modification of methods currently used by the Corps of Engineers to estimate flood damages, and subsequent development of computerized procedures for estimating these damages based on flood characteristics, property features and values, damage susceptibility and indirect loss functions.

(5) Assessment of the availability of data at Federal, State and local agencies required for evaluation of FPM plans.

(6) Synthesis of mathematical models and input data into an integrated computer program.

Specific project analysis tasks:

(1) Familiarization of the INTASA team with Reach 13 of the Connecticut River Basin.

(2) Detailed analysis and evaluation of data available for input to the SIMULATOR, and preliminary determination of sufficiency of this data for program implementation.

(3) Modification of program procedures to accomodate specifics of the case study as well as gaps in available data.

(4) Analysis of Reach 13 and training the NED project team in the use of the SIMULATOR.

(5) Presentation of case study results with particular emphasis on sensitivity studies and their implications for benefit evaluation.

C. Project Organization and Activities

The project was administered and directed by the Office of the Chief of Engineers. Mr. E. Cohn, Economist in the Economic and Evaluation Branch, provided the technical assistance throughout the project period. Project administration was initially provided by Mr. R.M. Gidez, Assistant Chief of the Planning Division, and then by Mr. W.J. Donovan, Chief of the Plan Formulation and Evaluation Branch, Planning Division.

During the first part of the case study, staff members of the New England Division (NED) were instrumental in the determination of the study area, geographic areas and activity types; and in the collection of data related to land use, flood damages, economic rent components, and land values. Towards the end of the case study, they participated in running the computer program, in preparing input data, and in interpreting results. The main day-to-day support was provided by Messrs. L. Bergen, M. McArdle, and S. Rubin. Mr. J. Ignazio participated in progress and review sessions. Messrs. F. Ferreira, I.J. Risman, and J. Finegan provided valuable input data on site development cost, flood damages and hydrology. Messrs. D. Hottenstein and M. Parker of OCE assisted the NED staff during a two week period in the initial data collection effort.

During the contract period, the various activities related to the project included preparation of Interim Memoranda, field work at NED, progress and review meetings, and SIMULATOR workshops. A summary of all major activities in terms of content, participants and key documents follows:

1. Interim Memoranda

In addition to monthly progress reports, the following interim memoranda were prepared:

- Interim Memorandum I (Ref. 3), "Data Requirements for the Flood Control Benefit Simulator," prepared for the NED project team. This memorandum describes in detail the input data requirements of the SIMULATOR, specifies the information needed for Reach 13 of the Connecticut River Basin, and specifies the format for this information.

- Interim Memorandum II (Ref. 4), "Procedure for Obtaining First Estimates of Locational Advantages," prepared for NED project team. This memorandum describes a procedure for arriving at an approximate estimate of the benefits due to locational advantage and at the relative contributions made by each economic rent component. The purpose of these approximate estimates is to guide the data collection effort.

- Interim Memorandum III (Ref. 5), "Refined Data Collection," prepared for NED project team. This memorandum describes the refinements needed in the initially collected data. The data for which more detail was needed were determined by studying the initial data together with the preliminary results from running the SIMULATOR.

- Interim Memorandum IV (Ref. 6), "Flood Control Benefit Simulator: Work Outline for Remainder of FY '72," prepared for the Office of the Chief of Engineers. This memorandum describes results to be expected at the end of fiscal year 1972. It includes a description of additional work to be completed in order to obtain a realistic estimate of benefits on Reach 13, issues to be resolved in order to finalize the first version of the SIMULATOR, and improvements to be made in the simulation program.

- Interim Memorandum V (Ref. 7), "Areas of Research and Development Related to the Flood Control Simulator," prepared for OCE. This memorandum describes several areas where additional research and development effort are needed to take full advantage of the capabilities of the SIMULATOR. It includes efforts related to implementing the SIMULATOR and to improving models used.

2. INTASA Activities at New England Division Offices

In the course of the project, J. Rosing and D.P. Petropoulos stayed at the NED offices for about six man-months divided over four extended periods during which the following was accomplished:

- Period 1. (January 9, 1972 - January 21, 1972). Data were collected on Reach 13 and initial runs were made using the program.
- Period 2. (February 21, 1972 - March 4, 1972). Improvements were made on the initial data; Mr. Steve Rubin was instructed in running the SIMULATOR using several examples of sensitivity runs.
- Period 3. (April 24, 1972 - April 28, 1972). Refined data were collected and additional sensitivity runs were performed. Sample problems were prepared to familiarize NED project team with interpretation of the output.
- Period 4. (June 4, 1972 - June 10, 1972). Final sensitivity runs were performed and the results were discussed with the NED project team.

3. Meetings and Workshops

Major progress, review and workshop-type meetings that were held include:

- July 14, 1971. (INTASA). Discussion of problems related to development of SIMULATOR with J.C. Day and R.N. Weisz of the University of Arizona. Also present were J. Tang of the Institute for Water Resources (IWR) and E. Cohn of OCE.
- August 5, 1971. (INTASA). Discussion of flood damage evaluation with C.L. Sumrall, Jr. and land use planning with H.R. Gardner of the Lower Mississippi Valley Division and R.C. Roberts of the St. Louis District. Also present were B. Stern of the South Pacific Division and J. Moore of the San Francisco District.
- August 16, 1971. (NED). Initial meeting with Staff members of the New England Division to explore possibilities for an NED case study. In addition to NED staff members, E. Cohn and G. Bear of OCE, and N.V. Arvanitidis of INTASA were present.
- September 8 and 21, 1971. (SPD). Discussions of procedure for estimating site development cost differences between N. Gravdahl of South Pacific Division (SPD) and J. Rosing and C.H. Jolissaint of INTASA.
- October 28 and 29, 1971. (NED). Meeting with staff members of NED to discuss work schedule and data requirements. Also present at the meeting were R.M. Gidez, W.J. Donovan, E. Cohn and G. Bear of OCE and N.V. Arvanitidis, J. Rosing and D.P. Petropoulos of INTASA.
- March 7, 1972. (HEC). Presentation of the SIMULATOR at the seminar on Hydrologic Aspects of Project Planning at the Hydrologic Engineering Center (HEC) in Davis, California by J. Rosing and N.V. Arvanitidis of INTASA.

- March 22 through 24, 1972. (IWR). Presentation of the SIMULATOR at the Economist Conference in Galveston, Texas by E. Cohn of OCE, assisted by N.V. Arvanitidis of INTASA.

- May 3 and 4, 1972. (INTASA). Detailed presentation of the models, data requirements and program characteristics. Present were J. Auburg and D. Gjesdahl of the Missouri River Division, J. Velehradski and B. Daniel of the Omaha, Nebraska District, and W. Shurtz and J. Landes of the Kansas City, Missouri District.

- May 26, 1972. (HEC). Detailed presentation of the program to members of HEC. Present at the meeting were A.J. Fredrich, H. Reese, and A. Feldman of HEC, W.J. Donovan and D. Koch of OCE, R.C. Roberts of the St. Louis District, and B. Stern of the South Pacific Division.

- June 6, 1972. (SPD). Discussion of results obtained with the site development cost model between N. Gravdahl of SPD and C.H. Jolissaint of INTASA.

- June 8, 1972. (NED). Presentation of additional results of NED case study. Present at the meeting were J. Ignazio, L. Bergen, M. McArdle and S. Rubin of NED, and J. Rosing, D.P. Petropoulos and W.L. Theile of INTASA.

- June 26 through 28, 1972. (IWR). Workshop on Flood Control and Flood Plain Management in Madison, Wisconsin attended by J. Rosing. The SIMULATOR was presented and discussed.

D. Highlights of the SIMULATOR and the Computer Program

An overview of the SIMULATOR is presented in Chapter II. Major highlights include:

- Benefits due to a FPM plan are measured only by damage reduction if land use is the same with and without the plan, and by locational advantage if land use is different.

- The main components describing locational advantages are differences in flood damages, fixed area development cost, site development cost, transportation cost, amenity values and social environment effect. The first four components are directly related to economic efficiency while the last two have a strong social component, and therefore, are more subjective in nature. The major inputs that determine differences in amenity value and social environment effects are obtained outside the program.

- The land use allocation model is such that interaction with the planner is essential for proper project analysis. A completely independent optimization procedure for allocating land uses requires many simplifying assumptions, the implications of which may not always be clear to the user. As such, these optimization procedures have limited usefulness.

Therefore, in the SIMULATOR, implicit assumptions were kept to a minimum, while requiring the planner to make explicit assumptions in terms of specifying ultimate land use plans and land use requirements over time.

- Land use allocation over time is performed at two levels. The first level is used to arrive at a land use, locating aggregate activities to subareas at the end of each allocation period. The second level is used to provide the desired accuracy for benefit evaluation by locating detailed activities to parcels at the end of each evaluation period. Aggregate activities are used to initially limit the data collection and to account for interdependencies among activity types, while subareas account for spatial interdependencies.

- The study area and dummy location are defined so as to limit the scope. The study area is formed by areas for which the net earnings can be affected by FPM plans, excluding areas that are far away, widely dispersed, difficult to identify, or for which data collection is impractical. These latter areas comprise the dummy location, used to approximately reflect changes in land use outside the study area.

- The SIMULATOR reduces data collection efforts by using results from sensitivity studies. Following an initial estimate of all input variables, the variables to which benefits are most sensitive can be isolated. The data collection effort can then concentrate on critical problem variables.

The major highlights of the computer program are:

- The computer program uses an overlay structure and data files so that total storage requirements are reduced. The overlay structure also allows for replacing certain program functions without interfering with the rest of the program.

- The total storage requirements are below 100k (octal). Computer-run times for the NED case study were about 50 seconds of central processing time and 100 seconds of peripheral processing time per program run on the CDC 6400.

- The program checks the input data extensively and provides informative diagnostics if data is out of bounds, inconsistent, or if data cards are missing, out of order, or otherwise incorrect.

- Data changes for sensitivity studies can be made easily by specifying the number of the card to be changed in the basic data deck, together with the change to be made. The changes for the different runs of a sensitivity study can be submitted and executed simultaneously.

- Different levels of detail in the printout can be specified for each overlay. The printout is organized so that significant sources contributing to the benefits can be easily identified.

- The program can be run through any number of overlays, stopped, and restarted after examining the output. This is especially helpful when it is desirable to check the land use before proceeding with the benefit evaluation.

E. Summary of Test Case Results

The following are major results from applying the SIMULATOR on Reach 13 of the Connecticut River Basin:

- Damage reduction benefits to existing and future activities from additional protection through upstream reservoirs accounts for 80% of total benefits. For the purpose of benefit evaluation, therefore, the main emphasis should be on accurately estimating flood damages. The reason for the low contribution of locational advantage is that reasonable alternative sites outside the flood plain are available at relatively short distances.

- The ultimate land use plan with additional protection resulted in negative locational advantage due to initial underestimation of residual damages. The program's output was used to guide modification of this plan so that the effect of residual damages was minimized and NEE benefits improved.

- Benefits were found to be sensitive to the social discount rate, level of protection, first floor elevation, and increase in value of damageable components. All other parameters are relatively unimportant, especially because of the overall low contribution of locational advantage to benefits. However, it was also found that increasing the value of economic rent components over time would increase the importance of locational advantage.

- Benefits from flood plain zoning without additional flood protection were substantial. Even with additional protection zoning is desirable so that the highest realizable benefits can be obtained.

- Benefits from additional protection on Reach 13 of the Connecticut River Basin are summarized below:

Damage Reduction		
Existing Activities (1972)	$9,157,717	
Future Activities (after 1972)	1,183,961	$10,341,678
Locational Advantage		
Economic Rent Formula	$1,078,123	$ 1,078,123
Economic Rent/Land Value Formula	1,034,000	
Land Value Formula	456,123	
Land Value Formula (Flood Plain Only)	5,064,873	
Total Benefits		$11,419,801

F. Recommendations

Several recommendations can be made regarding the first operational version of the SIMULATOR, its implementation, and further improvements. Details are given in INTASA proposal IRP 72-08, and Reference 7.

Regarding the present version, the following recommendations have been approved and are currently under development:

- The program should be extended to perform many of the calculations associated with data manipulation so as to reduce the input data requirements. For example, all data related to subareas can be internally calculated from input data required for the parcels.

- In the computation and presentation of benefits from damage reduction, a distinction should be made between activities that are located in the flood plain between the time of the study and the first year of the FPM plan, and activities that will locate in the flood plain after the first year of the plan.

- The option should be included to characterize the dummy location for various activity types by the average economic rent of the subareas included in the study area or by externally specified values of the economic rent.

- The SIMULATOR should be modified so that direct estimates of economic rent differences can be used. Thus a preliminary estimate of the relative importance of damages reduced and locational advantage may be determined before obtaining estimates for individual components.

- The worst possible flood event should be evaluated and corresponding damages printed.

- Allowance should be made for possible changes in the stage frequency over time as a result of increasing urban land use in the flood plain either inside or upstream from the study area.

- Manuals should be prepared that provide a guide to the Corps planner on how to use the SIMULATOR, on detailed programming logic, and on collection of input data (Refs. 8 and 9).

As detailed in Reference 7, program implementation includes:

- Changes in conceptual aspects of the SIMULATOR should be administered at a national level to prevent duplication of effort and to maintain uniformity.

- The SIMULATOR should be interfaced with other Corps' programs in areas such as land use, hydrology, and agriculture.

- Collected data should be stored and maintained in a standard format for use in future studies. These data would be accessible to all field offices enabling similar regions of the country to broaden their data base.

- The feasibility and design of centralized processing and storage facilities should be evaluated, and should include data for flood damages, transportation cost, site development cost, amenity values, and social environment effects. These efforts would reduce the expense of data collection and improve the data base.

- Implementation of the SIMULATOR in Corps field offices requires in-house analysis and programming expertise so as to exploit the assets and remove limitations by enhancing the program's capabilities as needed for specific studies.

As detailed in Reference 7, recommendations for improvement in the models include:

- The present version of the program estimates benefits from structural flood control projects and flood plain zoning regulations. Extensions to other uses are expected to be relatively simple since the main components of land use analysis, and evaluation of damage reduction and locational advantage will play a major role in other applications.

- An important extension is the program's adaption to perform more complete FPM studies; i.e., alternatives such as land fill, flood warning, and building codes would be examined. Other extensions include evaluation of projects that not only provide flood control but also develop and maintain the natural amenity of an area, and evaluation of relocation as an alternative to flood protection.

- Models should be developed capable of estimating the economic rent components of amenity value and social environment effects.

- The models used for estimating economic rent differences should be improved. The procedures presently used are the first efforts in modeling economic rent components. Further development, testing, and verification of these models is needed to obtain assurance in regard to the accuracy and practicality of the simulation method. In particular, the transportation model should be improved to consider modal split, public transport, and multiple destinations.

- Use of the SIMULATOR unveils uncertainty aspects of FPM benefit estimation through sensitivity studies. Thus, it is desirable to develop a measure accounting for the uncertainty in estimated benefits.

- The SIMULATOR provides an efficient procedure for estimating the benefits for a number of alternative FPM plans. The comparison of these alternatives, however, requires estimates of both the benefits and the cost. Simplified methods should be developed for estimating the cost of FPM plans.

G. Outline of Report

Chapter II gives an overview of the SIMULATOR as of June 30, 1972. In addition, the measures for benefit evaluation are summarized.

Chapter III describes the procedures used for estimating flood damages and economic rent components such as fixed area development cost, site development cost, transportation cost, amenity values and social environment effect.

Chapter IV describes the two levels of the allocation procedure used for the land use model. It discusses the characteristics of the model and advantages of the two-level approach, together with the requirement of close interaction between planner and model.

Chapter V presents the data requirements in general and specifically describes the data used in the NED case study.

Chapter VI presents the results of the NED case study. First, the basic run which forms the reference for all sensitivity runs is discussed in detail. Then, the results of the different sensitivity runs are presented and discussed to illustrate the scope of the sensitivity studies that can be performed and the type of information that can be derived.

Chapter II

AN OVERVIEW OF THE SIMULATOR

A. Introduction

The SIMULATOR is summarized in this chapter, and the advantages of a computerized procedure for the evaluation of alternative FPM plans is presented. The theoretical basis for measuring economic benefits by damage reduction and locational advantage is discussed and illustrated with an example. The levels of aggregation used to describe geographic areas and economic activity types throughout this report are introduced. Finally, the program and related mathematical models are outlined.

B. A Note for the Planner

The SIMULATOR is a tool which allows the planner to consider a wide range of FPM plans within a limited study period and budget. The planner can determine the most important data requirements early in the study, thus limiting the data collection effort. He can quantify benefits, and determine their sensitivity to uncertain parameters, different assumptions, and alternative policy decisions. Given ultimate land use plans and land use requirements over time, he can derive, study and modify a variety of land use plans under alternative FPM programs. The present version allows the planner to consider structural alternatives and flood plain regulation by zoning although the basic framework is such that it can be expanded to include other FPM options by extending the input data and the computer logic of the SIMULATOR. Finally, the SIMULATOR provides the planner with a unified procedure for the documentation and analysis of land use plans, benefit evaluation and study results.

An overview of the SIMULATOR is presented in Figure 2.1. The SIMULATOR is divided into input data and three main parts:

- Input Data. Basic data are needed for calculating flood damages, land values, and the components of economic rent. In addition, data is needed for ultimate land use plans with and without FPM and land use requirements over time.

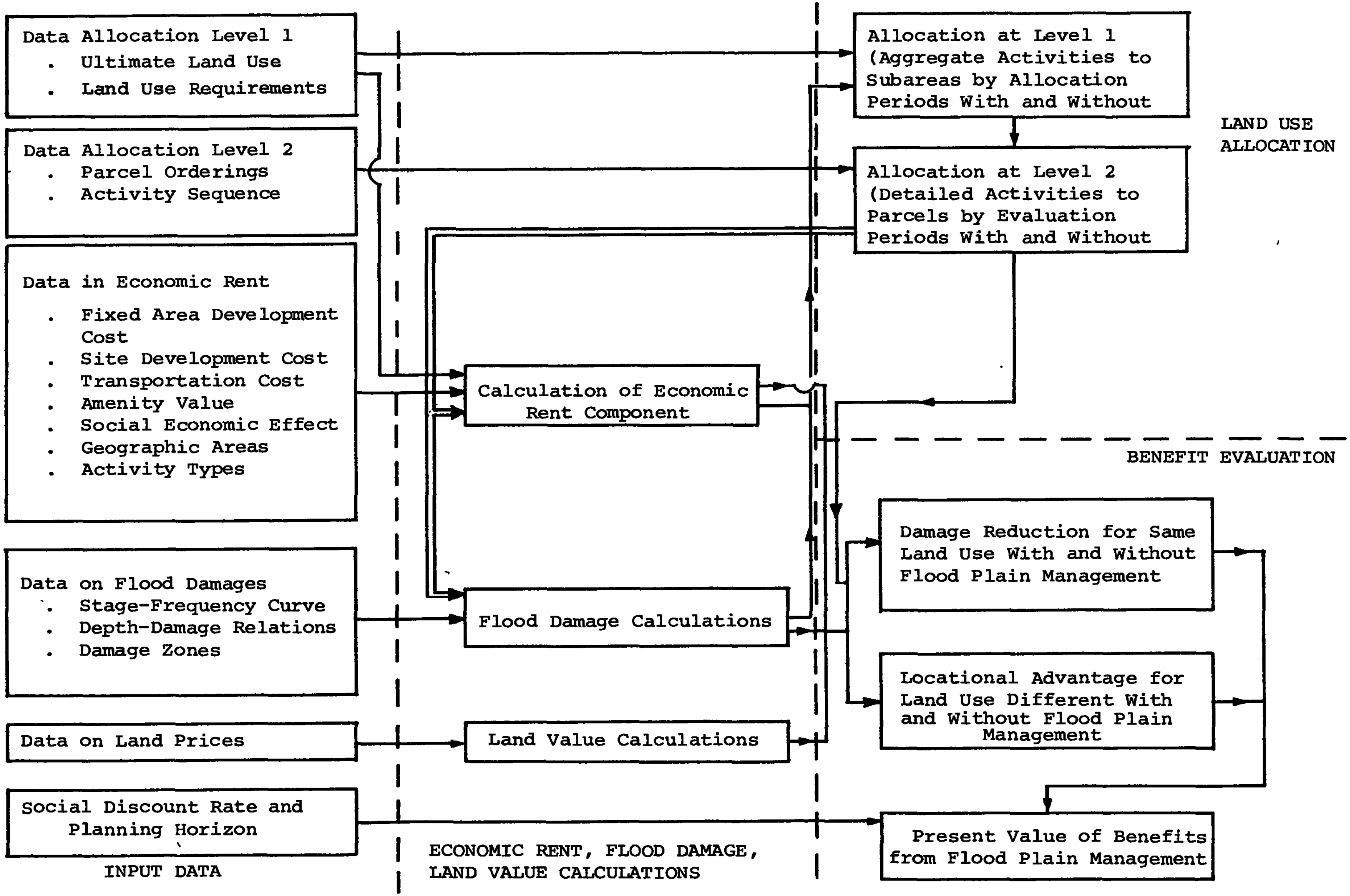


Figure 2.1 OVERVIEW OF FLOOD PLAIN MANAGEMENT SIMULATOR

- Calculations for Economic Rent, Flood Damage and Land Value. For land use allocation, flood damages and economic rent components are calculated during the initial year of the planning period for aggregate activity/subarea combinations. For benefit evaluation, the same calculation is performed for detailed activity/parcel combinations, where the land use allocation over time is used to account for the social environment effect of neighboring land uses and also to reduce the storage requirements for the flood damage calculation.

- Land Use Allocation. The land use allocation model is the central part of the SIMULATOR. Before benefits from a specific plan can be evaluated, the land use over time with and without the plan must be forecasted. The allocation of land use is performed at two levels. The first level is used to arrive at a land utilization over time and locates aggregate activities in subareas. It accounts for interdependencies between activity types; need to reserve land for future uses with higher productivity; availability of land outside of the study area; social and political constraints on land uses, and irrational behavior of land users. The second level locates detailed activities to parcels and provides the detail required to obtain desired accuracies in benefit evaluation.

- Benefit Evaluation. Using the detailed land use allocation, the NEE benefits accruing to a FPM plan are determined at each evaluation period by reduction in flood damages and locational advantage. For activities that locate the same with and without FPM, benefits are measured by locational advantage, and three different methods can be used for its measurement. The first is based on economic rent differences and flood damages, the second on land values and flood damages, and the third on a combination of the two previous methods. Finally, present value of benefits is calculated using the social discount rate and planning horizon.

Computerization of benefit evaluation procedures adds new dimensions that may require changes in the planner's approach to FPM program analysis. More specifically, the planner must now utilize the capabilities of the computer for routine tasks and devote more time in the formulation of alternatives and in the identification of critical program issues. Some of the more traditional advantages of computerization as they apply to the SIMULATOR are described below:

- Automation of Routine Calculations. It provides the capability to perform more calculations with less time and effort. The subsequent savings can then be devoted to addressing issues surfacing from increased complexity of FPM program analysis.

- Flexibility and Efficiency. Computerization provides the flexibility required for timely interaction with the public and various planning agencies. It is now easier to consider alternative plans, change assumptions or parameter estimates, and obtain new values for benefits. Also, computerization provides a large amount of relevant information at a low cost in terms of time and money.

- Sensitivity Studies. The most significant advantage of computerization is its use in sensitivity analysis. It becomes relatively easy to determine sensitivity of benefits to different input parameters with a reasonable expenditure of time and effort. Such studies are important because of the uncertainty in many variables projected over the planning horizon, and because of their usefulness in guiding the planner's efforts to improve the accuracy of the benefit estimate.

- Data Reduction. The results of sensitivity studies can be used effectively to reduce the total amount of data needed for benefit evaluation. An initial estimate of all input variables is made, and the variables to which the benefits are most sensitive are determined. The collection effort can then concentrate on data needed for determining the values of the most important variables.

- Standard Format. Use of the computer program by all Districts of the Corps of Engineers will result in a standard format for presenting both the benefits and the sensitivity of these benefits to either uncertain or subjective parameters.

C. Benefit Measures

The proper measure for benefits from a FPM plan was addressed previously (Refs. 1,2, and 10). The benefits are measured by the difference in net earnings with and without the plan, where earning to both the activities and the landowners are included. For land that is in the same use irrespective of the plan, this difference is measured by flood damage reduction. In addition, an intensification factor may be included. This intensification benefit is due to changes in the surrounding land uses as a result of the plan. For example, increased residential use of the flood plain with the plan may increase the value of existing residences, or agricultural use may change to more valuable crops.

For land that is in different uses with and without the plan, the difference in net earnings is referred to as locational advantage, and can be expressed as the sum of the difference in economic rents and the associated difference in flood damages. The economic rent is associated with a particular combination of economic activity and location, and is given by the annual net earnings to both the economic activity and the land owner, excluding average annual flood damages. This definition of economic rent is convenient because the SIMULATOR was developed to measure NEE benefits. These benefits measure the increase in total net earnings and are not concerned with distributional aspects. Thus, for the purpose of evaluating these benefits, no distinction needs to be made between activity and land owner. Furthermore, flood damages are excluded from the economic rent because it is desirable to present these separately.

1. Measuring Locational Advantage

Models for estimating flood damages at different locations have been developed in the past and can be used in the SIMULATOR. However, there are no such models available for estimating economic rent components (Ref. 11, 12 & 13). Therefore major emphasis in the following discussion will be on the economic rent components portion of locational advantage.

Economic rent, given by the net earnings to both the activity i and location k, is expressed as follows:

$$S_{ik} = G_{ik} - C_{ik} \tag{2.1}$$

where

G_{ik} represents the gross income to activity i and location k;

C_{ik} represents all costs incurred by activity i and location k except land rent and flood damages.

Given any two locations l and k, the difference in economic rent is expressed by

$$\Delta S_{ilk} = \Delta G_{ilk} - \Delta C_{ilk}$$

where

$$\Delta G_{ilk} = G_{il} - G_{ik} \text{ and } \Delta C_{ilk} = C_{il} - C_{ik} \tag{2.2}$$

In estimating locational advantages, differences in economic rents are needed and not total values. This is important because all economic rent components that are the same at different locations can be eliminated thus limiting the data requirements. The remaining components, related to differences in gross income and costs to both activities and landowners, make up the economic rent differences.

The correct use of damage reduction and locational advantage in measuring benefits is obtained by considering the net earning to all activities and locations that can be affected by a specific plan, where the net earnings are defined as the economic rent net of flood damages. Thus the net earnings to activity i and location k are given by:

$$\hat{S}_{ik}(p) = S_{ik}(p) - r_{ik}(p) \tag{2.3}$$

where

$\hat{S}_{ik}(p)$ is the net earnings to activity i and location k;

$S_{ik}(p)$ is the economic rent to activity i and location k;

$r_{ik}(p)$ is the flood damage incurred by activity i and location k;

p denotes a FPM plan;

k indicates the location of activity i with plan p.

The benefits are then defined as the difference between the total net earnings with and without the plan, or

$$B(p) = \sum_i \hat{S}_{ik}(p) - \sum_i \hat{S}_{ik}(0) \tag{2.4}$$

$$= \sum_{i \in A} \left[\left\{ S_{ik}(p) - S_{ik}(0) \right\} + \left\{ r_{ik}(0) - r_{ik}(p) \right\} \right] +$$

$$= \sum_{i \in A} \left[\left\{ S_{ik}(p) - S_{i\ell}(0) \right\} + \left\{ r_{i\ell}(0) - r_{ik}(p) \right\} \right]$$

where

B(p) are the benefits resulting from plan p;

A indicates the set of activities that locate the same with and without the plan;

where

B indicates the set of activities that locate differently with and without the plan;

0 denotes no FPM plan.

The first sum in Equation (2.4) measures the benefits to activities that locate the same irrespective of the plan with the first term measuring intensification benefits and the second term damage reduction. The second sum measures locational advantage for activities that locate differently with and without the plan, with the first term measuring economic rent differences and the second term differences in flood damages.

An upper bound for the locational advantage to activities that locate differently with and without the plan is provided by the sum of the damage reduction and intensification benefits that would have been obtained if those activities had located the same with and without the plan. That is:

$$\sum_{i\in B}\left[\left\{s_{ik}(p) - s_{i\ell}(0)\right\} + \left\{r_{i\ell}(0) - r_{ik}(p)\right\}\right] \leq \sum_{i\in B}\left[\left\{s_{ik}(p) - s_{ik}(0)\right\} + \left\{r_{ik}(0) - r_{ik}(p)\right\}\right] \tag{2.5}$$

A complete derivation of this upper bound is presented in Reference 1. Its validity is clarified by considering the following example. An activity is located in the flood plain with protection and would have located outside the flood plain if protection had not been provided. It is assumed that the economic rents in the flood plain are not influenced by the level of protection. If protection is now suddenly removed, then the activity prefers the locational disadvantage of the alternative location outside the flood plain to the increase in expected damages that it will incur by remaining in the flood plain. In this case, the locational disadvantage outside the flood plain is smaller than the increase in flood damages inside the flood plain. Or, as expressed in Equation (2.5), the locational advantage of the flood plain is smaller than the damage reduction if the activity locates in the flood plain with and without protection.

Three alternative methods for estimating locational advantage are included in the SIMULATOR in order to explore the possibility of reducing the total input data:

- Economic rent formula
- Land value formula
- Economic rent/land value formula

These methods are characterized by the type of data required and are described in detail in Section E of this chapter.

The procedures for estimating the components of economic rent differences are discussed in detail in Section E of this chapter, and include:

- Fixed area development cost
- Site development cost
- Transportation cost
- Amenity value
- Social environment effect.

2. Estimating Flood Control Benefits: An Example

The application of economic benefit measures to a FPM plan is illustrated by the example in Figure 2.2 where the plan is structural flood protection. The example considers agriculture and one type of residential activity. Residences h_1 are located in the flood plain both with and without protection, while residences h_2 are located in the flood plain with protection and outside the flood plain without protection. Locations not used by residences h_1 or h_2 are taken by agriculture a. It is assumed that economic rent differences are not influenced by flood protection.

Using f to indicate a location in the flood plain and o to indicate a location outside the flood plain, the total net earnings with protection is expressed by:

$$\sum_i \hat{S}_{ik}(p) = \left\{ S^f_{h_1} - r^f_{h_1}(p) \right\} + \left\{ S^f_{h_2} - r^f_{h_2}(p) \right\} + S^o_a \qquad (2.6)$$

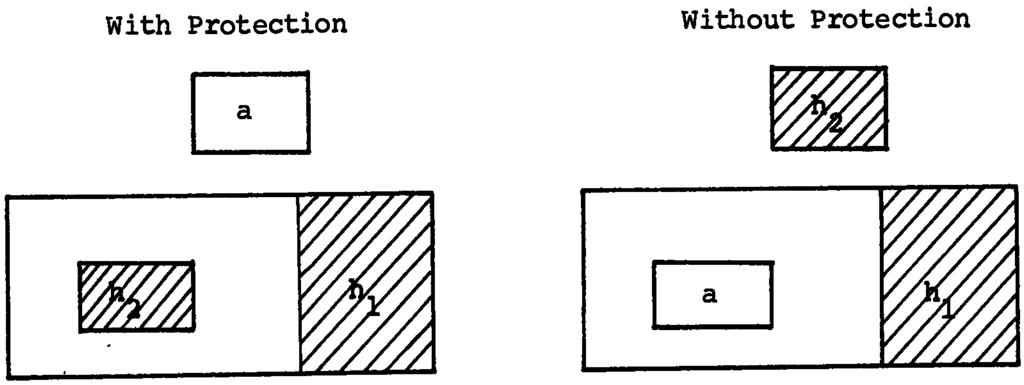


Figure 2.2 EXAMPLE OF FLOOD CONTROL BENEFITS

Similarly, the net earnings without protection are given by:

$$\sum_i \hat{S}_{ik}(0) = \left\{ S^f_{h_1} - r^f_{h_1}(0) \right\} + S^o_{h_2} + \left\{ S^f_a - r^f_a(0) \right\} \tag{2.7}$$

Subtracting the total net earnings without protection from the total net earnings with protection, the benefits are given by:

$$B(p) = \left[r^f_{h_1}(0) - r^f_{h_1}(p) \right] + \left[\left\{ S^f_{h_2} - S^o_{h_2} \right\} + \left\{ S^o_a - S^f_a \right\} + \left\{ r^f_a(0) - r^f_{h_2}(p) \right\} \right] \tag{2.8}$$

The first expression in Equation (2.8) gives damage reduction benefits to residences h_1 that are located the same with and without protection. The second expression gives locational advantage associated with residences h_2 and agriculture a that locate differently with and without protection. Within this expression for locational advantage, the first term is the difference in economic rent between locating residences h_2 in the flood plain and outside the flood plain; the second term is the difference in economic rent between locating agriculture a outside the flood plain and inside the flood plain; and the last term measures the difference in flood damages incurred by agriculture a without protection and by residences h_2 with protection.

For the above example, economic rent differences inside and outside the flood plain and flood damages with and without protection are presented in Table II-1. The flood control benefits, obtained using Equation (2.8) are summarized in Table II-2. Note that the damages to residences h_1 are less than those to h_2 while at the same time the economic rent differences are the same. As a result, it is economical for residences h_1 to locate in the flood plain without protection, while it is not economical for residences h_2 to do so. The upper bound on the locational advantage presented in Equation (2.5) is satisfied and is equal to the damage reduction if residences h_2 located in the flood plain both with and without protection, or $2,000 - $200 = $1,800.

An alternative, though incorrect, procedure for calculating the locational advantage is to consider only activities in the flood plain, and to assume that no changes occur outside the flood plain. The resulting benefit, referred to as land enhancement, is equal to the difference between the net economic rent to residences h_2 with protection and agriculture a without protection, or $5,800 - $260 = $5,540. However, as was shown in Table II-2, the upper bound is equal to $1,800. Thus, the $5,540 benefit claimed for land enhancement violates the $1,800 upper bound on benefits from locational advantage and shows the danger of considering only the effects within the flood plain as well as the usefulness of the upper bound. It cannot be assumed that an activity such as residences h_2 will locate in the flood plain only with protection, but will vanish if protection is not provided. Instead it will most likely locate at some alternative site outside the flood plain. The real benefit of protection is the difference in net economic rent between the flood plain location and the best alternative site outside the flood plain.

D. Geographic Areas and Economic Activities

The aggregation of both geographic areas and economic activities will be discussed in more detail when describing the various models in subsequent

Table II-1

ECONOMIC RENT AND FLOOD DAMAGES

Activity	Annual Economic Rent ($/acre): Outside Flood Plain	Annual Economic Rent ($/acre): Inside Flood Plain	Expected Annual Flood Damages ($/acre): Without Protection	Expected Annual Flood Damages ($/acre): With Protection
Residences h_1	$ 5000	$ 6000	$ 700	$100
Residences h_2	5000	6000	2000	200
Agriculture	200	300	40	5

Table II-2

FLOOD CONTROL BENEFITS

Damage Reduction			
Residences h_1	$	$600	
Locational Advantage			
Economic Rent Differences for Residences h_2	1000		Upper Bound
Economic Rent Differences for Agriculture a	-100	= 740	< 1800
Residual Damage Difference	-160		
Total Flood Control Benefits		$1340	

Chapters. The levels of aggregation are presented in Table II-3. A brief description of these aggregations, and their uses in the analysis follows.

1. Aggregation of Geographic Areas

The study area and dummy location are determined in order to limit the geographic area included in the FPM study. At the next level of aggregation, economic growth areas and zones are determined which, together with information on future land use development, are used to identify subareas. Subareas are used to allocate land uses over time with and without a FPM plan. They identify areas that will develop as a unit and reflect the influence of the infrastructure. At the final level of aggregation, subareas are divided into parcels which are used to evaluate benefits from FPM.

Table II-3

LEVELS OF AGGREGATION

Purpose of Aggregation	Geographic Areas	Activity Types
Limited Scope of Problem	Study Area & Dummy Location	General
Land Use Allocation	Economic Growth Area, Zones and Subareas	Aggregate Activities
Benefit Evaluation	Parcels	Detailed Activities and Structure Types

The relationships between zones, subareas and parcels is illustrated in Figure 2.3 with an example of one economic growth area. Two flood damage zones and two alternative areas outside the flood plain are considered. The flood

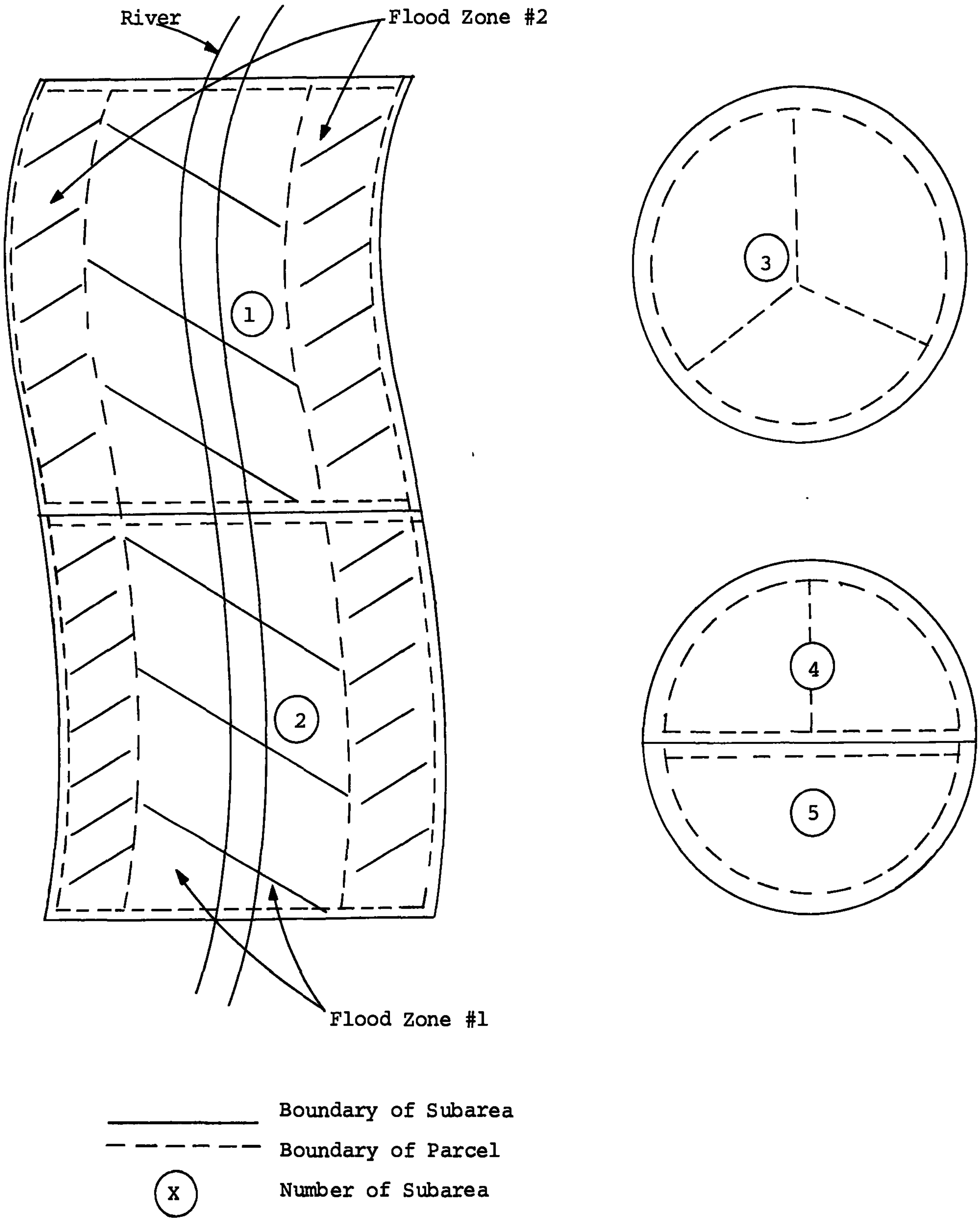


Figure 2.3 ZONES, SUBAREAS AND PARCELS

plain is divided into subareas 1 and 2, and one of the areas outside the flood plain is divided in subareas 4 and 5. The other area outside the flood plain is considered as a single subarea 3. Each subarea consists of one or more parcels as indicated.

2. Aggregation of Economic Activities

For economic activities, different activity types are defined so as to allow groupings of similar land uses, where the precise characteristics used to distinguish between activity types depends on the level of aggregation desired. At the first level of aggregation, general activity groups are defined to indicate the scope of the activities involved in a particular FPM study and include community development, industrial land use, and agriculture. At the next level, aggregate activities are distinguished for use together with subareas in the allocation of land uses over time. They identify the activity types that are interdependent and traditionally locate together in the same vicinity. At the last level of aggregation, detailed activity types and structural types are distinguished to use with parcels in order to achieve accuracy in the benefit evaluation.

E. Simulation Program

In this section the SIMULATOR is described in general terms including a description of its main functions, and a presentation of the program characteristics. The purpose is to obtain a general understanding of the capabilities of the SIMULATOR without going into the details of models and programming logic.

1. General Overview of Simulation Program

A general overview of the SIMULATOR was presented in Figure 2.1 and in the description accompanying that figure in Section B. The SIMULATOR is divided into input data and three main parts: calculations for economic rent, flood damage and land value; land use allocation; and benefit evaluation. First, using the appropriate input data, the economic rent differences and flood damages are calculated for aggregate activity/subarea combinations. Together with additional input data related to land use, these calculations are used to determine the land use at the end of each allocation period, expressed in terms of locating aggregate activities to subareas. This is further refined using a second level of allocation, which provides the land use at the end of each evaluation period in terms of detailed activities and parcels. At the end of each evaluation period, NEE benefits are measured by damage reduction and locational advantage, and are determined based on the results of the allocation and on the economic rent differences, land value differences and flood damages. Finally, the present value of the benefits is obtained using the social discount rate and planning horizon.

The general layout of the simulation program is presented in Figure 2.4. The SIMULATOR uses an overlay structure together with data files in order to reduce total storage requirements. Overlays are independent programs that can be called, one at a time, into central memory by the main program. Thus, at any particular time, only one of the seven overlays used in the SIMULATOR will be operating. Communication between overlays is accomplished partly by central memory and partly by data files where data is stored temporarily.

The main program reads, checks and prints basic input data and controls the execution of overlays. The determination of flood damages, economic rent components, and land values for different activity/location combinations involves overlays 1, 2, and 5. Overlay 1 is used to calculate components of economic rent differences while overlays 2 and 5 are used to calculate flood damages for land use allocation and benefit evaluation, respectively. The reason for this separate calculation of flood damages is the resulting reduction in total storage requirements. Land use allocations at level 1 and 2 are performed in overlay 3 and 4, respectively. Subsequently, benefits are evaluated for each evaluation time period in overlay 6 and the present values of benefits are determined in overlay 7. This overlay also provides the final output of the program.

The use of different data files is summarized as follows. For all aggregate activity type/subarea combinations, the components of economic rent differences and flood damages are stored on files 1 and 2 respectively. This information is used in land use allocation at level 1. File 3 stores the resulting land use of aggregate activity/subarea combinations for different allocation periods both with and without FPM. This is used for allocation at level 2, the results of which are stored in file 4 for use in benefit evaluation. File 5 stores basic information needed for the damage calculation in

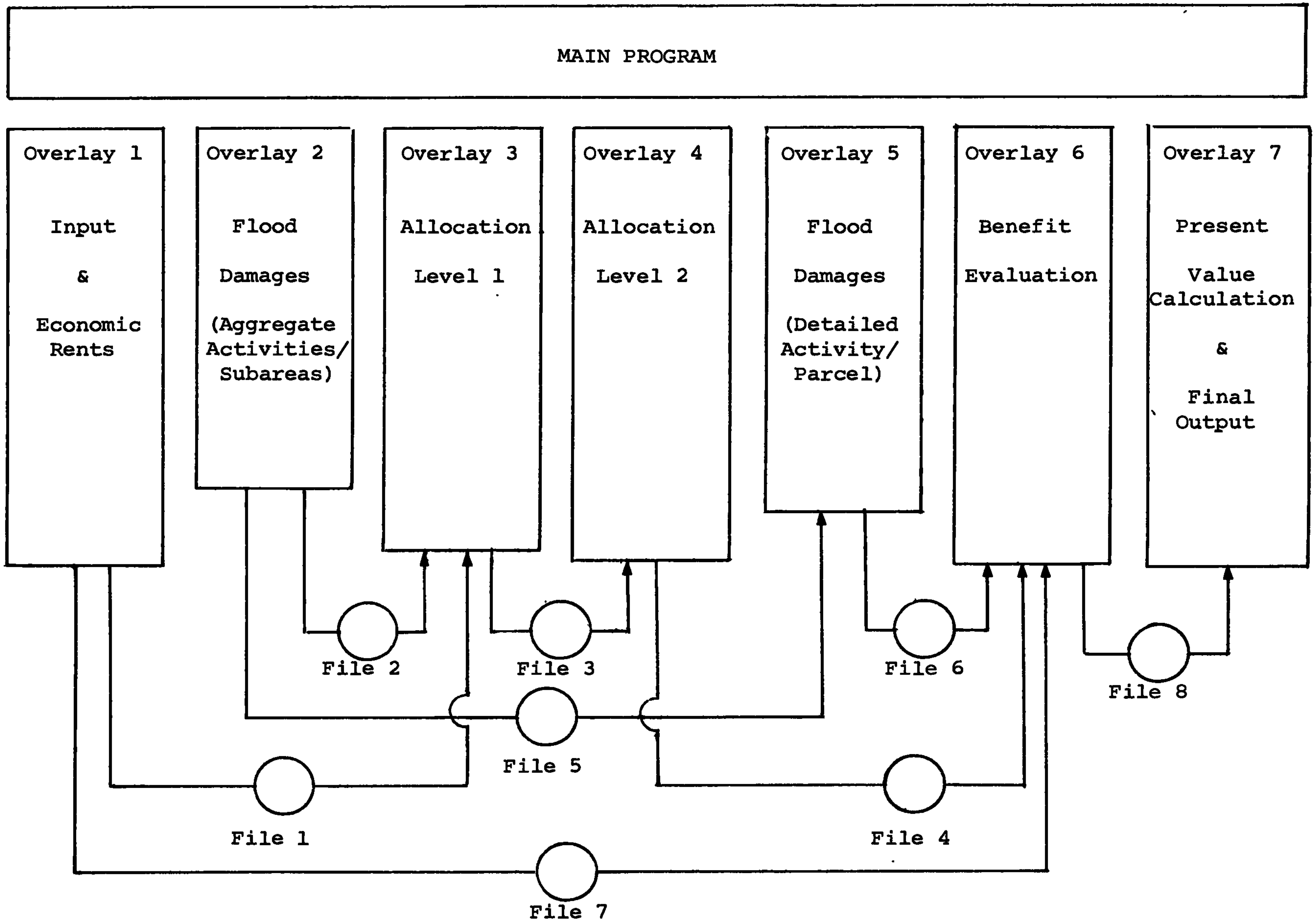


Figure 2.4 LAYOUT OF SIMULATION PROGRAM

overlay 5, where damages for relevant detailed activity/parcel combinations are calculated. The results of this calculation are stored in file 6, and will be used in the benefit evaluation. Similarly, in file 7, the components for economic rent differences by detailed activity/zone are stored for use in benefit evaluation. Finally, benefits at the start of each evaluation period are stored in file 8, and are used to determine present values of benefits and to present the final output of the simulation program.

2. Program Characteristics

Through the use of an overlay structure and data files presented in Figure 2.4, total storage requirements of the SIMULATOR were kept below 100K octal. These storage requirements were achieved for the limits on problem size listed in Table II-4. These limits can be changed, although this may result in higher storage requirements depending on the values specified for the new limits. Problem size of the NED test case is also listed in Table II-4 for comparison.

Table II-4

SIZE OF FLOOD PLAIN MANAGEMENT PROBLEM

DESCRIPTION	PROGRAM LIMIT	NED TEST CASE
Allocation Periods	10	5
Evaluation Periods	40	10
Aggregate Activities	15	9
Subareas	20	18
Detailed Activities	45	24
Parcels	100	40
Number of Reaches	15	4
Damage Zones Per Reach	10	9
Other Zones		
Site	10	4
Transportation	20	18
Amenity	10	4
Social Environment	20	18

Central and peripheral processing times for executing each overlay on CDC 6400 are presented in Table II-5 for the NED test case. The commercial costs associated with these run times are also shown, based on $400 per hour for central processing time, and on converting peripheral process time to central processing using a factor of 1/3. The total computer charges for one complete run for the NED test case, excluding printing of output, is below ten dollars. This low cost makes the SIMULATOR a useful tool for performing sensitivity studies.

Table II-5

COMPUTER RUN TIME AND COSTS ON CDC 6400

	Central Processing Time in Seconds	Peripheral Processing Time in Seconds	Cost in Dollars*
1) Basic Input and Economic Rent Calculations	1.85	2.98	$ .32
2) Damage Calculations (Aggregate)	3.20	3.60	$ .49
3) Allocation Level 1	5.05	4.59	$ .73
4) Allocation Level 2	5.02	8.36	$ .87
5) Damage Calculations (Detailed)	2.41	6.02	$ .49
6) Complete Benefit Calculation	16.67	63.09	$4.19
7) Present Value Calculation and Output	9.71	5.82	$1.29
TOTAL	43.91	94.46	$8.38

* Peripheral processing seconds are converted to equivalent central processing seconds using a conversion factor of 1/3. A cost of $400 per hour of central processing time is assumed.

Several program run options are available when using the SIMULATOR. These include a restart feature where the overlay structure of the program is exploited to allow restarting in the middle of the program. The program can be run through any number of overlays, be stopped, and, after examining the output, be restarted. Thus, after running the program only through overlay 4, it is used as a land use allocation program. Once an acceptable land use allocation over time is achieved, both with and without FPM, benefit-analysis is performed by running overlays 5, 6 and 7. Additional program flexibility allows the user to select any or all of the benefit formulas for locational advantage.

Several input and output features of the program provide operational convenience. Input data is checked extensively by the program, which provides informative diagnostics if data is out of bounds or inconsistent, and if input cards are missing, out of order, or otherwise incorrect. Furthermore, three different levels of detail can be specified for printing the output of each overlay. The first level skips all printing, the second prints input to that overlay and summarizes all important computational results, and the third provides extensive detail for a thorough analysis of results of the particular overlay. Finally, the output of overlay 7, which presents the results of benefit evaluation, is organized to assist the planner in tracing back the significant sources that contribute to total benefits. For this purpose, the breakdown of benefits by economic rent components, flood damages and land values is displayed for each aggregate activity type and for each evaluation time period.

The overlay structure separates the different functions thus allowing for replacement of certain program functions without interfering with the rest of the program. For example, the land use allocation model can be used for purposes other than FPM, or it can be used in cases where measures other than net economic rents are used.

3. Main Program Functions

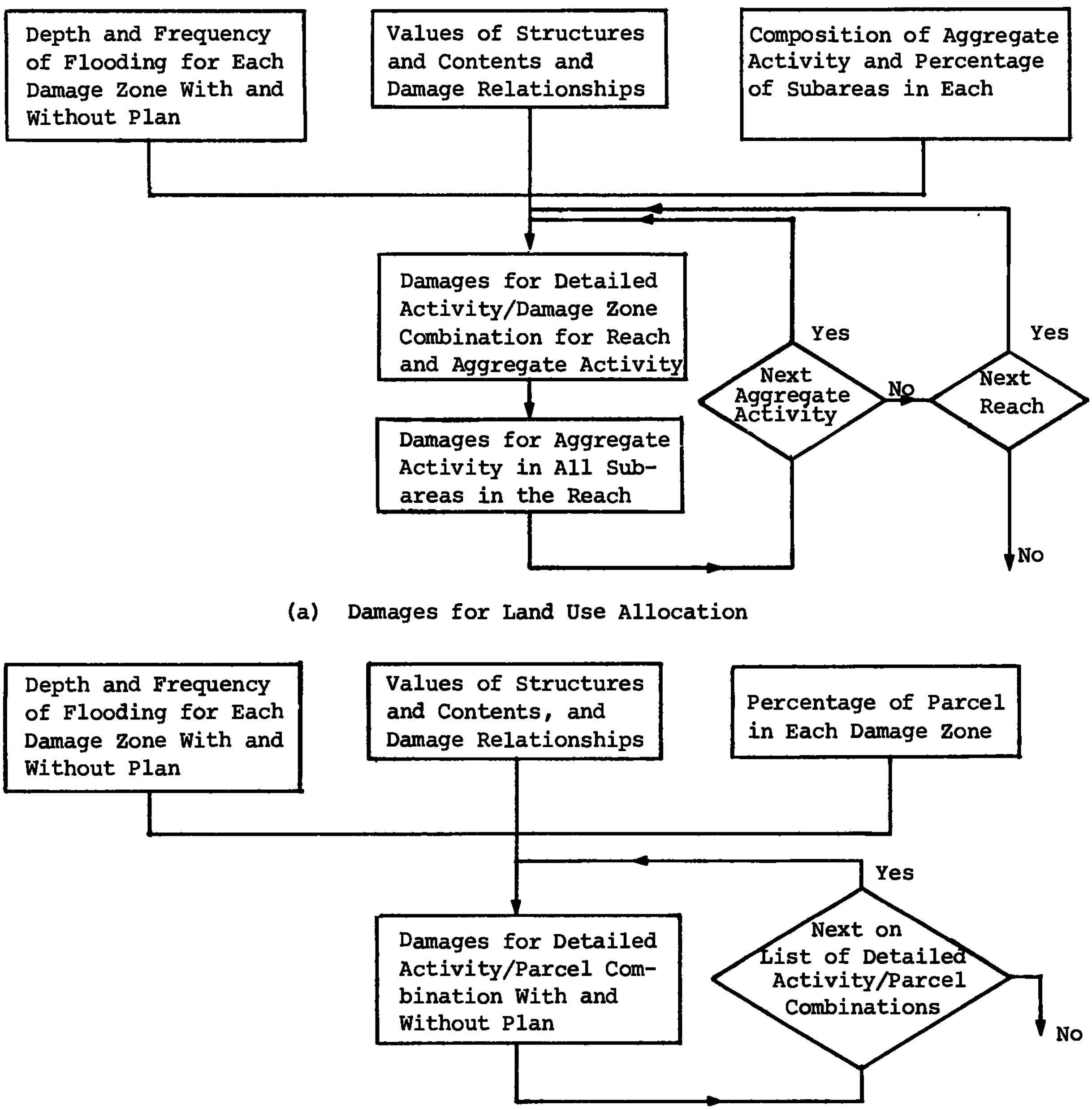
The main functions of the SIMULATOR are estimation of flood damages, estimation of components of economic rent differences, land use allocation, and benefit evaluation as presented in Section B of this chapter. These functions will be discussed in more detail in Chapters III and IV. The following is included to provide a general idea of the models used.

a. Estimation of Flood Damages

Flood damages are estimated in dollars per acre for the initial year of the FPM plan. Changes over time as a result of increasing values of structure and content, or as the result of depreciation, will be accounted for in the allocation and benefit evaluation procedures. In land use allocation, flood damages are needed for all aggregate activity/subarea combinations. However, in benefit evaluation, the land uses are known. Thus, because of the possibility of a large number of damage zones, flood damages are calculated only for those detailed activity/damage zone combinations that will occur in order to keep the storage requirements low.

The procedure followed for estimating flood damages in land use allocation and benefit evaluation is presented in Figure 2.5. For land use allocation, the data consist of depth and frequency of flooding for each damage zone; composition of aggregate activities and percentage of a subarea in each damage zone; and values for structure, contents, and fixtures, and depth-damage relationships for different activity types which are given as percentages of value. As indicated in Figure 2.5, aggregate activities are considered sequentially for each reach, and flood damages are calculated for all detailed activity/flood damage zone combinations within that reach and for that aggregate activity type. These damages are then reduced to damages for aggregate activity/subarea combinations. This procedure is followed, both with and without FPM using appropriate depth-frequency information. Thus, storage is not required for all possible detailed activity/damage zone combinations.

For benefit evaluation, flood damages are calculated considering land use with and without a FPM plan in order to reduce the total storage requirements. Thus, a list of all present and future activity/parcel combinations, both with and without the plan, is prepared. Data used in calculating flood damages consist of depth and frequency of flooding, percentage of parcel in each damage zone, and depth-damage relationships as shown in Figure 2.5. Damages are then calculated, both with and without the plan, for all detailed activity/parcel combinations presented in the list.



(a) Damages for Land Use Allocation

(b) Damages for Benefit Evaluation

Figure 2.5 ESTIMATION OF FLOOD DAMAGES

b. Estimating Components of Economic Rent Differences

The components of economic rent difference, except for fixed area development, are expressed in terms of dollars per acre and are estimated for the initial year of the planning period. Changes in the value of components over time, as a result of increased productivity, are accounted for in the allocation and benefit evaluation procedures. In this section, fixed area development cost and amenity value are discussed, and procedures for estimating site development cost, transportation cost and social environment effect are outlined.

Procedures followed in preparing fixed area development cost and amenity value for future use in the program are straightforward. Fixed area development cost refers to the initial investment of providing the main interconnection of a remote area with existing road, power, water and sewage systems. This cost is incurred at the beginning of an area's development. Fixed area development cost is generally not needed in land use allocation, but is used later for benefit evaluation. The sequence in which areas with a fixed development cost develop is given as input for land use allocation. In benefit evaluation, cost of development is incurred in its entirety as soon as one subarea within the area starts to develop. The values for fixed area development cost are determined externally, and are read in for each area. No further processing of this data is needed.

Natural amenities are associated with residential activities and are defined by amenity zone. Values read in are defined by the price residential activities would be willing to pay for amenities such as a view, proximity to a lake or river, or the presence of trees and rolling hills. Although these effects can be observed in market prices for land, additional information based on interviews with residents may be needed to determine relative values of present and future willingness to pay for amenities. Annual values for amenities are obtained for each residential activity/amenity zone combination, using the private discount rate and market horizon. These values are used to derive amenity values associated with different community development/subarea combinations.

The procedure for estimating differences in site development cost is presented in Figure 2.6a. Data consist of site and activity characteristics related to site development cost and various unit costs associated with clearing,

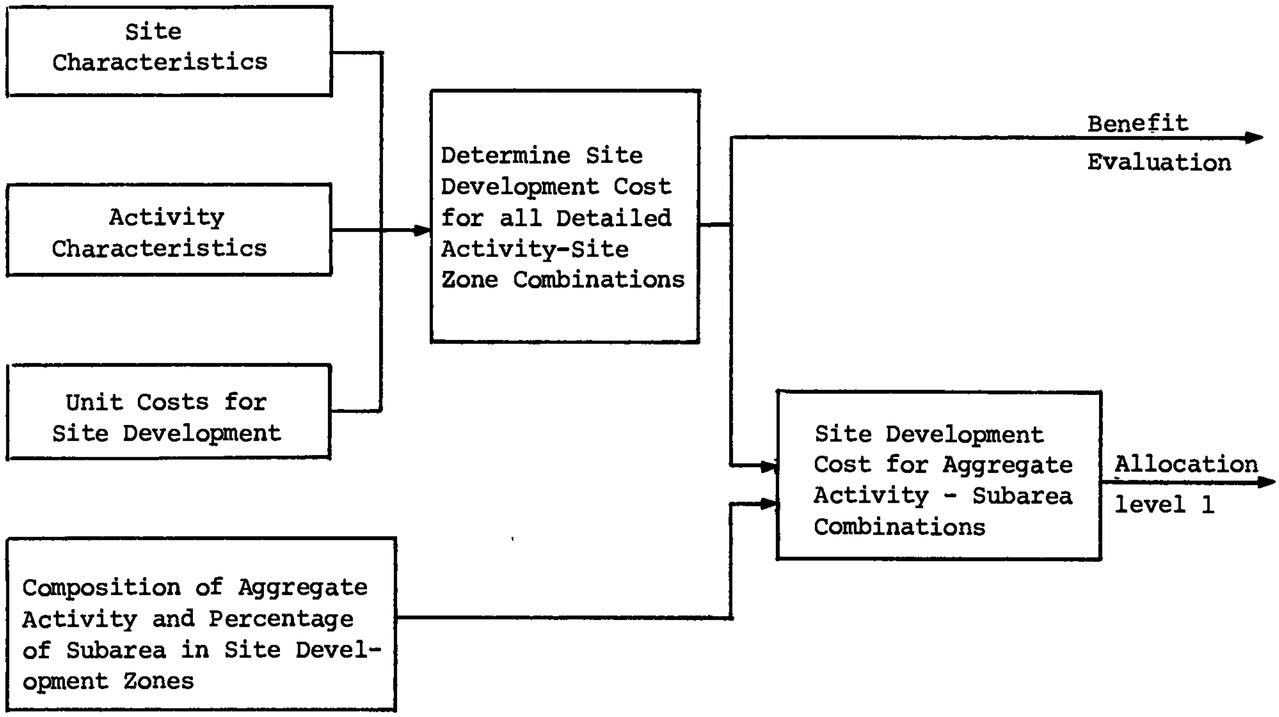


Figure 2.6a ESTIMATING SITE DEVELOPMENT COSTS

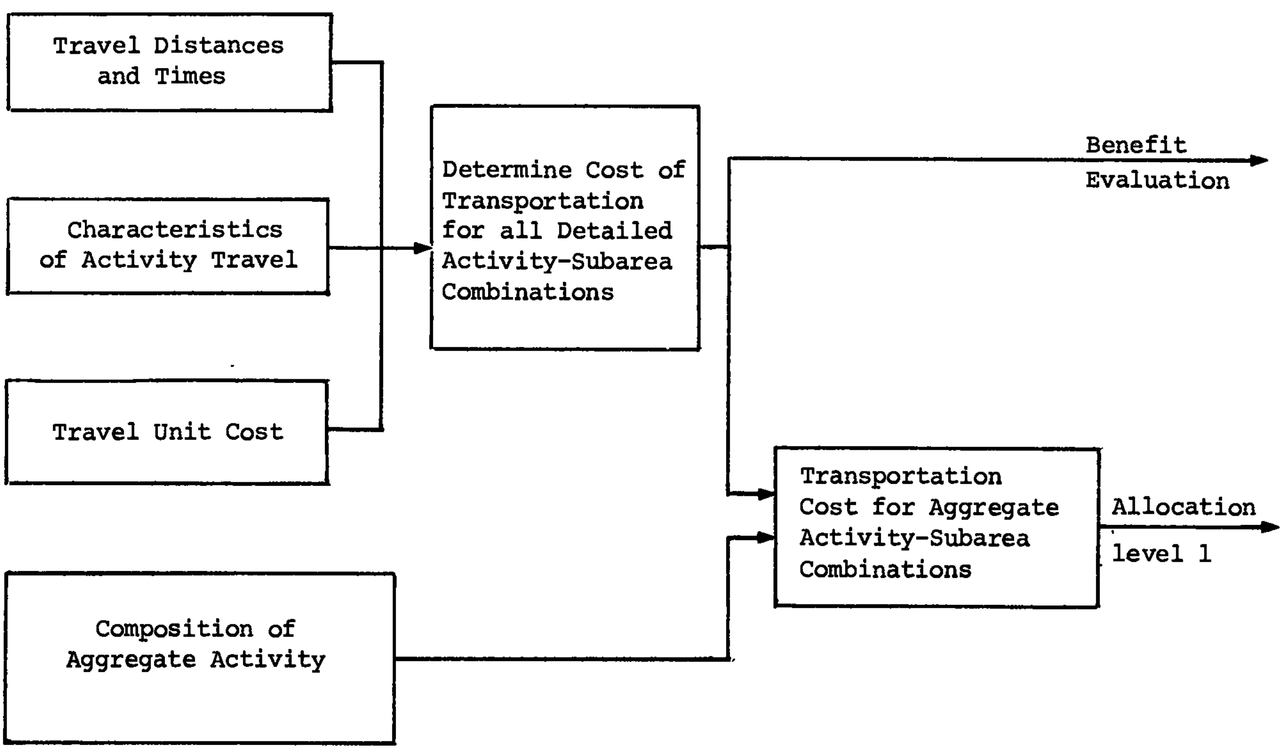


Figure 2.6b ESTIMATING TRANSPORTATION COSTS

grubbing, excavation, etc. These data are used to calculate site development cost for each detailed activity type/site zone combination. Based on these costs, on the composition of aggregate activities, and on the percentage of subareas in each development zone, site development cost for each aggregate activity/subarea combination is determined for use in land use allocation at level 1. Site development cost for each detailed activity/site development zone combination is stored for later use in benefit evaluation (See Fig. 2.4).

The procedure for estimating differences in transportation cost is presented in Figure 2.6b. Data are travel distances and travel times, activity characteristics related to transportation, and unit travel costs. In specifying travel distances and times, subareas are used as transportation zones. For residential activities, the difference in commuting cost is expressed in terms of operational cost and wages if trucks are the only mode of transportation. In all other cases, total transportation costs are needed. Based on the above data, transportation cost for all detailed activity/subarea combinations are calculated and stored for later use in benefit evaluation. In addition, these costs, together with the composition of aggregate activities, are used to determine transportation cost for aggregate activity/subarea combinations used in land use allocation at level 1.

The procedure for estimating social environment effects is summarized in Figure 2.6c. This effect is associated with the social environment, such as the change in value associated with the proximity to industry, low income housing, or project related recreation. Data consist of information on the potential interdependency between economic rents at different locations, where subareas are used as zones for the social environment effect. Only two possibilities are considered. Either there is or there is not an interdependency between economic rents at two locations; these locations may be subareas, or a subarea and an area outside the study area. Next, unit values are specified for the social environment effect of activities such as industry, low income housing or project related recreation on different residential activity types. These effects are incurred if residential activities are located in subareas in which economic rent will be influenced by these activities. As a result, social environment effect depends on present and future land uses in the area. For allocation of land use at level 1, the social environment effect for community development/subarea combinations is based on ultimate land use plans. For benefit evaluation, the social environment effect is based on updated land uses, and is determined for residential activity/subarea combinations.

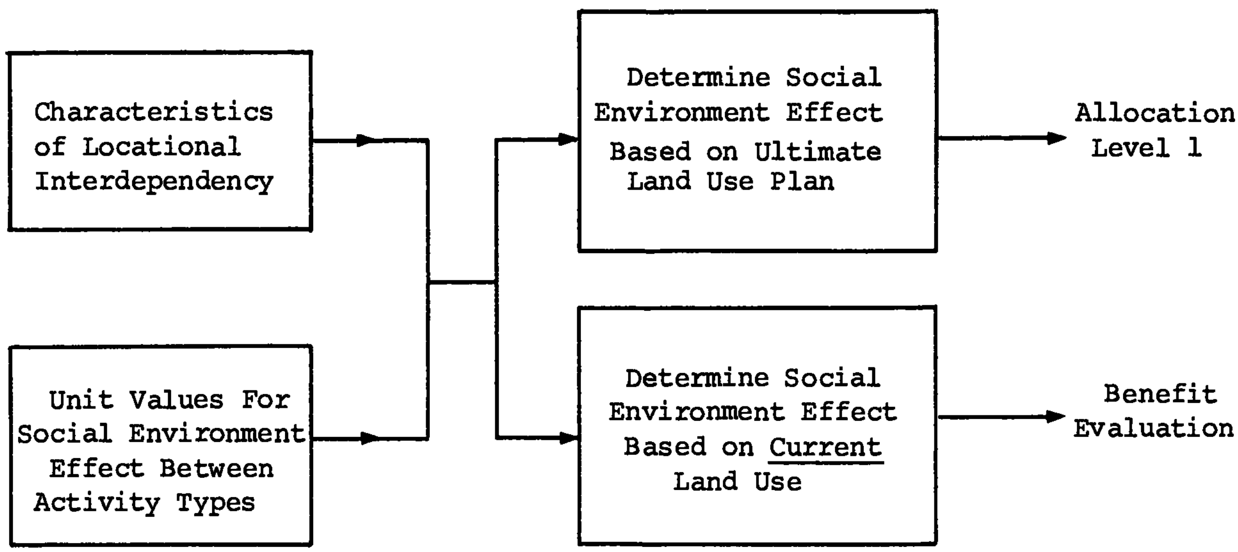


Figure 2.6c ESTIMATING SOCIAL ENVIRONMENT EFFECT

Total values for economic rent and not differences will be used for agricultural activities because sufficient data on these economic rents are available in many detailed studies performed on the productivity of land in agricultural use. For activities other than residences or agriculture, such as industrial, institutional, wholesale and distribution, region serving retail, local commercial, and public buildings, it is assumed that gross income will either not depend on location or will be compensated for by decreased or increased gross income to competing activities at other locations. Thus, the components included in estimating economic rent differences for these activities are restricted to fixed area development cost, site development cost, and transportation cost.

c. Allocation of Land Use

Allocation of land use is performed at two levels. The first level is used to arrive at a realistic land use over time, and the second level is used to provide the detail required for benefit evaluation. No overall optimal land use model is used, because available models cannot include all social and political constraints or account for the many interactions between land uses. Furthermore, the model should provide an estimate of what is likely to happen in the future rather than what would happen in an idealized situation. For these reasons, the land use model developed by INTASA is flexible and depends on interaction with the planner. The planner will consider changes in input data to the land use allocation model, such as ultimate land use plans, based on information presented by the SIMULATOR. This may result in improved land use plans and increased total net economic rents.

The procedure for allocating land uses is presented in Figure 2.7. Data used at level 1 are ultimate land use plans for the study area in terms of acres reserved for each aggregate activity in different subareas; land requirements at the end of each allocation period by aggregate activity type; economic rent differences and flood damages by aggregate activity type and subarea; and sequence in which areas with a fixed development cost will be used. Using the above information, activities are located by the highest present value of net economic rent to subareas included in the first area to be developed. Once the first area is filled, the next one is considered, and so on. Alternatively, the sequence of subarea development may be provided externally, thus allowing the planner to evaluate alternative patterns of development. This is useful when performing sensitivity studies on FPM plans, especially related to flood plain zoning. At the end of allocation at level 1, the program can be stopped to review the resulting allocation over time. The ultimate land use plan may be changed then, if desired. Allocation at level 1 is therefore an iterative procedure, and requires close interaction between the land use planner and the model.

Allocation at level 1, which is the crucial part of the model, concentrates on the first order of influence of regional infrastructure, interdependency of activity types and locations, and future land use potential. It locates aggregate activities to subareas for each allocation period. Aggregating activities assures that activities depending on each other locate together, i.e., residences and local commercial activities. Subareas are used to assure that the area develops along reasonable patterns and that contiguous areas

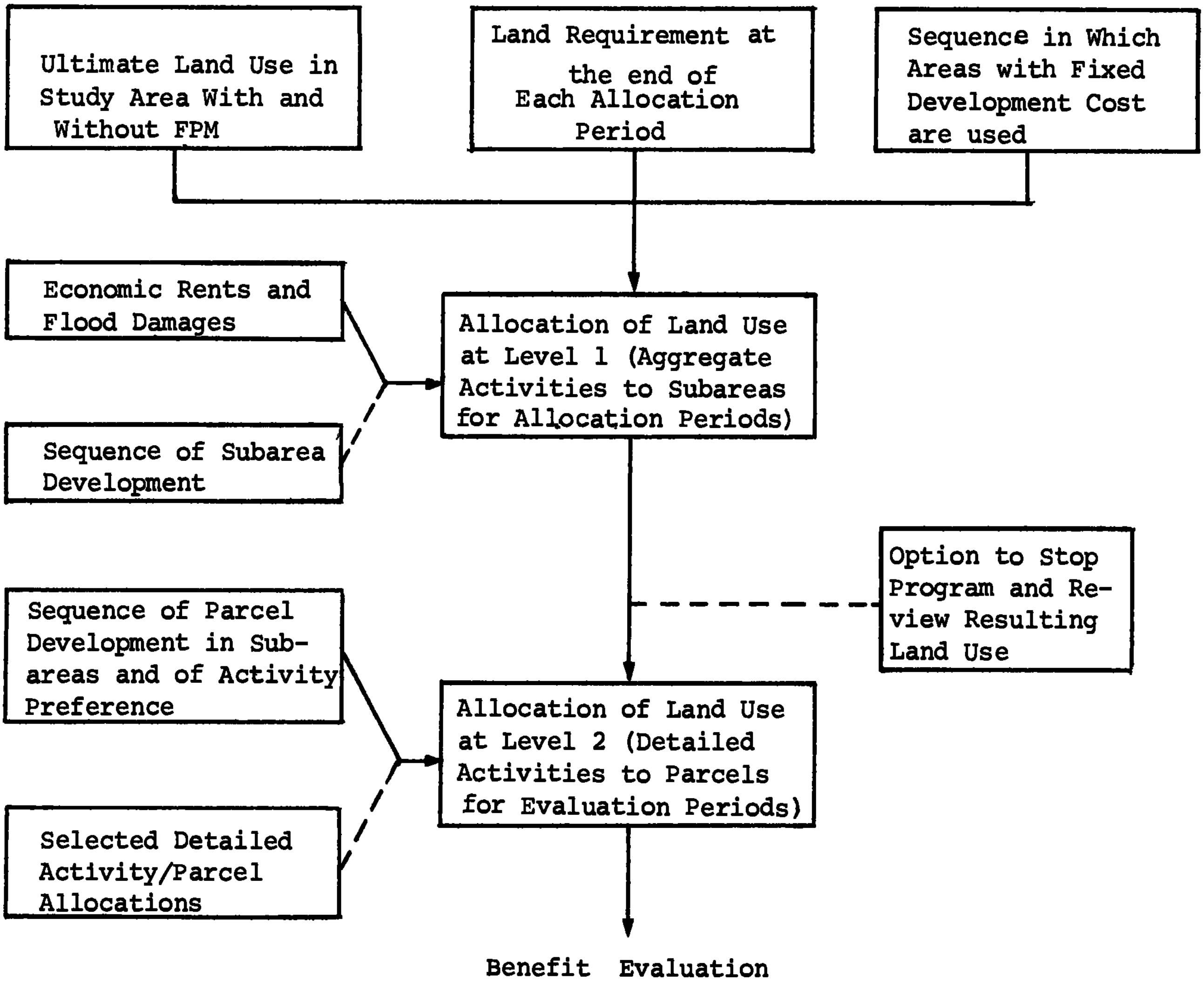


Figure 2.7 LAND USE ALLOCATION

develop as a unit. Ultimate land use plans constrain land use and make it possible to reserve land for future uses. The planner interacts with the land use model by specifying alternative ultimate land use plans. The results of allocation at level 1 are used to determine the location of detailed activities to parcels for each evaluation period.

Allocation at level 2 uses the results of the allocation at level 1 together with input data provided by the planner on ordering of parcels within each subarea, and the sequence in which detailed activities may choose their location in a subarea. By providing this data, the planner can include his knowledge on special conditions and interdependencies. At the same time, benefits from FPM are not expected to be very sensitive to the exact sequence of parcel development, and thus a simple allocation procedure is desirable. When more information on location of certain detailed activities is available, this data may be specified separately and be included in the allocation, as indicated in the Figure 2.7. Level 2 provides the benefit evaluation procedure with the allocation of detailed activity types to parcels at the end of every evaluation period.

For benefit evaluation, land uses that are the same with and without FPM, and land uses that are different are needed. For this purpose, existing uses of the flood plain at the time of the study as well as its future uses before the start of the project are provided as input to the SIMULATOR. Additional land uses during each evaluation period with and without FPM are compared, and the list of detailed activity/parcel combinations that locate the same and that locate differently with and without FPM is kept current.

d. Benefit Evaluation

In evaluating benefits from a FPM plan, values for flood damages, economic rent components and the land values are required at the end of each evaluation period. These are determined by values during the initial year of the plan and percentage increases or decreases over time. Changes over time are the result of depreciation of structures and of increases in economic rent components, land values, and values of structures, contents and fixtures due to increases in productivity or personal income. Present value of FPM benefits is the sum of discounted benefits during each year of the total planning horizon. For the purpose of determining benefits during each year, the increase in land use within each evaluation period is assumed to be constant. As a result, site development cost during each period is constant, while the remaining values for economic rent components and flood damages are obtained by linear interpolation.

Damage reduction is the proper benefit measure when land use is the same with and without the FPM plan (Ref. 2). The procedure for its determination at the end of an evaluation period is outlined in Figure 2.8. Land uses that are the same with and without the plan are separated into land uses existing at the time of the study and future land uses. For each relevant activity/parcel combination, damage reductions are obtained from the list that provides expected damages during the initial year of the plan. These damages may be adjusted for changes in values of structure, contents and fixtures. Damage reduction is derived separately for existing and future land uses, and is summed in order to measure benefits for activities that locate the same with and without the plan.

Locational advantage is the proper benefit measure when land use is different with and without the plan (Ref. 2). Three different formulas for measuring locational advantage are included in the SIMULATOR. The first method, using economic rents and flood damages, is illustrated in Figure 2.9a. Contributions of economic rent components and damages are determined during the evaluation period for land uses with the plan. Then these same contributions for land uses without the plan are subtracted. The result is the difference in economic rents and in flood damages associated with land uses with and without FPM. The sum of these two differences provides the locational advantage.

The second method uses land values and flood damages, and is illustrated in Figure 2.9b. Land values are determined for the evaluation period under the assumption that there is no flooding. The procedure followed in estimating locational advantage is the same as when using economic rents, except that economic rent components are displaced by land values.

The third method uses both economic rents and land values, in addition to flood damages. Economic rents and flood damages are used for activities that are expected to contribute heavily to benefits, that is for activities that locate in the flood plain with the plan, and outside the flood plain without the plan. In addition, if there is any change in an activity's location within the flood plain as a result of the plan, the associated change in flood damages to

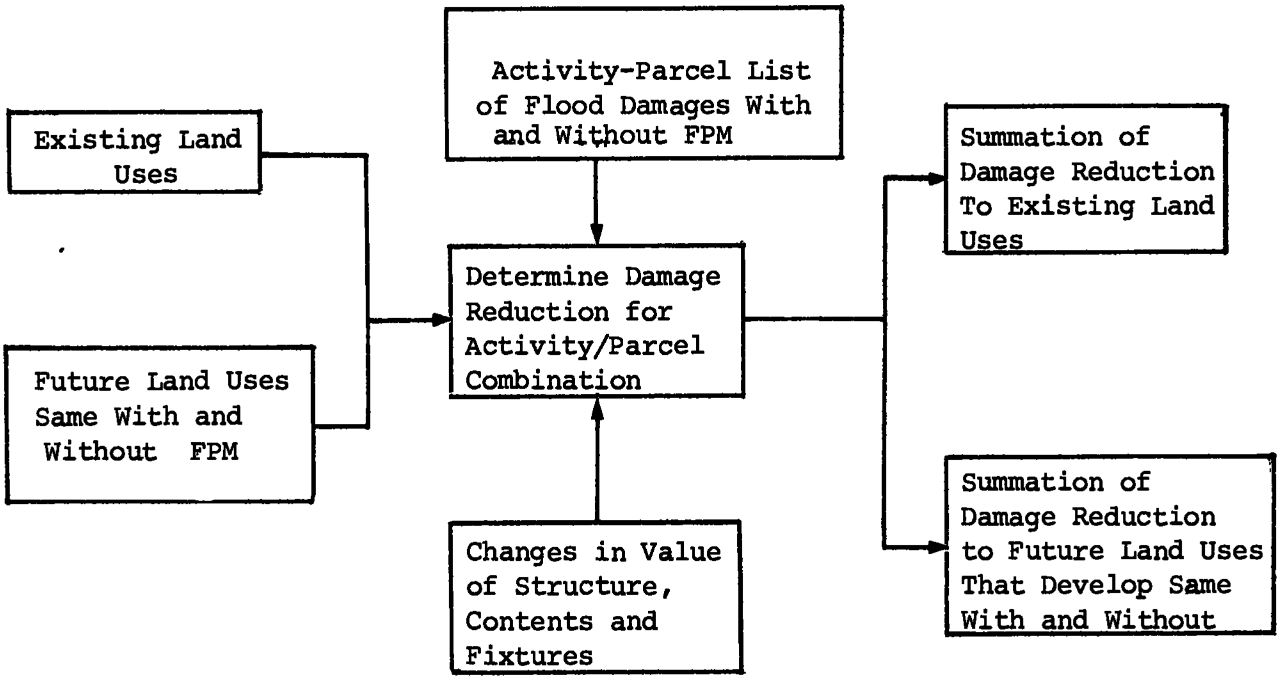


Figure 2.8 EVALUATION OF DAMAGE REDUCTION

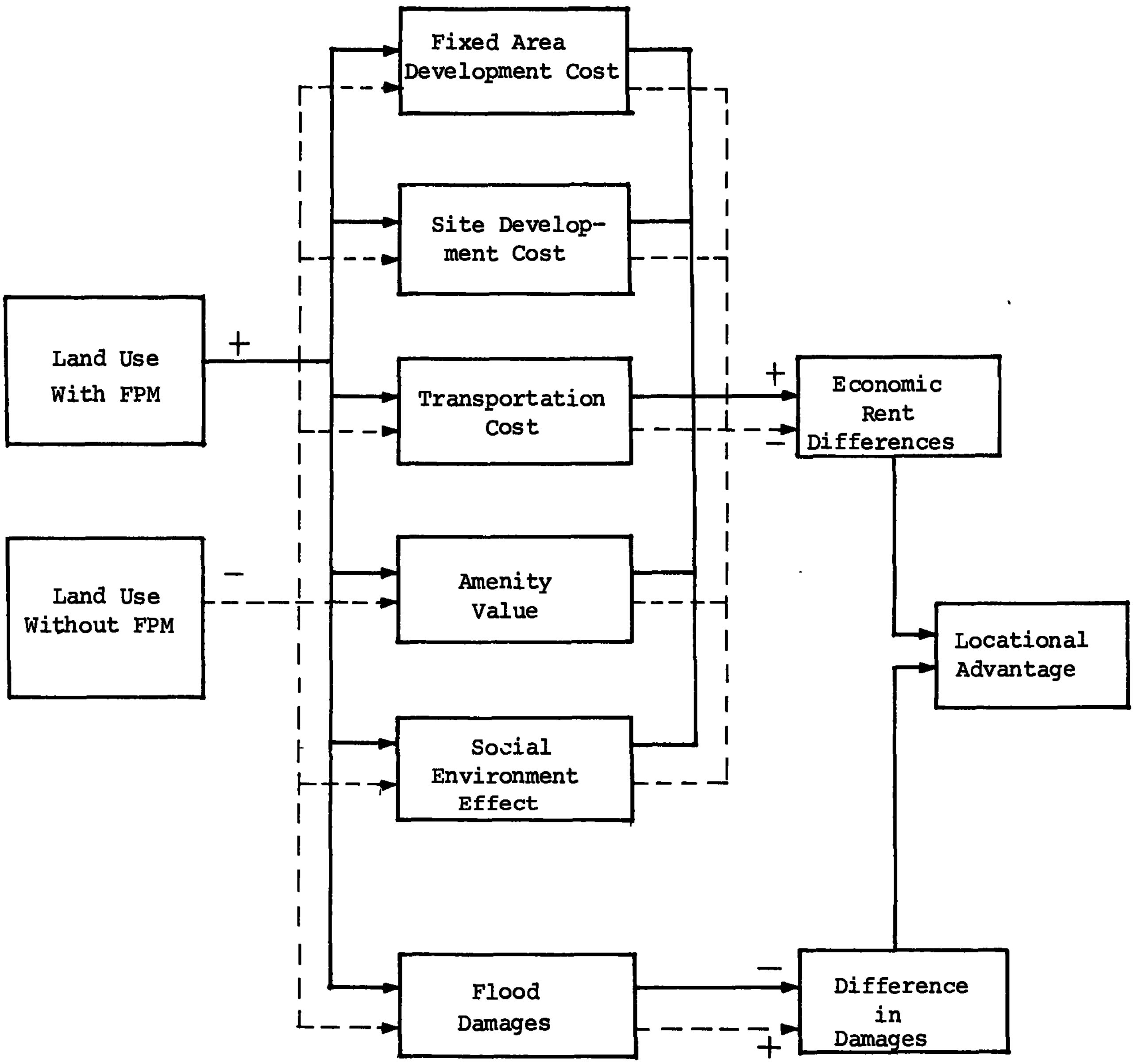


Figure 2.9a. ESTIMATING LOCATIONAL ADVANTAGE USING ECONOMIC RENT FORMULA

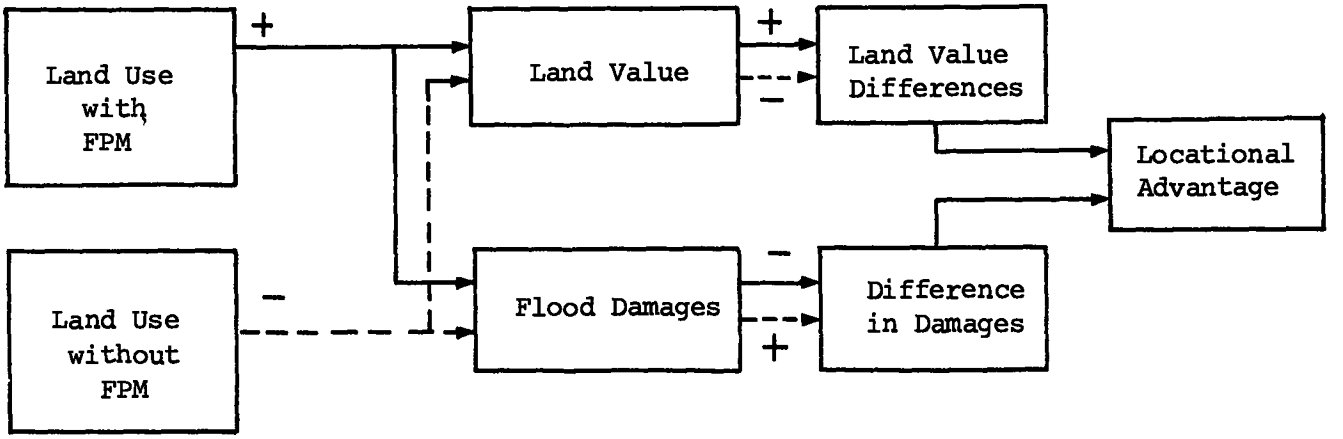


Figure 2.9b ESTIMATING LOCATIONAL ADVANTAGE USING LAND VALUE FORMULA

that activity is included as a part of locational advantage. The benefits due to relocation of the remaining activities are expected to contribute only a small part to the total benefits, and are approximated by land value differences. A more detailed discussion of this approximate method of benefit measurement is given in Reference 2.

F. Summary

The SIMULATOR was summarized in general terms in order to provide an overall understanding of its capabilities including input data requirements. Advantages of the SIMULATOR for benefit evaluation were presented; and proper measures for the evaluation of benefits from a FPM plan were derived and illustrated with an example. It was demonstrated that for land uses which are the same with and without the plan, benefits should be measured by damage reduction; for land uses which are different, benefits should be measured by locational advantage. The relationship of several basic concepts associated with different levels of aggregating geographic areas and economic activities was presented, and the need for these different levels was discussed.

The general layout of the SIMULATOR was presented including a description of overlay structures and data files. It was observed that these overlay structures and data files keep the total storage requirements below 100K (octal), and allow for replacement of certain program functions without interfering with the rest of the program. The example of the NED case study was given, in which the cost for one run was under ten dollars, in order to demonstrate that the SIMULATOR is a practical tool for FPM studies.

The main program functions were described and included general summaries of models used for estimation of flood damages, estimation of economic rent differences, allocation of land uses, and benefit evaluation. Cost components of economic rent included differences in fixed area development cost, site development cost, transportation costs, amenity values and social environment effects. The model for land use allocation described level 1 and level 2 allocation procedures, where the first level locates aggregate activities to subareas at the end of each allocation period and is used to arrive at a realistic land use allocation over time; and where the second level locates detailed activities to parcels during each evaluation period and is used in benefit evaluation. Finally, the benefit evaluation procedure, which determines damage reduction and locational advantage at the end of each evaluation period and provides present value of the annual benefit, was described. Alternative measures for locational advantage were presented. These included the economic rent formula, land value formula, and economic rent/land value difference.

Chapter III

ESTIMATION OF FLOOD DAMAGES AND ECONOMIC RENT DIFFERENCES

A. Introduction

The models used in the SIMULATOR for estimating flood damages and economic rent differences are described in this chapter. The procedures developed for determining economic rent include: fixed area development cost, site development cost, transportation cost, amenity value and social environment effect. The description of models is in general terms; details of the program are presented in the Programmer's Manual (Ref. 8). The models for economic rent components are of a preliminary nature, and improvements are expected when more experience is gained through field implementation.

B. Estimation of Flood Damages

In order to evaluate benefits of alternative FPM plans, expected annual damages must be calculated throughout the flood plain under a number of different conditions. For example, flood control projects with different levels of protection may be considered by changing the stage-frequency curves. Other examples include the estimation of damages when flood proofing is provided using land fill to change elevation of the flood plain; or when the damage susceptibility of structures, contents and fixtures is reduced by using flood walls, improved construction materials, or flood warnings. In this section, the model used for estimating flood damages is presented, and the procedure followed in using the model is described (Refs. 14 and 15).

1. Flood Damage Estimation Model

Expected annual damages, for activity x at location k with FPM plan P is determined by:

$$r(x,k;P) = V(x) \int_0^1 G\,(f;X,Z,R,P)\;df \qquad (3.1)$$

where,

x and k	indicate a damageable component and a location, respectively;
P	indicates the FPM plan;
r(x,k;P)	is the expected annual damage to component x at location k with plan P;
V(x)	is the value of the damageable component x;
f	is the flood frequency;
X	indicates the class of component that has the same damage susceptibility as x but may have different values;
Z	indicates zones with uniform flood damage;
R	is a reach where the stage difference between two floods is constant;
G(f;X,Z,R,P)	is the damage factor for a flood with frequency f associated with an activity of class X in damage zone Z of Reach R given plan P.

Integration over frequency f provides the expected annual damage factor, which is applied to the value of the damageable component in order to determine its expected annual damage.

The curve G(f;X,Z,R,P), which gives the damage factor as a function of frequency f, is obtained by combining two other curves (see Fig. 3.1). The first curve, H(d;X), gives the damage factor as a function of depth of flooding for different classes of damageable components. The second curve, d(f;Z,R,P), gives depth of flooding as a function of frequency of flooding for a particular damage zone Z in Reach R given plan P. By substituting this last function for depth of flooding in H(d;X), the curve G(f;X,Z,R,P) is obtained. The expected annual damage factor is then derived by integration over f, as illustrated in Figure 3.1.

In specifying depth of flooding as a function of frequency, a reference flood is used in order to reduce the input data requirement. The relationship used is illustrated in Figure 3.2 and is given by

$$d(f;Z,R,P) = s(f;R,P) + d(f_r;Z,R,P_r) \qquad (3.2)$$

where

$d(f;Z,R,P)$	is depth of a flood with frequency f in damage zone Z of Reach R given plan P;
$s(f;R,P)$	is stage of a flood with frequency f in Reach R given plan P, and measured with respect to the reference flood;
f_r	is frequency of the reference flood;
P_r	is the plan under which the reference flood is defined.

From the above equation it follows that it is sufficient to provide stages of sample floods measured with respect to the reference flood together with depth of the reference flood in each damage zone. Using the relationship in Equation (3.2), the depth of flooding for all sample floods in each damage zone is derived.

2. Use of Flood Damage Estimation Model

The flood plain is divided into reaches based on flood profiles for different sample floods, on stream velocity, and on amount of sediment and debris. Reaches are chosen so that stage differences between sample floods is approximately constant throughout a reach, as shown in the example in Figure 3.3. In addition, the velocity and amount of sediment and debris should be uniform throughout the reach. The same reaches will be used for all FPM alternatives, and therefore, sample flood profiles for all alternative flood control measures are considered when choosing reaches.

The random nature of flooding in each reach is characterized by stage-frequency curves, $s(f;R,P)$, where stage is measured with respect to a reference flood in order to reduce the total data. The stage-frequency curve is valid throughout the reach, which is equivalent to assuming that all floods in the reach are parallel to the stream bed at distances specified by the stage-frequency curve (see Fig. 3.3). The stage-frequency curves are specified by frequencies and stages for several sample floods. To form end points of the curve, both the highest flood that causes no damage and the maximum probable flood are included as sample floods. Each reach is divided into flood damage zones so that depth of flooding is approximately the same throughout the zone. Given depth of the reference flood in the damage zone, $d(f_r;Z,R,P_r)$ depths of

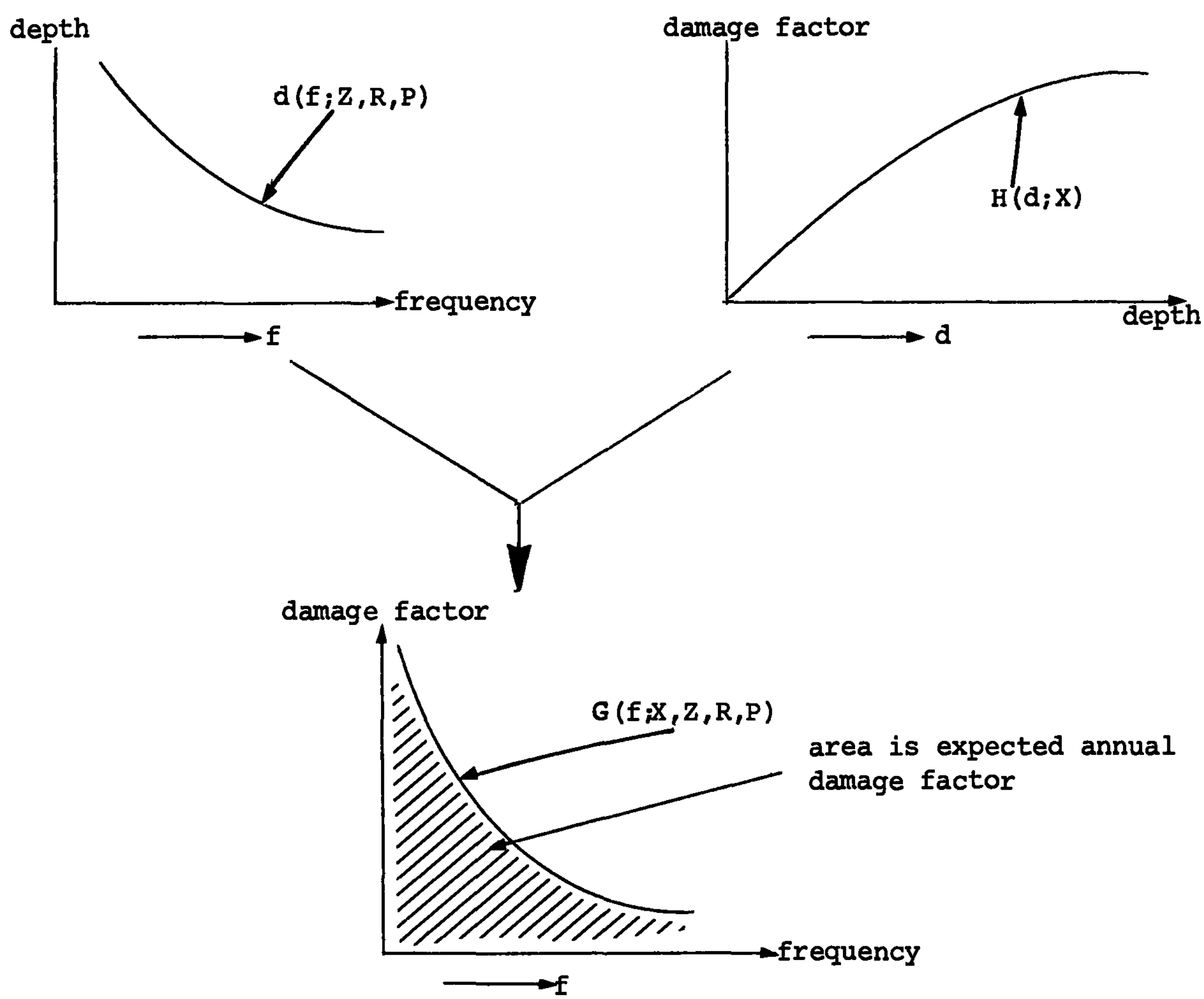


Figure 3.1 CALCULATION OF EXPECTED ANNUAL DAMAGE FACTOR

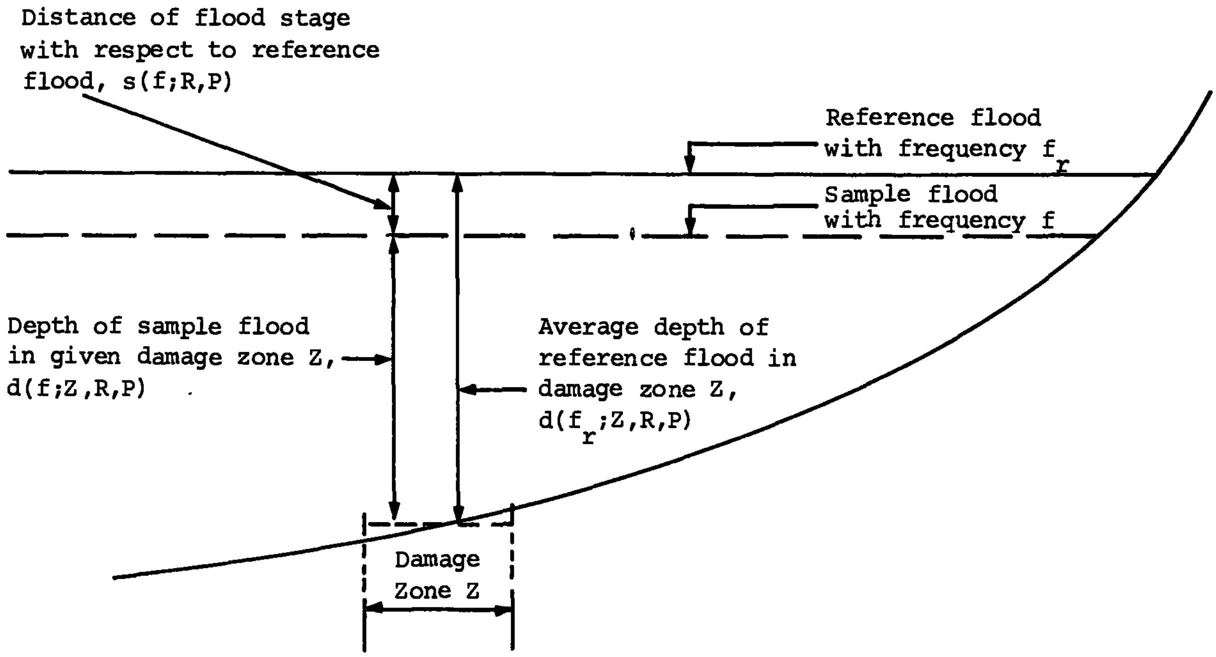


Figure 3.2 THE USE OF A REFERENCE FLOOD

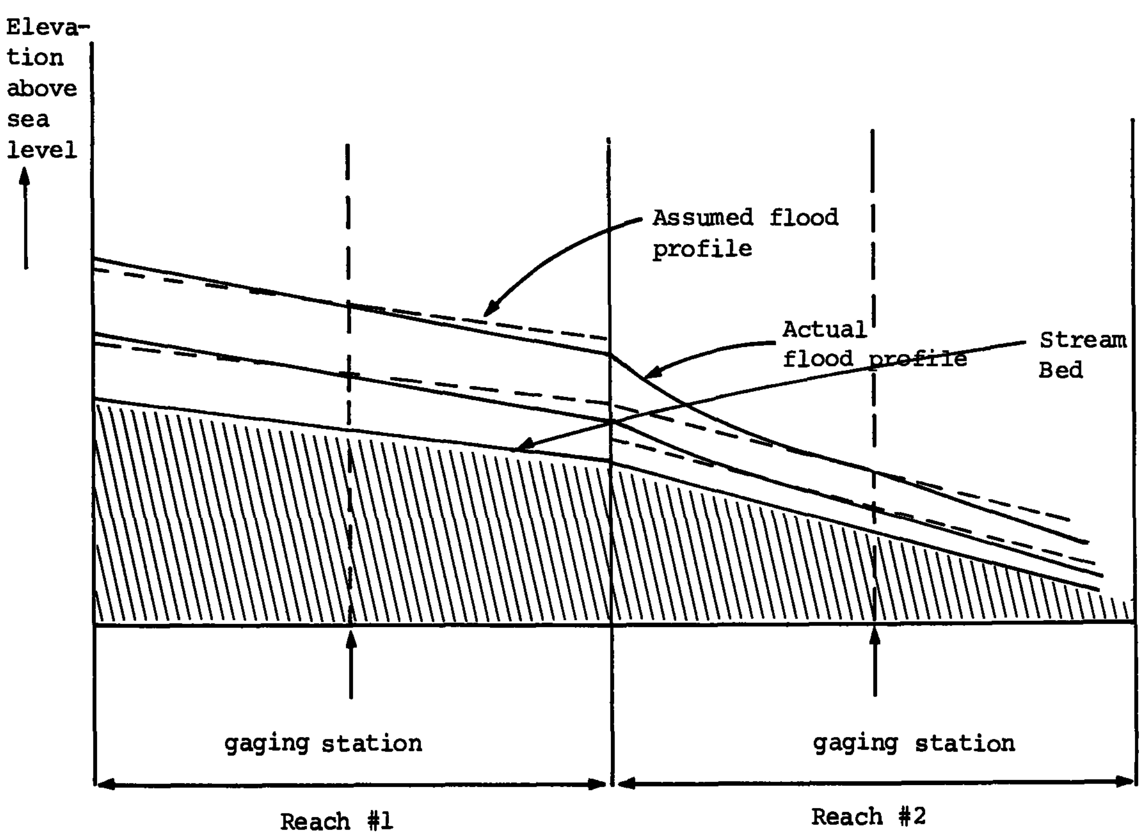


Figure 3.3 REACHES AND FLOOD PROFILES

all sample floods can be derived from the stage-frequency curve, as illustrated in Figure 3.2.

For the calculation of expected annual damages, additional data is needed to relate depth of flooding to damages; (1) for physical damages, the relationship is given by a damage factor-depth curve for structure, contents and possibly fixtures, of each residential structure type and nonresidential activity type, and by associated values of these damageable components. The damage factor-depth curve gives physical damage to a particular damageable component as a function of depth of flooding, where a physical damage is expressed as a fraction of the value of the damageable component. Thus, for a particular damageable component, damages are assumed proportional to value of that component. Different curves are used for structures, contents and fixtures because their susceptibility to damages is not the same. (2) For nonphysical damages such as loss of income, the relationship between depth of flooding and damages can be expressed as a fraction of an activity's total expected physical damages; or by the maximum amount of nonphysical losses and the associated damage factor-depth curve, which expresses amount of loss as a fraction of the maximum.

Thus, for a particular damageable component and flood damage zone, the depth-frequency curve of the damage zone is combined with the approximate damage factor-depth curve, in order to obtain the damage factor-frequency curve, as indicated in Figure 3.1. The area under the damage factor-frequency curve is the expected annual damage factor and is obtained by integration. By multiplying this area by value of the damageable component, expected annual damage for the particular combination of damageable component and damage zone is obtained. This procedure is followed in estimating expected annual damages for structures, contents and fixtures. Expected annual nonphysical damage can be obtained using a similar procedure, or by multiplying the total physical damages by a nonphysical damage factor.

As described in Chapter II, Section E, damage calculations are performed separately for land use allocation and benefit evaluation in order to reduce the overall storage requirement.

C. Estimation of Economic Rent Components

Economic rent differences are needed for the evaluation of benefits measured by locational advantage. The models used to quantify elements comprising economic rent are described in the following subsections.

1. Fixed Area Development Cost

Fixed area development cost is determined outside of the program and is read in as total dollar costs. In benefit evaluation, it is assumed that this cost is incurred as the initial investment when one subarea within a group starts to develop. Thus, part of the benefit from a FPM plan may be the result of differences in timing of the fixed area development costs with and without the plan.

2. Site Development Cost

For a particular activity, simple models are used to determine site development cost differences between alternative locations in order to capture components of the locational advantage associated with preparing sites and constructing buildings. Because only differences are needed, site preparation and construction costs that are independent of the site need not be considered (Refs. 16, 17,18). These component costs are summed and the total cost, referred to as site development cost, is expressed as follows:

$$D_{ik} = C(s_k;c) + R(a_i,s_k;c) + F(a_i,s_k;c) + U(a_i,s_k;c) + S(a_i,s_k) \qquad (3.3)$$

where

D_{ik}	gives site development costs per acre associated with locating activity i on site k, and includes those parts of site preparation and construction costs that are dependent on location;
a_i	indicates descriptive characteristics of activity i;
s_k	indicates descriptive characteristics of site k;
c	indicates unit costs;
$C(s_k;c)$	gives clearing, grubbing and landscaping costs for site k;
$R(a_i,s_k;c)$	is the cost of roads associated with locating activity i on site k;

$F(a_i;s_k;c)$ is the foundation and parking lot excavation cost associated with locating activity i on site k;

$U(a_i,s_k;c)$ is the utility and connection trench excavation cost associated with locating activity i on site k;

$S(a_i,s_k)$ is a special cost associated with locating activity i on site k.

As seen in Equation (3.3), data for the calculation of site development cost is divided into three types: (1) data that characterize the activity types, (2) data that describe site characteristics, and (3) unit cost data. Required activity characteristics are lot size, ground floor space, foundation excavation on level ground, length and depth of trenches, length of public and private roads, and for a residential activity, the structure type. Site characteristics include slope, soil composition, density of vegetation, and soil bearing capacity. Unit costs include labor, equipment and material costs for excavation, clearing, grubbing, debris disposal, planting and protecting trees, and road building. (Unit cost data are optional because the program can default to internal values.) Based on the above data, each component of site development cost is calculated using models described in this section. Costs are calculated for each detailed activity/site zone combination, as well as for each aggregate activity/subarea combination as described in Chapter II, Section E.

a. Site Development Cost Associated With Site Preparation

The cost of site preparation, $C(s_k;c)$, is independent of activity type and includes grubbing, clearing, disposal of debris and basic landscaping which refers to planting or protecting trees. Site costs per acre for these categories are available in cost estimating handbooks (Ref.18), or can be obtained from the Cost Estimation Section of the Corps of Engineers and from local construction firms. Thus, no further modeling of site preparation cost is required.

b. Site Development Cost Associated With Roads

The components of cost of road building that are sensitive to location, $R(a_i,s_k;c)$, are road material cost, and excavation and filling costs. Road material cost depends on the soil bearing capability, which influences the cross sectional road design. The model used in the program determines thickness design parameters for base and subbase layers, as indicated in Figure 3.4. Given the

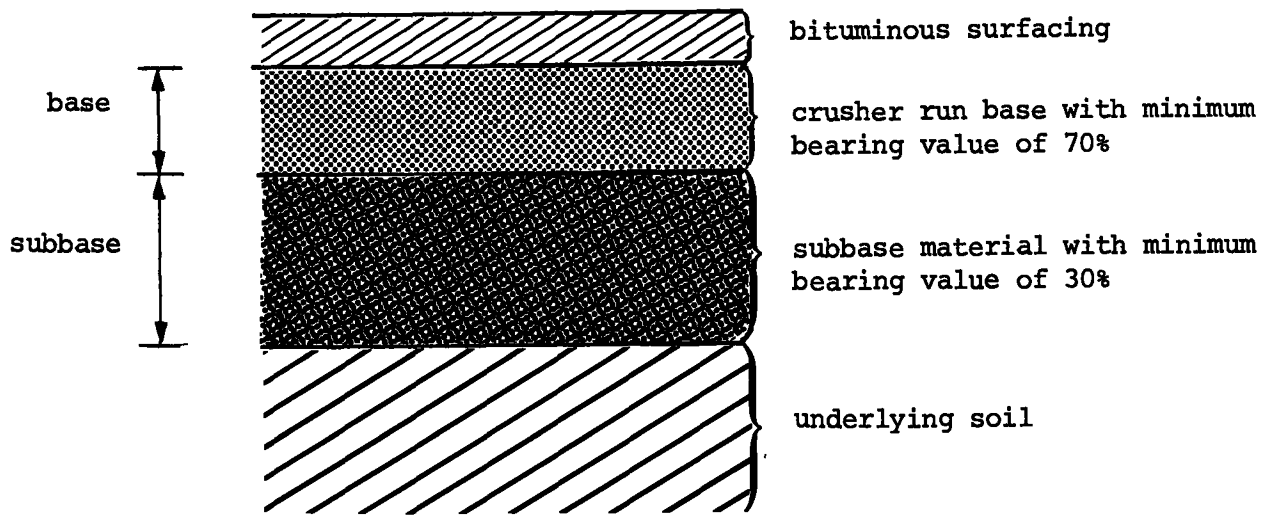


Figure 3.4 CROSS SECTION DESIGN OF ROADWAY

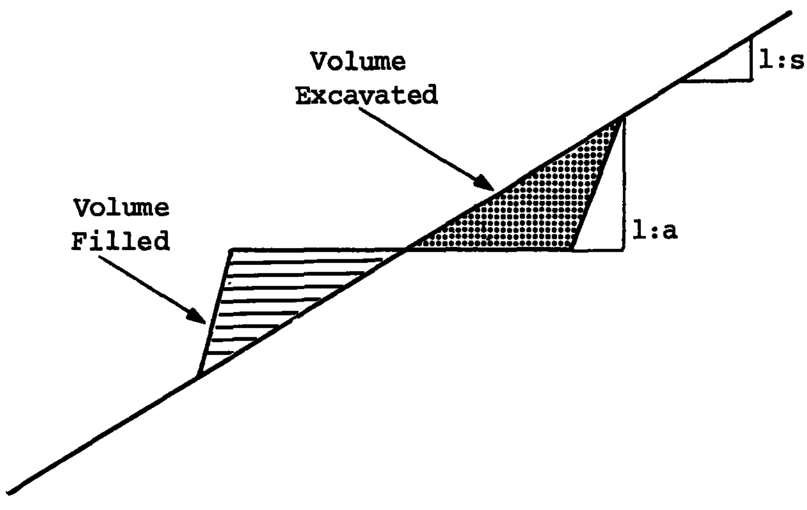


Figure 3.5 ROADWAY EXCAVATION

California bearing ratio (CBR) of underlying soil, and assuming a roadbed of 30 feet wide using 30 CBR subbase material and 70 CBR base material, thickness parameters are determined and convered into cubic yards of material per linear foot of road. Unit cost data for these materials are used to obtain the cost of road material.

The cost of excavating and filling depends on slope and soil composition. The effect of slope on excavation cost is examined by considering total excavation requirements as a function of slope. Excavation in cubic yards per linear foot of roadway running across the slope is estimated following Figure 3.5. In the program, embankments of 1:2 are used for common earth and 1:4 for rock. The linear footage of roads per acre is computed using lot size and feet of public road per lot for each activity type. An approximation for percentage of roads running across the slope is made as shown in Figure 3.6. Using this percentage relationship, total footage of roads per acre running across the slope is determined. Total road excavation per acre is then obtained by multiplying this footage of roads by the volume excavated per linear foot. Finally, total road excavation cost is determined by multiplying excavation in cubic yards by cost of excavation per cubic yard. This last cost depends on soil type, which therefore affects excavation cost. In a similar way, the total road fill cost per acre is determined.

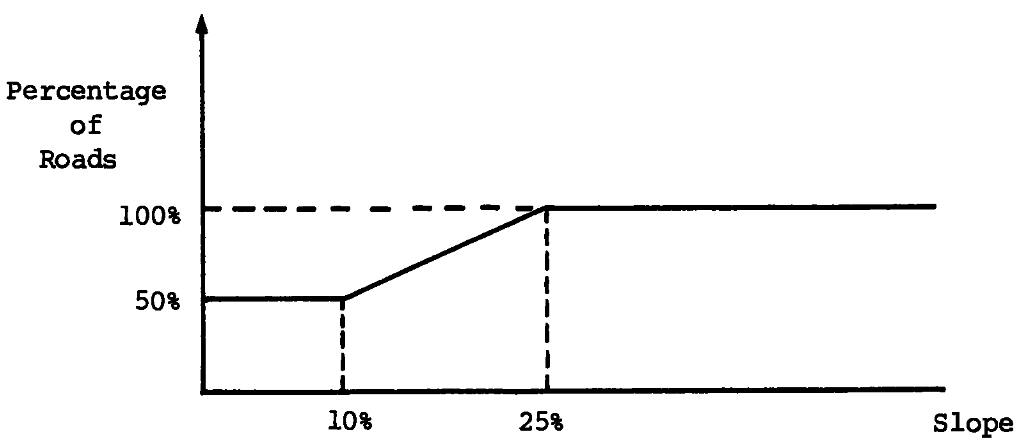


Figure 3.6 PERCENTAGE OF ROADS RUNNING ACROSS SLOPE AS A FUNCTION OF SLOPE

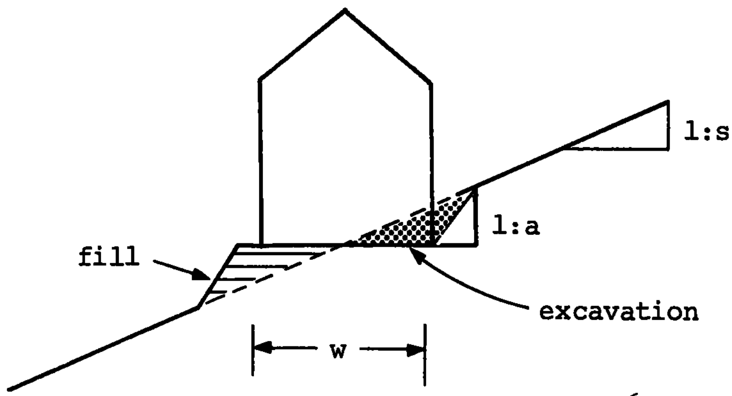
c. Site Development Cost Associated With Foundation and Parking Lot Excavation

Foundation costs vary from site to site as a result of soil bearing characteristics, soil type and slope. Building code specifications for foundations are usually generous so that foundation dimensions are adequate for a wide range of soil bearing capabilities. Deviations from this occur in practice only when pilings or special supports are needed which are included under special costs.

The foundation costs component of site development, $F(a_i, s_k; c)$, depends on excavation, where amount of excavation required varies with slope, and unit costs of excavating with soil type. The model for determining the increase in foundation excavation and filling requirements, as a result of slope, is illustrated in Figure 3.7 for a one story house without basement. The dotted area must be excavated over a length of the house where the length is assumed to be twice the width. The striped area must be filled over the same length. Variations in this model account for other structural types, such as split level construction, residences with basement and apartment buildings with parking lots. Volume to be excavated as a result of slope is added to that normally required on flat land. This sum is multiplied by unit excavation cost, based on soil composition, to obtain the total excavation cost. Similarly, volume to be filled as a result of slope is multiplied by the appropriate unit fill cost. The sum of excavation and fill costs gives the part of foundation cost that depends on site characteristics.

d. Site Development Cost Associated With Trenches

The cost of providing utilities to a site, $U(a_i, s_k; c)$, varies with trench excavation costs, while the cost of utility lines is fairly constant. Excavation costs depend on soil type, length of trench, and trench depth, where the latter depends on slope. The overall linear footage of main utility trenches is given in proportion to public road footage, while the footage of trench connecting main trenches to the structure is specified separately. A typical layout of trenches is indicated in Figure 3.8. Using depth and width of the main utility trenches and associated total footage per acre, the total volume of excavation for each main utility trench per acre is calculated. Similarly, for the connection trenches, volume excavated per connection trench multiplied by



1:a is embankment slope

1:s is site slope

Figure 3.7 FOUNDATION EXCAVATION FOR ONE STORY HOUSE WITHOUT BASEMENT

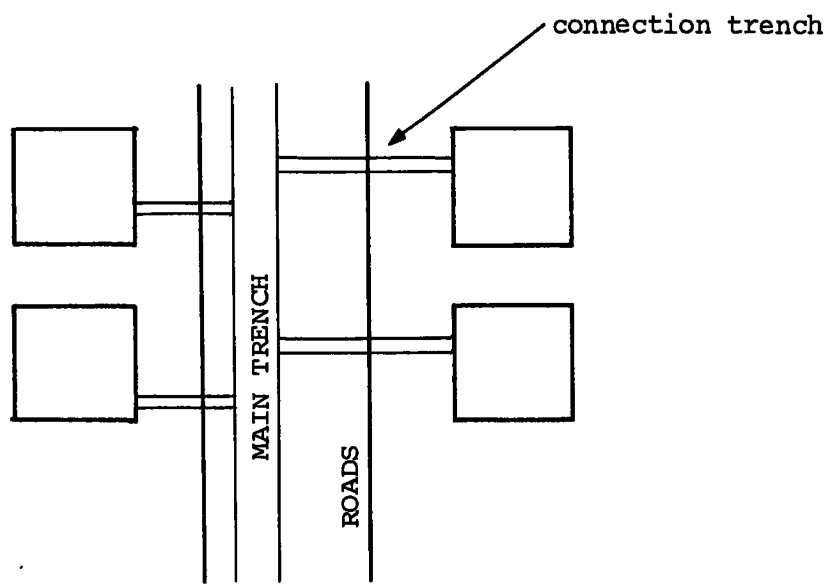


Figure 3.8 TYPICAL TRENCH LAYOUT

density of structures per acre gives the total volume excavated per acre. Multiplying the volumes for each trench type by excavation cost associated with soil type yields the part of site development costs related to trenching.

e. Special Costs

The special cost component of economic rent, $S(a_i, s_k)$, is needed in order to include costs peculiar to a particular study. Examples of such costs are piling and waterproofing. These costs are indicated for the activity/site development zone combination for which they apply, and are calculated outside of the program.

3. Transportation Cost

The economic rent component of locational advantage related to transportation measures the difference in transportation cost for activities between two locations. For the general case, transportation cost difference for activity i at two locations ℓ and k is expressed as follows:

$$\Delta T(i,\ell,K) = C(D_{i\ell}, H_{i\ell}, Q_i, M_{i\ell}) - C(D_{ik}, H_{ik}, Q_i, M_{ik}) \qquad (3.4)$$

where,

i	is an activity, and ℓ and k are locations;
$\Delta T(i,\ell,k)$	is the annual transportation cost difference for one acre of activity i between locations ℓ and k;
$D_{i\ell}$	is the distance from location ℓ to activity i's center of destination;
$H_{i\ell}$	is the travel time from location ℓ to activity i's center of destination;
Q_i	is the annual quantity to be transported per acre of activity i, which may be given in number of trips or in tonnage per year;
$M_{i\ell}$	is the mode of transportation used by activity i from location ℓ, and includes the unit costs associated with that mode;
$C(D_{i\ell}, H_{i\ell}, Q_i, M_{i\ell})$	is the total annual transportation cost for one acre of activity i at location ℓ.

If, for activity i, the mode of transportation from locations ℓ and k is a car or truck, then the expression in Equation (3.4) can be simplified as follows:

$$\Delta T(i,\ell,k) = \Delta C_1(\Delta D_{i\ell k},Q_i,M_i) + \Delta C_2(\Delta H_{i\ell k},Q_i,M_i) \qquad (3.5)$$

where

$\Delta D_{i\ell k}$	is the difference in distance between locations ℓ and k to activity i's center of destination, or $\Delta D_{i\ell k} = D_{i\ell} - D_{ik}$;
$\Delta H_{i\ell k}$	is the difference in travel time between locations ℓ and k to activity i's center of destination, or $\Delta H_{i\ell k} = H_{i\ell} - H_{ik}$;
$\Delta C_1(\Delta D_{i\ell k},Q_i,M_i)$	is the difference in operating cost between location ℓ and k using transportation mode M_i;
$\Delta C_2(\Delta H_{i\ell k},Q_i,M_i)$	is the difference in value of travel time or wages between locations ℓ and k using transportation mode M_i.

In the following, the procedure used for determining the transportation cost for detailed activity/subarea combinations is described in general terms, where subareas are used as transportation zones. This transportation cost difference is used to obtain the transportation cost for each aggregate activity/subarea combination, as described in Chapter II, Section E.

a. Residential Activities

For residential activities, commuting to and from work is the largest transportation cost dependent on location. In the model, locational advantage related to transportation is assumed equal to the difference in commuting cost. It is further assumed that all commuting occurs by private automobiles (a more sophisticated model would be needed to allow for public transportation). For a residential activity, the transportation cost difference between two subareas ℓ and k can be estimated following Equation (3.5), or

$$\Delta T(i,\ell,k) = (c_r 2\Delta D_{i\ell k} \cdot \frac{1}{f} + C_t 2\Delta H_{i\ell k})\ n_w P_e P_i \qquad (3.6)$$

where

i is a residential activity and ℓ and k are subareas;

c_r is operating cost of the car per mile;

c_t is the value of travel time per minute;

n_w is the number of working days per year;

P_e is percent of population employed;

P_i is the number of residents per acre of activity i;

f is the car pool factor given by number of people per car;

$\Delta D_{i\ell k}$, $\Delta H_{i\ell k}$ and $\Delta T(i,\ell,k)$ are defined as before.

The first term between brackets in Equation (3.6) gives difference in running costs per commuting trip, and the second term gives difference in values of travel time per commuting trip; the multiplication term outside the brackets represents total number of commuting trips per year.

Differences in distances and travel times depend on the level of service provided by the transportation network. The model is such that anticipated changes in this network can be included by dividing the planning horizon into time periods, and by providing appropriate differences in distances and travel time for each of these periods.

b. Nonresidential Activities

Nonresidential activities for which transportation costs are computed include local commercial, region-serving commercial, warehousing and distributing, and industrial activities. Costs are associated with the transportation of both raw materials and finished products. Different modes of transportation such as truck, rail and river transport, are considered for nonresidential activities. The actual mode used for activities other than community land use depends on subarea and aggregate activity type, and is determined outside of the model. Furthermore, for a given mode of transportation, different travel distances and travel times are specified for different aggregate activity types. Anticipated changes in the transportation network can be included by dividing the planning horizon into several time periods, and by providing related data for each network.

If the transportation for a nonresidential activity from two subareas, ℓ and k, is by truck, calculating transportation cost difference is expressed as follows:

$$\Delta T(i,\ell,k) = (c_r 2\Delta D_{i\ell k} + c_w 2\Delta H_{i\ell k}) \frac{Q_i}{V_t} \tag{3.7}$$

where

- i is a nonresidential activity and ℓ and k are subareas;
- c_r is running cost of the truck per mile;
- c_w is the wage of a truck driver;
- Q_i is the annual tonnage to be transported per acre in use by activity i;
- V_t is size of the truck;
- $\Delta D_{i\ell k}$, $\Delta H_{i\ell k}$ and $\Delta T(i,\ell,k)$ are defined as before.

If the transportation mode for nonresidential activities from two subareas, ℓ and k, is not by truck for both, then total transportation cost must be calculated following Equation (3.4). The difference in total transportation cost is expressed as follows:

$$\Delta T(i,\ell,k) = \left\{ D_{i\ell} p(i,\ell;M_{i\ell}) - D_{ik} p(i,k;M_{ik}) \right\} Q_i \tag{3.8}$$

where all variables are defined as before and

- $p(i,\ell,M_{i\ell})$ is the unit price for transporting one ton for activity i from subarea ℓ using mode $M_{i\ell}$.

4. Amenity Value

The locational advantage component related to amenity value at two different locations measures the difference in economic rent as a result of physical amenities that are the same with and without protection. Amenity values are considered only for residential activities. They are defined by the willingness to pay for a location with certain physical amenities, as compared to a location without any special amenities, either inside or outside the flood plain.

The SIMULATOR does not include a model for determining amenity values because of the localized and subjective nature of this component. Input data may be the land price difference that each residential activity type is willing to pay for a location with certain physical amenities, such as view of the river, lake or rolling hills, as compared to a location without any such special amenities. Amenity values are quantified by transforming land price differences into annual land value differences, using a private discount rate and market horizon. In this manner, amenity values for each residential activity type/amenity zone combination are obtained for use in benefit evaluation. Amenity values for aggregate activity/subarea combinations are derived by properly weighing contributions of the various residential activity/amenity zone combinations.

The major aspect in estimating amenity values is the manner in which willingness to pay for different physical amenities is determined. Observed land prices may be useful as guides to estimating land value differences for locations with different physical amenities. However, land prices may not reflect people's willingness to pay now or in the future for such amenities. Additional information, based on interviews with residents for example, may be needed to arrive at realistic amenity values. The planner can use the SIMULATOR to investigate the effect that various assumptions on willingness to pay have on land use and benefits.

5. Social Environment Effect

The locational advantage component related to social environment effect measures the influence of different neighboring activities on economic rent of a residential activity. For example, the effect on community land use of activities such as industry, low income housing or of activities related to a flood control project such as recreation at a reservoir is considered. No social environment effect is assumed for activities other than community land uses. Subareas are used as zones of uniform social environment effect.

The procedure for determining social environment effect uses the following data: (1) information on potential interdependency between economic rents at two locations; (2) land use for each subarea by aggregate activity type; (3) unit values for the effect of neighboring low income housing, or activities other than community land uses, on the economic rent of different community developments. For example, to determine the social environment effect on high income housing in subarea ℓ, the following steps are required:

Step 1: Identify subareas that could influence the economic rent on subarea ℓ as a result of land use. The information is given in Table III-1 where "X" indicates potential interdependency. Only two possibilities are considered, there either is or is not potential interdependency between locations. The locations involved may be subareas, or a subarea and an area outside the study area for which the land use is specified. No potential interdependency will be assumed for two locations that are far apart or separated from each other in any other way, as by a ridge, river or freeway. Thus, from the table, subarea ℓ is potentially influenced by subareas 1 and 3, and by area 2 outside the study area.

Step 2: Determine the land use in the subareas identified in Step 1 that could influence economic rent to subarea ℓ. In the example, the land use on subarea 1 and 3 is needed. As described in Chapter II, Section E, for land use allocation, the ultimate land use plan is used in determining the social environment effect, while, for benefit evaluation, the updated land use plan is needed.

Step 3: Determine the social environment effect based on a residential activity's willingness to pay for proximity to or distance from each influencing activity. For this purpose, change in land price resulting from the proximity of influencing activities is required. Annual values for the social environment effect are then determined, using a private discount rate and market horizon. If there is more than one influencing activity, the social environment effects are summed. The major difficulty here is estimation of residential activity's willingness to pay, because of the subjective and localized nature of the valuation of effects of neighboring activities, such as low income housing, industry or project-related recreation.

Table III-1

POTENTIAL INTERDEPENDENCIES BETWEEN LOCATIONS

Subareas						Areas Outside Study Area With Given Land Uses		
Subarea	1	2	3	ℓ	N	1	2	3
1	X		X	X				
2		X						
3	X		X	X				
.								
ℓ	X		X	X			X	
.								
.								
N					X			

The social environment effect is illustrated in Figure 3.9. The economic rent to activities on subarea ℓ may be influenced by activities on subarea 1 and 3 as well as by a development outside the study area but adjacent to subarea ℓ. It will not be influenced by activities on subarea 2. Assume that low income housing locates on subarea 1, nothing locates on subarea 3 and recreation related to the project locates on the area outside the study area. The social environment effect on high income housing on subarea ℓ will then be determined by the combined effect of low income housing and project-related recreation.

D. Summary

In this chapter procedures used in the SIMULATOR for estimating flood damages, fixed area development cost, site development cost, transportation cost, amenity value, and social environment effect were described. These were discussed in general terms without including the details of the computer program. The uses for both the land use allocation and benefit evaluation were indicated, and the special nature of amenity value and social environment effect components of locational advantage was pointed out.

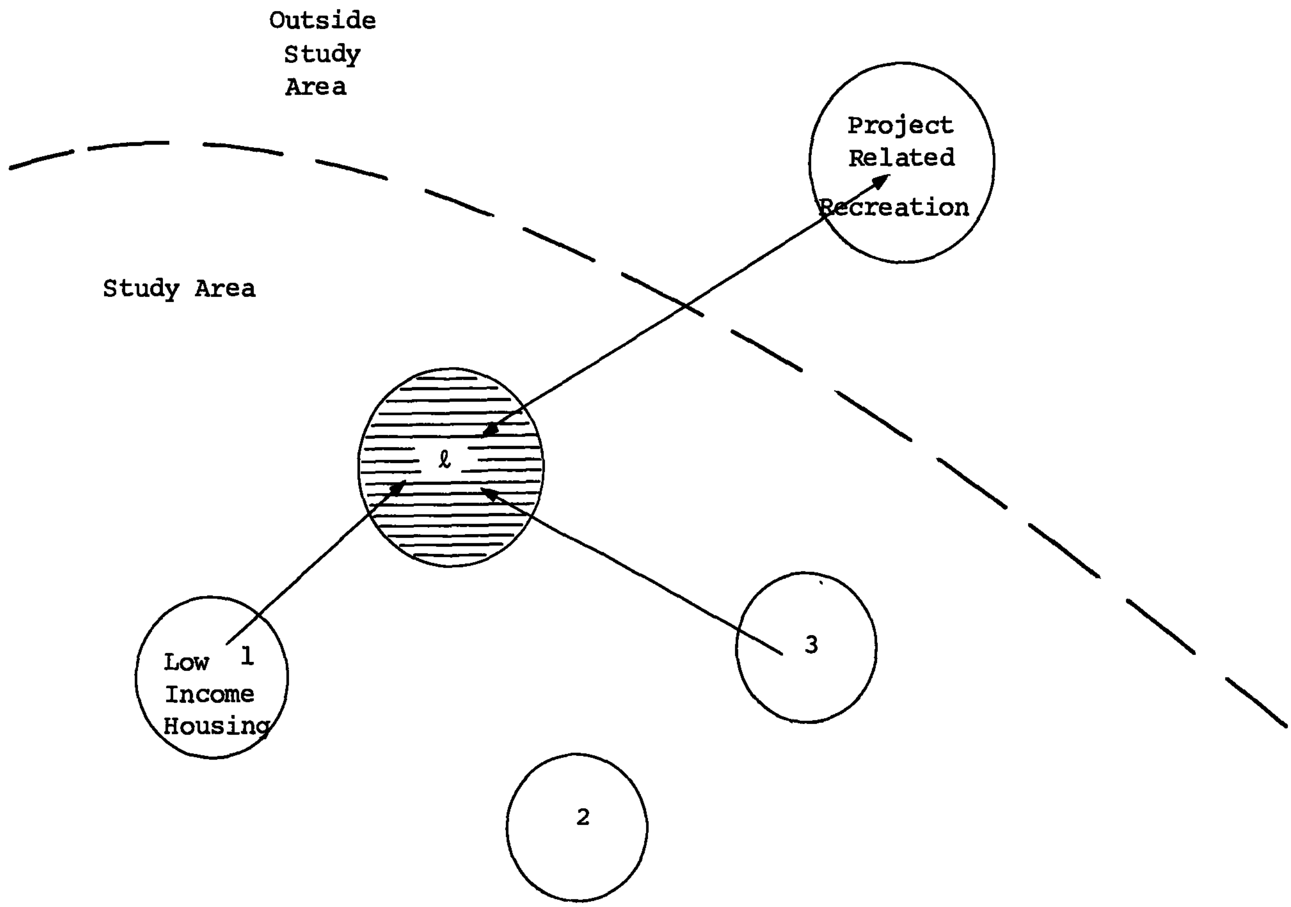


Figure 3.9 SOCIAL ENVIRONMENT EFFECT

Chapter IV

LAND USE ALLOCATION

A. Introduction

Alternative FPM plans will generally result in different land uses both inside and outside of the flood plain. The benefits of a FPM plan are the result of economic effects of that plan as contrasted to the situation in which nothing is done. These benefits are measured by damage reduction if the land use is the same irrespective of FPM and by locational advantage if the land use is different with and without FPM. The land use allocation model that provides the land use over time both with and without FPM is presented in this chapter.

B. Concepts Related to Land Use Allocation

Several concepts were introduced when the land use allocation model was developed. These included the study area, economic growth area, dummy location, land use requirement, and ultimate land use plan. This section discusses each of these concepts in more detail.

1. Affected Area and Study Area

For the evaluation procedure, benefits from a FPM plan are measured by the economic effect throughout the area where net earnings are affected by the plan. Changes in the net earnings at a particular location may be the result of a reduction in flood damages, a change in economic rent as a result of changing land use in the surrounding area, or a change in activity using the location. There are several practical problems associated with the evaluation of benefits for the total affected area: the affected area is not known prior to solving the allocation problem and must be estimated; the size of the estimated affected area may be very large; obtaining data on the economic rents for the entire estimated affected area may be difficult in practice. An approximation of the affected area is therefore needed.

This approximation, referred to as the study area, is obtained by including those areas of the region surrounding the flood plain that are expected to provide alternative locations to activities which would compete for flood plain land with a FPM plan. Areas that are far away, widely dispersed, difficult to identify, or for which data are not readily available are excluded for practical reasons. The study area includes the following:

- The flood plain land.
- The immediate area around the flood plain, where changes in economic rent can reasonably be expected as a result of the FPM plan.
- Alternative locations in the general region that may constitute reasonable alternatives to flood plain development, and for which data are available.

The study area may be chosen on the basis of knowledge concerning the potential development of the area, assuming alternative FPM plans. Thus, areas are included on the basis of information obtained from regional and local plans, or from surveys of feasible alternative sites outside the flood plain which are in lower use. Areas outside the flood plain that are expected to develop in the same manner irrespective of FPM are excluded.

2. Economic Growth Areas

An activity's choice of location depends, in some cases, on development pressures that are not explicitly recognized in modeling economic rents. In such cases, the allocation problem may be decomposed by distinguishing economic growth areas. These areas partition the study area so that only sites within the same economic growth area are considered as alternative locations. Thus, the choice of economic growth area logically comes before the choice among alternative sites within a given economic growth area, and will be made by the planner.

3. Dummy Locations

A dummy location may be needed to account for locations that cannot be included in the study area, either because they cannot be identified, or because their explicit inclusion complicates the study to an unwarranted extent. Thus, the dummy location represents average locations available for each type of land use outside the identifiable part of the affected area. In the present version of the SIMULATOR, a dummy location is characterized indirectly for each aggregate activity type by specifying that it is identical to a given subarea in terms of economic rent. When the study area is partitioned into economic growth areas, a dummy location is characterized differently for each economic growth area.

A particular aggregate activity is located on the dummy after all land reserved for that use in the relevant economic growth area has been exhausted. Thus, the characteristics of the dummy location play no essential role in the allocation procedure per se, but become important when estimating benefits.

4. Land Use Requirements

Land use requirements are defined as the acres required by each aggregate activity seeking a location in the study area, either with or without a FPM plan. These requirements are exogenously determined by the planner for aggregate activity types at the end of each allocation period. When the study area is partitioned into economic growth areas, land requirements are determined separately for each of these areas.

If the amounts of land required for a particular use are different with and without the plan, the largest amount for that use represents the land use requirements. Thus, all land uses that are different with and without the plan are considered in project analysis.

5. Ultimate Land Use Plans

The ultimate land use plan gives the acres reserved in the different subareas for each aggregate activity with and without FPM. For a particular activity, reserved acres may or may not be used by the end of a planning horizon, depending on land use requirements for that activity type. If, for a particular activity, land use requirements exceed total acreage reserved in the economic growth area, all reserved acres for that activity will be used by the end of the planning horizon, and in addition some acres will be allocated to the dummy location.

C. General Characteristics of Land Use Model

The land use allocation model is used to forecast what is likely to happen as the result of different FPM plans. This forecasting problem is complex for several reasons:

- Difficulties in accounting for interdependencies between activity types.
- Need to reserve land for future uses with higher productivity.
- The availability of land outside the study area.
- Social and political constraints on land uses.
- Uncertainties in predicting future development.
- Irrational behavior of land users.

The available optimization models for land use allocation require extensive simplifying assumptions (Refs. 19 , 20, and 21), the implications of which may not always be clear to the users. As such, the allocation provided by these models have limited usefulness. The land use model in the SIMULATOR is structured so that simplifying assumptions are kept to a minimum, while requiring the planner to make explicit assumptions in the input data through the specification of ultimate land use plans, land use requirements over time, and sequence of development of areas with fixed development cost. Part of the land use allocation is therefore placed in the hands of the planner in order to provide a connection with the real world. Thus, the planner can take note of social and political constraints, for example, that will have an effect on land use. The SIMULATOR provides the planner with land uses over time that will be obtained from different levels of flood protection resulting from alternative FPM plans.

The allocation of land use is performed at two levels, as described in Chapter II, Section E.

1. Allocation at Level 1

Data for land use allocation at this level consist of the following:

- Allocation periods during which increase in land use is assumed constant.
- Cumulative requirements for each aggregate activity at the end of each allocation period.

- Ultimate land use plan that gives the ultimate use in acres for each subarea by aggregative activity type.

- Sequence in which areas with a fixed development cost will be used.

- Present value of the net economic rent differences, based on a private discount rate and market horizon as calculated by the SIMULATOR or, alternatively, the complete sequence of subarea development as provided by the planner.

Using these data, allocation of the land uses over time is performed sequentially by the SIMULATOR, allocation period by allocation period. Land uses for each aggregate activity are allocated independently within each allocation period. The aggregate activity is located, on the basis of highest present value of net economic rent, to subareas included in the first area to be developed. Once available land in the first area is filled, as specified by the ultimate land use plan, the next one is considered, and so on. Also, the planner has the option of providing the complete sequence of subarea development, thus forcing the development to take place in a predescribed manner so that he can evaluate alternative patterns of development. Output of allocation at level 1 provides the land use in each subarea at the end of every allocation period and the year in which each subarea starts being used for each aggregate activity.

Interaction between planner and land use model is essential for the allocation procedure, especially at level 1 when locating aggregate activities in subareas. For a given FPM alternative, the planner provides an initial estimate of ultimate land use in terms of acres reserved for each aggregate activity in different subareas. This estimate uses available information on locational preferences of activities, local or regional land use plans, zoning regulations, etc. Using this ultimate land use plan the SIMULATOR provides the planner with allocation over time as well as with information on present values of economic rents and expected flood damages by aggregate activity and subarea. With this information, the planner analyzes the simulated development of the study area and decides whether to accept the allocation or to revise the initial estimate of the ultimate land use plan.

The planner also provides the sequence in which areas with a fixed development cost develop. Thus, the planner can prevent certain areas from developing earlier than others, as a matter of policy. The planner can also provide the complete sequence of subarea developments, in order to evaluate the benefits accruing to alternative patterns of development. This is necessary in order to evaluate the effects of a FPM plan, such as zoning, on the irrational choice of flood plain users.

The two level allocation procedure provides considerable advantages. For example, by using aggregate activities for allocation at level 1, interdependencies among detailed activities are accounted for without need for explicit consideration. By using subareas, those areas that will develop as a unit are specified and first order influence of the regional infrastructure is taken into account. The limited number of aggregate activity types and subareas simplifies both specification of ultimate land use and analysis of the resulting allocation by the planner. Furthermore, by providing ultimate land use plans, competition among different activity types is eliminated from explicit consideration. This simplifies the allocation procedure as well as the determination of economic rent differences, which otherwise would be needed between different activity types. Ultimate land use plans also account for intertemporal interdependence among activities by withholding land for future uses with higher economic rents.

2. Allocation at Level 2

Allocation at the second level is used to provide the detail required to evaluate benefits accruing to a FPM plan. Data for the allocation at level 2 consist of the following:

- Land use by aggregate activities and subareas at the end of each allocation period, as given by the allocation at level 1.
- Initial year in which an aggregate activity starts using a subarea, as given by the allocation at level 1.
- Order in which parcels will develop within each subarea for community land uses and for other land uses.
- Sequence in which aggregate activities locate in a subarea.
- Information on detailed activity/parcel location, when available.

Ultimate land use of each parcel by detailed activity type is determined using these data. In a predetermined sequence, aggregate activities choose the parcel on which to locate within the subarea, based on ordering of parcels within the subarea and on remaining acres in the parcel. Detailed activities are then allocated to parcels, based on the composition of aggregate activity types.

Alternatively, information on the location of detailed activities by parcel may be used when available. Finally, the SIMULATOR allocates detailed activity parcels over time using a method similar to that used for allocation at level 1. The output of allocation at level 2 provides land use by detailed activity and parcels at the end of each evaluation period.

There are several reasons for providing the sequence outside of the program in which aggregate activities choose a location within a subarea, and in which parcels will develop within each subarea. By providing the sequence for aggregate activities, competition between activities need not be considered explicitly in the allocation model. Furthermore, the exogenously derived ordering of parcels results in a simpler computer program than when the ordering is based on net economic rents, and at the same time may be more realistic. Also, benefits from a FPM plan are not expected to be highly sensitive to the exact timing of use of parcels within each subarea, especially when the overall uncertainty of these benefits is considered.

D. Allocation of Aggregate Activities to Subareas

For each aggregate activity, allocation to different subareas is performed separately, based on land use requirements over time, the ultimate land use plan, sequence of subarea development resulting from net economic rent differences, and possibly the sequence in which areas with fixed development cost are used. The procedure is illustrated by the following example. Land use requirements at the end of 10, 20, 60 and 100 years are given in Figure 4.1 for aggregate activity #1; requirements for intermediate years are obtained by linear interpolation. Acres reserved for this activity in the ultimate land use plan and the associated sequence of subarea development are given in Table IV-1. These reserved acreages are set out along the vertical axis on the right side of Figure 4.1, following the sequence of their development, and determine the period during which each subarea develops. The results, given by the initial year of development for each subarea, and by acreage used during each allocation period, are presented in Table IV-1.

The flow of information for performing allocation at level 1 is presented in Figure 4.2. Input data directly related to land use allocation consist of land use requirement by aggregate activity type for each economic growth area

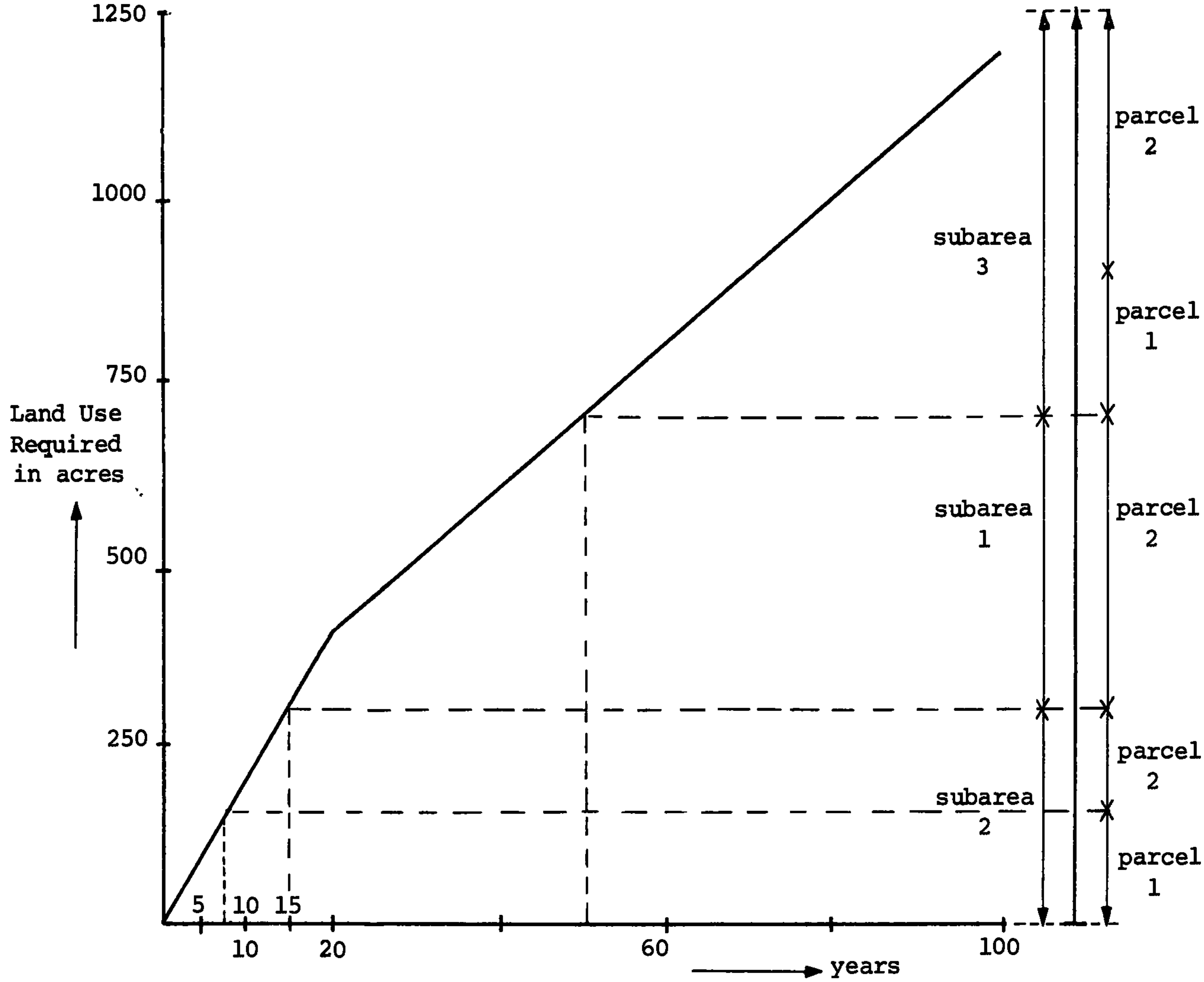


Figure 4.1 ALLOCATION PROCEDURE FOR AGGREGATE ACTIVITY #1

Table IV-1

RESULTS OF ALLOCATION AT LEVEL 1 FOR AGGREGATE ACTIVITY #1

Subarea	Ultimate Land Use in Acres	Sequence of Subareas	Initial Year of Development	Acreage Used During Each Planning Period			
				1	2	3	4
1	400	2	15		100	300	
2	300	1	0	200	100		
3	550	3	50			100	400

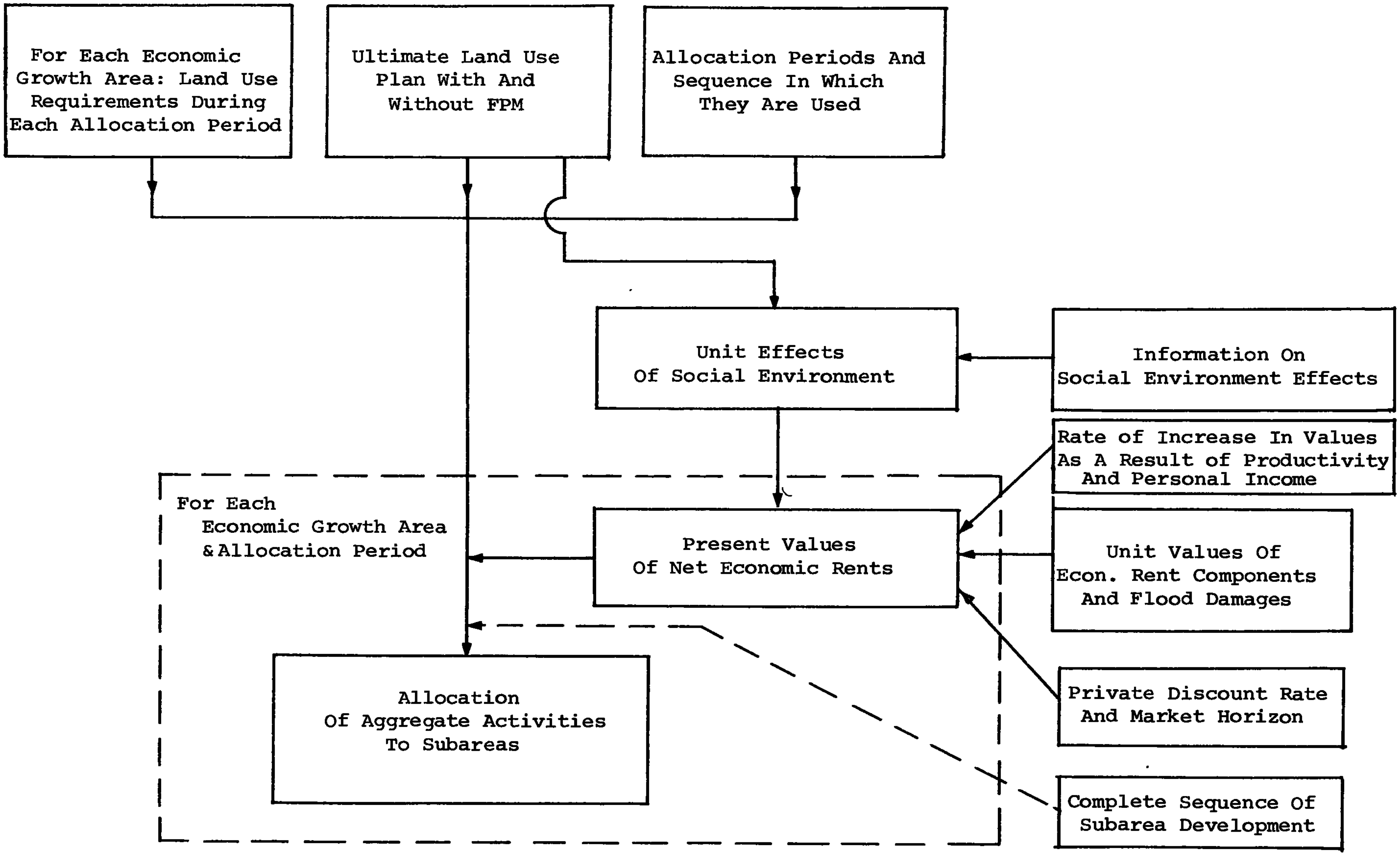


Figure 4.2 ALLOCATION OF AGGREGATE ACTIVITIES TO SUBAREAS (LEVEL 1)

at the end of every allocation period, ultimate land use plans with and without FPM, allocation periods, and the sequence in which areas with fixed development cost will be used. The allocation also requires present values of net economic rent for each aggregate activity/subarea combination. Values of flood damages and of all economic rent components except the social environment effect were already determined by the SIMULATOR for the first year of the FPM plan. Corresponding values for the social environment effect component are now calculated on the basis of ultimate land use plans. To obtain values for flood damages and economic rents in subsequent years, values for the first year are adjusted for possible changes resulting from depreciation or from increased productivity and personal income. Except for site development cost, which is incurred at the time an activity occupies a site, the components of economic rent and expected flood damages are expressed on an annual basis, and are discounted and summed to yield present value. This present value of net economic rents is derived using a private discount rate and market horizon, reflecting the private nature of location decisions.

For each economic growth area, aggregate activities are located over time in the different subareas. This allocation is performed sequentially for each allocation period, and is done independently for each aggregate activity type. For an aggregate activity the following steps are taken. Subareas are ranked by present value of net economic rent minus the loss of displaced agriculture, or by an externally provided sequence of subarea development. The activity is located in the most desirable subarea first, as long as land is available in that subarea for the particular use, then in the next most desirable subarea, and so on. In case of areas with fixed development cost, subareas belonging to the first area in the sequence are developed first. Again, if all available land for the particular activity type has been taken, subsequent areas are considered. Acres of available land in each subarea, as given initially by the ultimate land use plan, are reduced by acres allocated as allocation proceeds.

The final output of allocation at level 1 provides, for each aggregate activity, the number of acres allocated to the different subareas during each allocation period. Also, the time interval during which the subarea is developed for each aggregate activity is derived, based on the assumption that land requirements during an allocation period are uniform. The above information is needed for allocation at level 2, because the evaluation periods used at that level are, generally, shorter than the allocation periods used at level 1.

E. Allocation of Detailed Activities to Parcels

At the second level of aggregation, the outcome of allocation at level 1 is used to derive locations of detailed activities on parcels. The required input data consists of evaluation periods; preference ordering of parcels within each subarea, which may differ with and without FPM, and also may differ for community land use and other uses; and sequence in which aggregate activities location in a subarea, where a possible sequence is special uses, region serving retail, wholesale and distributing, industrial uses, and community land uses in descending order of income level.

The procedure followed in the SIMULATOR for allocation at level 2 is illustrated by extending the example of the previous section, which was concerned with aggregate activity #1. Assume that two aggregate activities are involved, and that detailed activities are the same as aggregate ones. Size of subareas and parcels, and ultimate land use by subareas are given in Table IV-2. Furthermore, assume that parcels are numbered by specified preference ordering, and that activity #2 will choose its location before activity #1. The ultimate land use of each parcel by the two activities is then obtained, as shown in Table IV-2. In this example, the ultimate land use of activity #2 in subarea 1 is 200 acres. The first 100 acres use all available land on the best parcel, #1, and the remaining 100 are allocated to the next best parcel, #2. The ultimate land use of activity #1 in subarea 1 is all allocated to parcel #2 because activity #1 has the second choice. The resulting ultimate land use is used, as before, to obtain land use at the end of each evaluation period. This is illustrated in Figure 4.1 for activity #1. On the right side, acreages reserved in each parcel are given in the sequence in which they will develop. The number of acres developed during each evaluation period are derived as before. If evaluation periods end at year 5, 10, 15 and 20, then 100 acres are allocated to parcel 1 in subarea 1 at the end of the first period, an additional 50 acres to both parcel 1 and 2 in subarea 1 at the end of the second period, 100 acres to parcel 2 of subarea 1 at the end of the third period, etc.

Table IV-2

ULTIMATE LAND USE OF ACTIVITY BY PARCEL FOR ALLOCATION AT LEVEL 2

Subarea	Size Subarea	Parcel*	Size Parcel	Ultimate Land Use			
				Activity by Subarea		Activity by Parcel	
				#1	#2**	#1	#2
1	500	1	100	300	200		100
		2	400			300	
2	550	1	400	300	250	150	250
		2	150			150	
3	700	1	350	550	150	200	150
		2	350			350	

* Parcels are numbered according to preference order
** Activity #2 chooses its location before activity #1

The main logical blocks of allocation at level 2 are shown in Figure 4.3. The SIMULATOR derives the ultimate land use of each parcel by detailed activity type, and then determines the detailed allocation over time. Derivation of the ultimate land use by parcel and detailed activity type is accomplished in two steps. First, the ultimate use of each parcel by aggregate activity type is obtained. This allocation is based on preference ordering of parcels, sequence in which aggregate activities are assumed to locate within a subarea, and ultimate land use of each subarea by aggregate activities. In the second step, this land use is further broken down by detailed activity type, on the basis of the percent composition of aggregate activities. For selected subareas, the ultimate land use by detailed activity type and parcel can be specified by the planner. Thus, it is possible to locate all local shops on the same parcel within a subarea, rather than having them distributed in equal proportion to residences. This is important for subareas subject to flooding, where activities more susceptible to damages may locate at higher elevations in the subarea.

When the detailed ultimate land use is obtained, the SIMULATOR derives the allocation of detailed activities to parcels over time. The procedure is analogous to that described in Section D. The detailed ultimate land use provides constraints on available land for each detailed use on each parcel; land use requirements are obtained for each subarea using the results of first level allocation, while parcel orderings provide the criterion for deciding where to locate activities over time.

F. Summary

In this chapter the land use allocation model used by the SIMULATOR was described in detail. First, the general characteristics of the model were discussed, and the need for a close interaction between planner and model emphasized. Then several concepts related to land use allocation were presented; such as study area, economic growth areas, dummy location, land use requirements, and ultimate land use plans. Finally, the allocation procedures at the first and second aggregation level were discussed in detail and illustrated with an example.

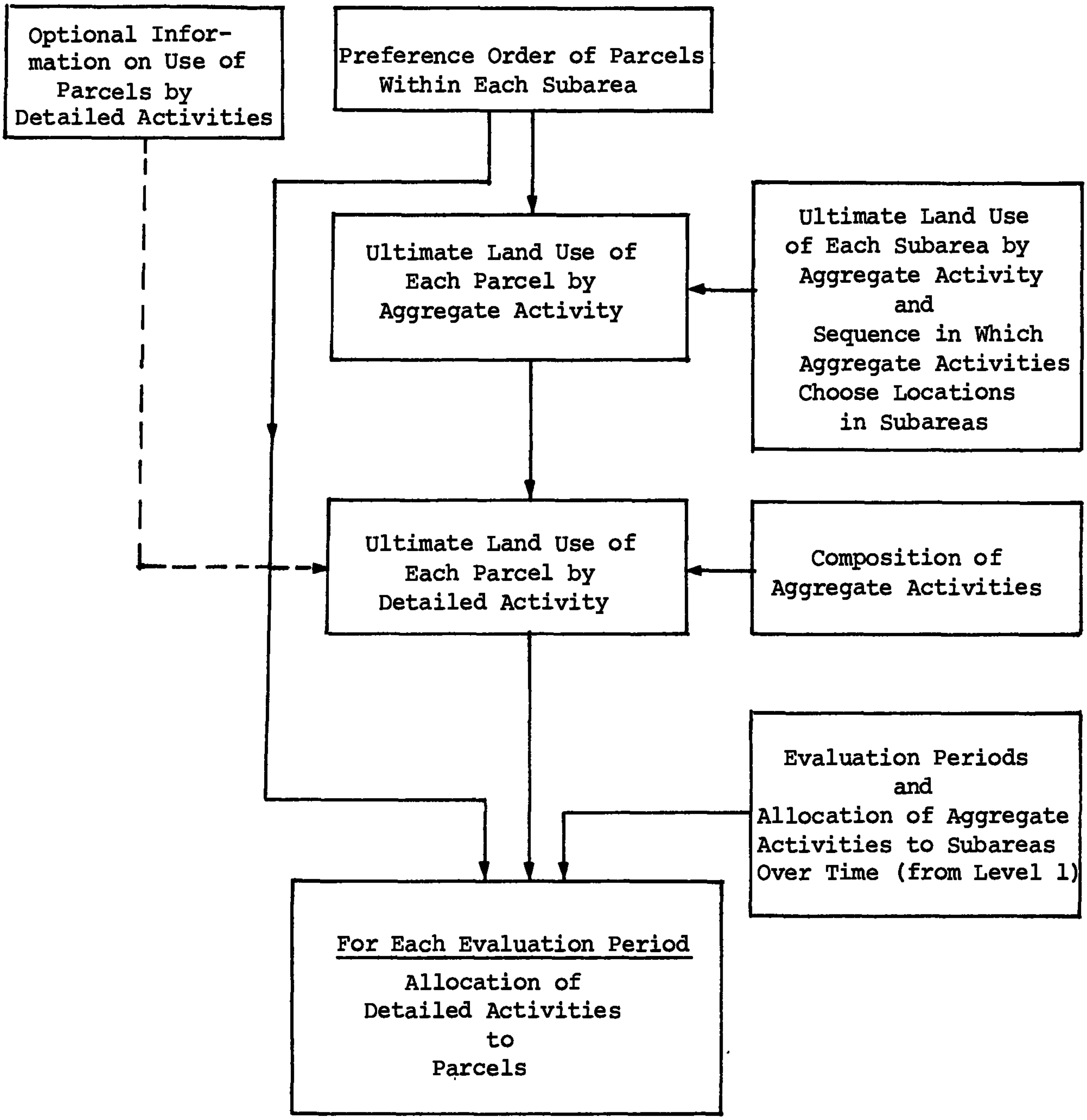


Figure 4.3 ALLOCATION OF DETAILED ACTIVITIES TO PARCELS (LEVEL 2)

Chapter V

INPUT DATA REQUIREMENTS OF THE SIMULATOR AND THE NED TEST CASE

A. Introduction

The input data required by the SIMULATOR is described in this chapter and is illustrated with the NED test case data. The physical and economic characteristics of the NED Test Case are described, followed by the general input data needed for the SIMULATOR. Next, the input data for estimating flood damages and economic rent differences are presented, and finally the data needed for the allocation of land uses over time is given. Normally, the data for the initial run is based on gross estimates. The results of a sensitivity study based on these estimates is used to determine which data should be further refined in order to arrive at a more accurate estimate of the benefits. The data for the NED test case are the result of such refinements in the initial estimates.

Different levels of refinement in the data are used for the program in order to reduce the total data collection effort.

B. The NED Test Case

The NED test case concerns Reach 13 of the Connecticut River, indicated on the location map in Figure 5.1. The more detailed map, presented in Figure 5.2, shows Reach 13 running over a distance of 20 miles from the Holyoke Dam to the boundary of Franklin County. The region is bordered on the west and the east by upland areas, with the Connecticut River running south through a central valley 15 to 20 miles wide. The valley has a range of mountains converging from the southwest of the river into the Mount Tom Range and continuing easterly, as the Holyoke Range, to join the eastern uplands. The flood plain is outlined by the dotted area on the map in Figure 4.2. The towns which are partly in the flood plain are Hatfield, Hadley, South Hadley, Northampton, Easthampton and Holyoke.

The existing flood control reservoirs upstream from Reach 13 reduce the

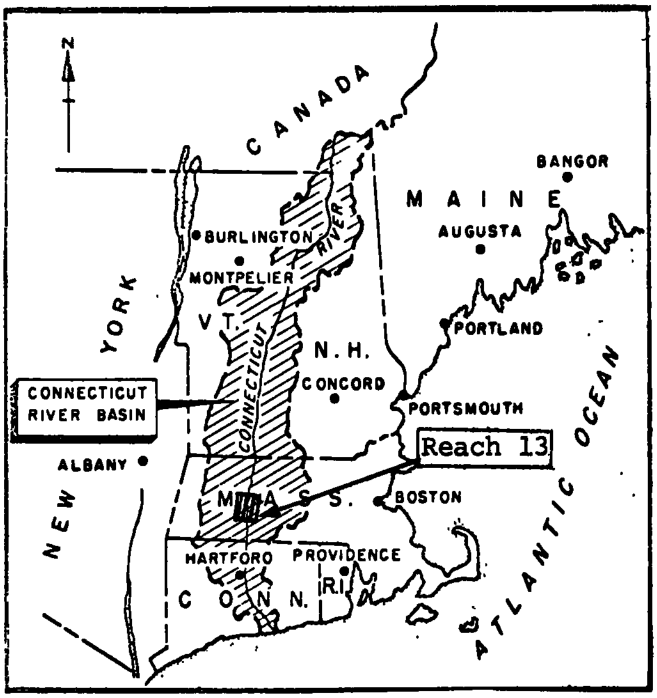


Figure 5.1 LOCATION MAP

discharge from the Typical Tributary Contribution Flood (TTCF) at the Calvin Coolidge Bridge by 21.6% (Ref. 22). The TTCF concept was introduced by the New England Division to account for the large number of tributaries in the Connecticut River Basin. It reflects the average reduction in discharge as a result of upstream reservoirs. In addition to the upstream reservoirs, a levee protects part of the flood plain in Northampton against floods less severe than the 100 year flood.

The region around Reach 13 is divided into the four economic growth areas indicated on the map in Figure 5.2. This division is based on the expected independence of the growth for each of these areas. As no new industries are expected to locate in the region, growth is expected to consist of community development. A sufficient number of alternatives to location in the flood plain are available within the region to accomodate the expected growth. The alternative sites selected in the course of the study are indicated on the map by the vertically striped areas outside the flood plain.

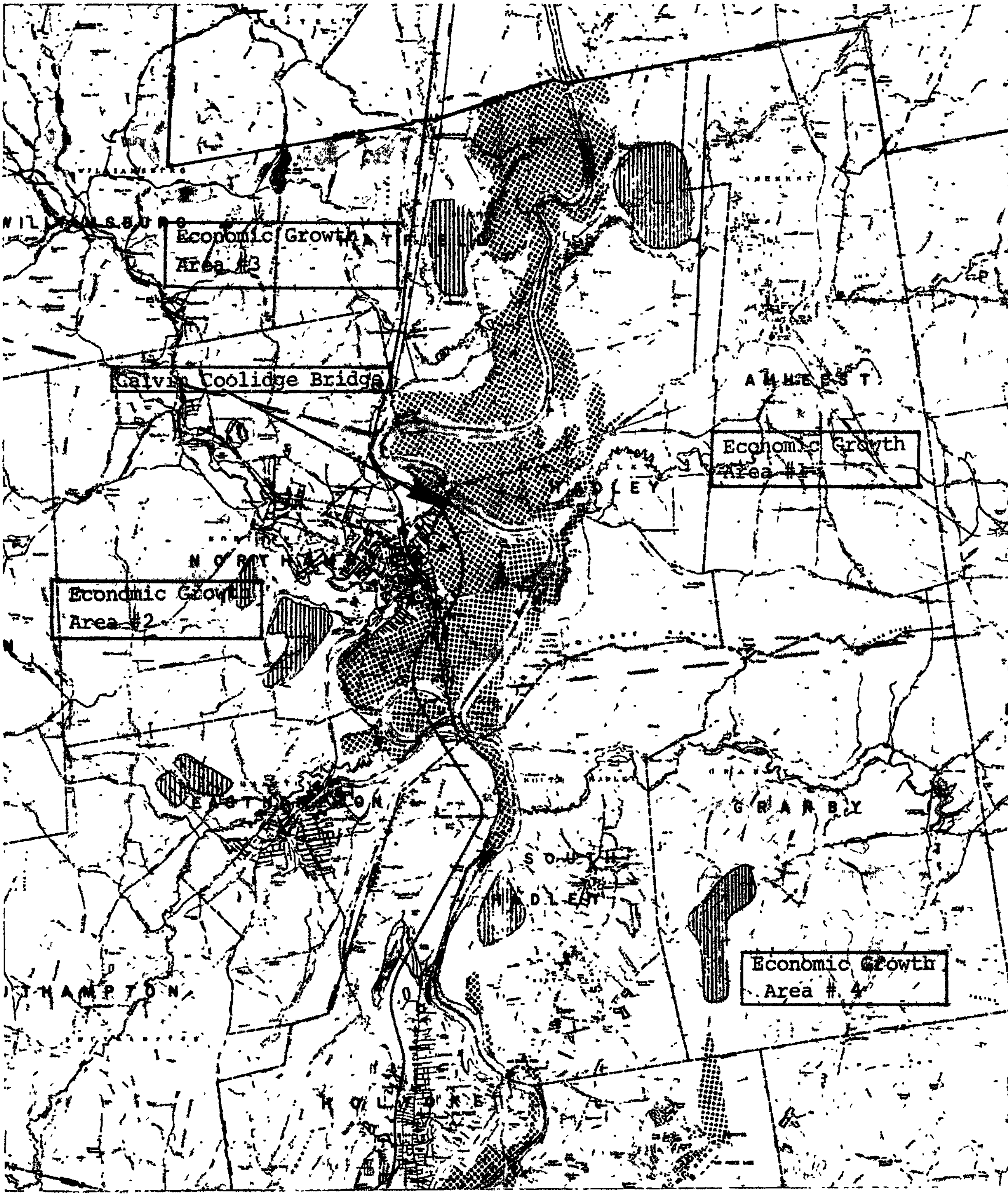


Figure 5.2 REACH 13 OF CONNECTICUT RIVER BASIN

C. General Input Data

The general input data for the NED test case included the following overall problem parameters:

- Social discount rate and planning horizon - 5 3/8% and 100 years.
- Private discount rate and market horizon - 10% and 20 years.
- Allocation periods used in allocating land uses over time - five periods ending at year 10,20,40,70 and 100.

Controls for the execution of overlays and for the level of detail in the printout of results were also required.

The allocation of activities and the evaluation of benefits require the identification of geographic areas and activity types. The geographic areas defined are the study area, zones, subareas, and parcels. These areas are drawn on a map on the basis of the physical and economic characteristics of the region and the map is used to specify the input data. For subareas these data include the following:

- Size.
- Relevant amenity zone.
- Percentage with amenities.
- Percentages in different site development zones.
- Percentages in agricultural use.
- Reach where located.
- Percentages in different flood damage zones within the reach.

The data for the NED test case are presented in Tables V-1 and V-2. No data relating subareas to transportation and social environment effect zones are needed because subareas are used to represent these zones.

Each subarea is composed of one or more parcels and additional data similar to that for the subareas are needed. These data for parcels are presented in Table V-3 and V-4, and were used to derive the data in Table V-1 and V-2.

Economic activities are defined by aggregate activity types, detailed activity types and structural types. The classifications used in the NED test

Table V-1

SUBAREAS AND AMENITY VALUE ZONES, SITE DEVELOPMENT COST ZONES AND AGRICULTURAL USE

Subarea	Size in Acres	Amenity Zone	Percentage with Amenities	Percentage in Site Development Zone			Percentage in Agriculture
				1	2	3	
1	550	1	100	100			95
2	650	1	100	100			95
3	716	1	100	100			75
4	235	3	100	100			95
5	716	3	100	100			65
6	3224	3	100	100			95
7	1604			100			85
8	729			100			85
9	1766			100			75
10	218	2	100	100			85
11	245	4	100	100			0
12	1041				100		85
13	1200				100		85
14	300				70	30	0
15	165				100		30
16	226	4	100		60	40	95
17	346				90	10	90
18	250			100			0

Table V-2

SUBAREAS AND FLOOD DAMAGE ZONES

Sub-Area	Reach	Percentage in Flood Damage Zone								
		1	2	3	4	5	6	7	8	9
1	2	28	53	19						
2	2				100					
3	2					25	75			
4	1						100			
5	1								100	
6	1	3	6	8	3	48		10	16	6
7	3	45		42			13			
8	3			28		37	35			
9	3	77	11				12			
10	3								100	
11	3							56	44	
18	4	40	35	25						

Table V-3

PARCELS AND AMENITY VALUE ZONES, SITE DEVELOPMENT ZONES, AND AGRICULTURAL LAND USE

Subarea	Parcel	Acres	Available Acres	Amenity Zone	Site Development Zone				Percentage Agriculture
					Zone	Percentage	Zone	Percentage	
1	1	31	23	1	1	100			75
	2	519	499	1	1	100			100
2	1	298	261	1	1	100			80
	2	352	242	1	1	100			100
3	1	716	492	1	1	100			78
4	1	82	80	3	1	100			90
	2	153	150	3	1	100			90
5	1	716	625	3	1	100			65
6	1	518	488	3	1	100			67
	2	234	233	3	1	100			100
	3	490	483	3	1	100			91
	4	560	530	3	1	100			90
	5	558	518	3	1	100			85
	6	488	478	3	1	100			87
	7	376	366	3	1	100			90
7	1	1424	1414		1	100			70
	2	180	150		1	100			80
8	1	275	159		1	100			90
	2	252	163		1	100			92
	3	202	200		1	100			95
9	1	1463	1342		1	100			65
	2	70	46		1	100			40
	3	92	73		1	100			33
	4	141	92		1	100			55
10	1	163	154	2	1	100			75
	2	55	0	2	1	100			0
11	1	16	0	4	1	100			50
	2	41	23	4	1	100			30
	3	46	31	4	1	100			0
	4	142	107	4	1	100			0
12	1	1041	965		2	100			75
13	1	1200	1190		2	100			40
14	1	210	190		2	100			0
	2	90	90		3	100			0
15	1	165	130		2	100			50
16	1	140	137	4	2	100			90
	2	86	82	4	3	100			100
17	1	346	298		2	90	3	10	40
18	1	100	20		1	100			0
	2	150	0		1	100			0

Table V-4

PARCELS AND FLOOD DAMAGE ZONES

Subarea/	Parcel	Reach	Percentage in Flood Damage Zone								
			1	2	3	4	5	6	7	8	9
1	1	2		100							
	2	2	60		40						
2	1	2				100					
	2	2				100					
3	1	2					25	75			
4	1	1						100			
	2	1						100			
5	1	1								100	
6	1	1			75		25				
	2	1		100							
	3	1					100				
	4	1					100				
	5	1								100	
	6	1	25				25				50
	7	1				20			80		
7	1	3	52		48						
	2	3						100			
8	1	3					100				
	2	3						100			
	3	3			100						
9	1	3	100								
	2	3						100			
	3	3	100								
	4	3		100							
10	1	3								100	
	2	3		50	50						
11	1	3		100							
	2	3								100	
	3	3	100								
	4	3							100		
18	1	4	100								
	2	4		60	40						

case are presented in Figure 5.3. The composition of middle income and apartment community development is presented in Table V-5, and is expressed in terms of the percentage of acreage used by each detailed activity type. Table V.6 presents the composition of residences by structure type, lot size and number of families per structure.

D. Data for Estimating Flood Damages

The data for estimating flood damages consist of the depth of the reference flood in each damage zone, the depth-frequency curves, and the damage-depth relationships. The depth of the reference flood in each damage zone is presented in Table V-7. The 1936 flood under natural conditions is used as the reference flood. The first three reaches are artificial and have the same characteristics. They were chosen in order to accomodate the total number of damage zones, which is limited to ten per reach. The last reach represents the flood characteristics behind the protective wall in Northampton. In Figure 5.4 the depth-frequency curves are presented, where the depth is measured with respect to the reference flood. The depth-frequency curves are given for the natural condition, for the existing level of protection corresponding to a 21.6% reduction of the TTCF, and for two additional levels of protection corresponding to a 35% and 47.5% reduction in the TTCF.

The damage-depth relationships are given by the percent damage-depth curve, the value of the damageable component in the initial year of the FPM plan, and the height of first floor above ground level. For a two story house with basement, the damage relationship for structure and contents is presented in Figure 5.5. The value of the structure is $28,000, the value of the contents is $10,000, and the height of the first floor above ground level is two feet. Similar relationships for structures, contents, fixtures and, in some cases, nonphysical losses are needed for other activities and structure types. To estimate damage for years other than the initial one, a rate of change resulting from increased personal income, is specified for the value of structure, contents, fixtures and nonphysical damages. Also, the reduction in the value of damageable structures as a result of depreciation is given. Initially, no changes in the value of damageable components were assumed for the NED test case.

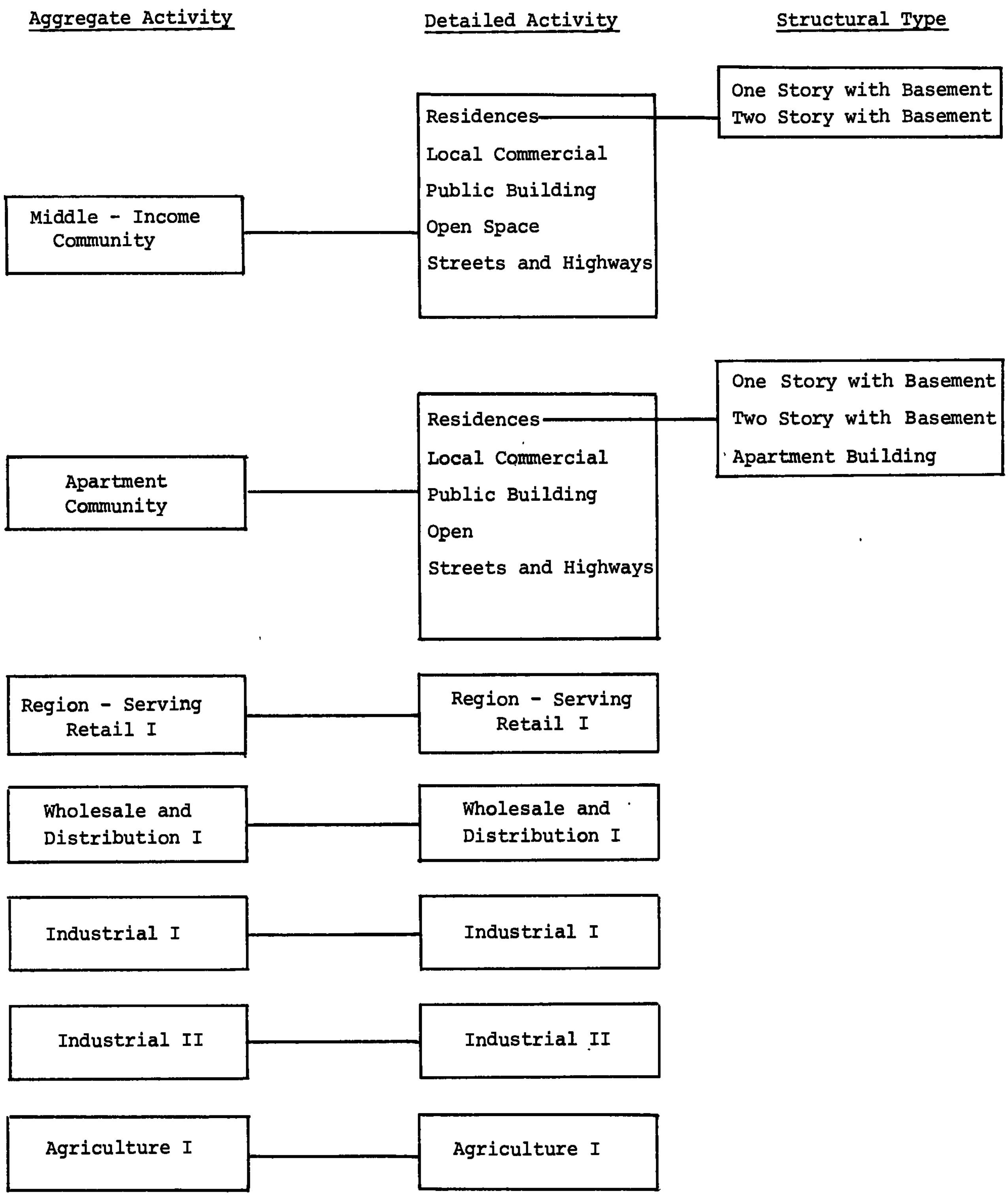


Figure 5.3 CLASSIFICATION OF ACTIVITY TYPES

Table V-5

COMPOSITION OF COMMUNITY DEVELOPMENT AS PERCENTAGE
OF TOTAL ACREAGE OCCUPIED BY THE AGGREGATE ACTIVITY

Detailed Activity Types	Middle Income Community	Apartment Community
Residences	57	52
Local Commercial	3	3
Public Building	3	3
Open Space	10	15
Streets and Highways	27	27

Table V-6

CHARACTERISTICS OF STRUCTURE TYPES

	Middle Income Community		Apartment Community		
	One Story w/b*	Two Story w/b*	One Story w/b*	Two Story w/b*	Apartments w/b*
Composition	25%	75%	5%	15%	80%
Lot size in acres	.5	.5	.5	.5	.5
Families per Structure	1	1	1	1	15

* w/b indicates with basement

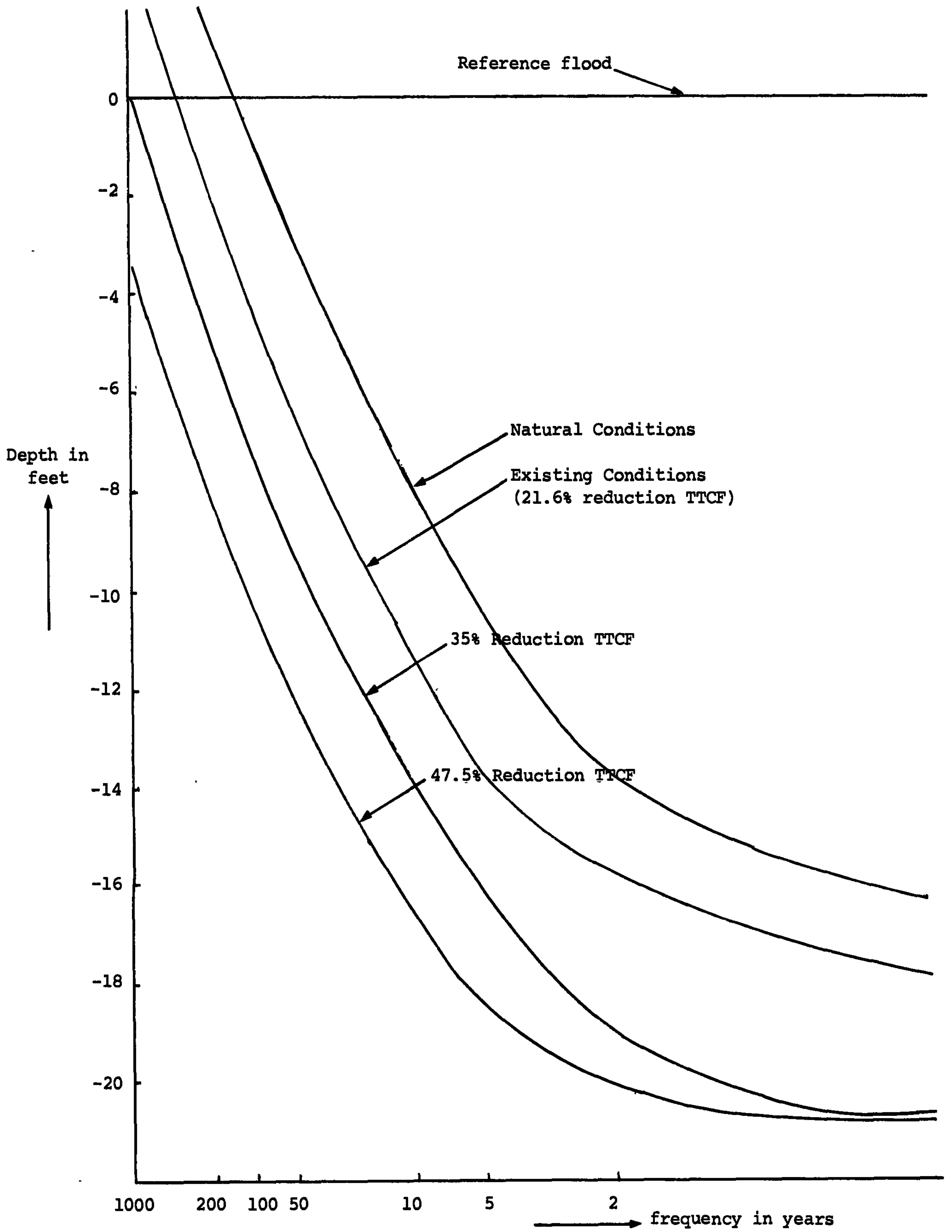


Figure 5.4 DEPTH-FREQUENCY CURVES

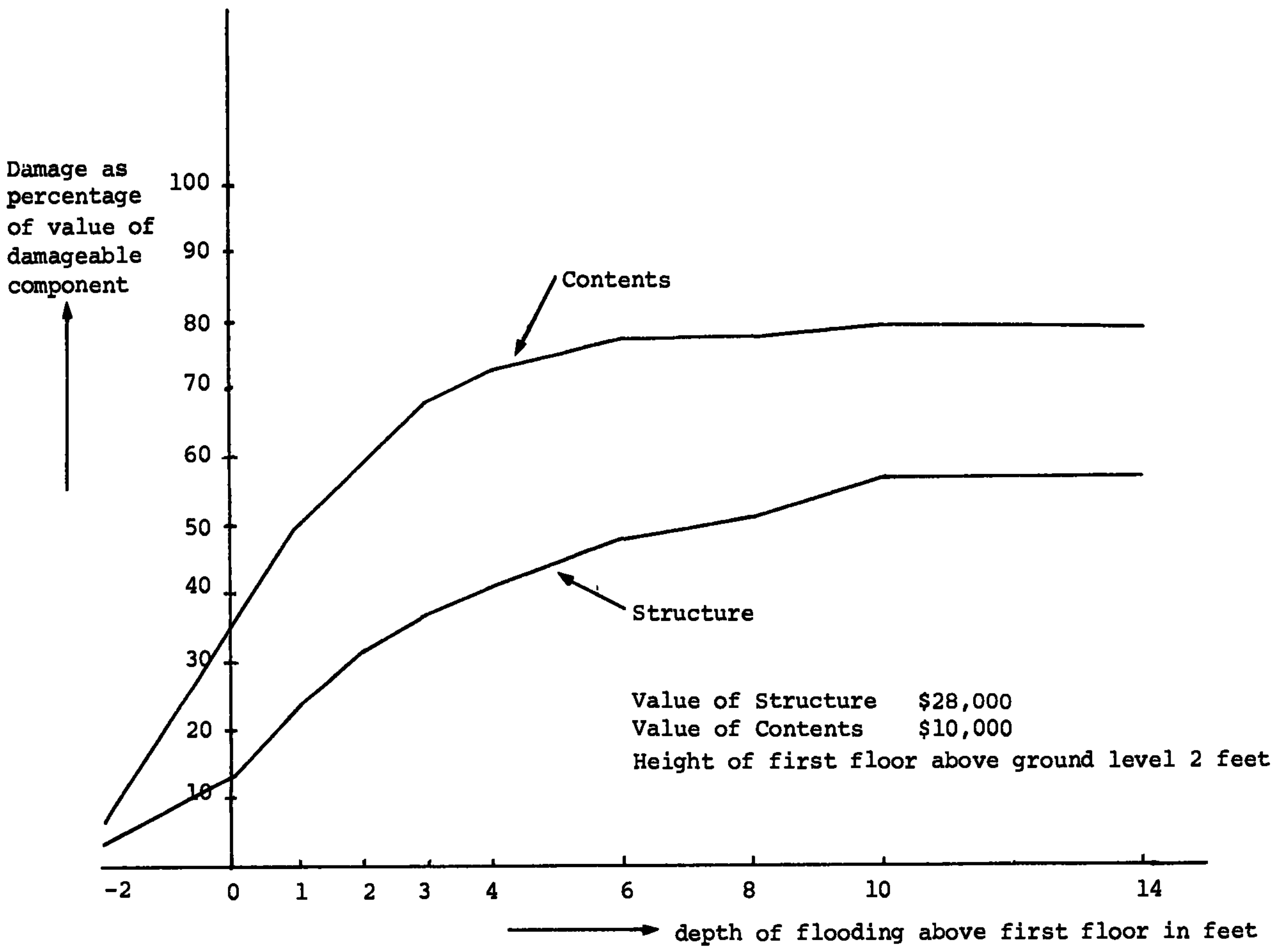


Figure 5.5 DAMAGE RELATIONSHIPS FOR TWO STORY RESIDENCE WITH BASEMENT

Table V-7

DEPTH OF REFERENCE FLOOD IN DAMAGE ZONES IN FEET

Reach	Damage Zones								
	1	2	3	4	5	6	7	8	9
1	19.0	18.0	15.4	12.0	9.0	7.4	6.0	2.0	0.0
2	14.0	9.0	6.0	4.0	2.0	3.0	-	-	-
3	15.5	12.5	11.5	10.5	9.5	8.5	5.0	0.0	-
4	16.0	10.0	0.0	-	-	-	-	-	-

E. Data for Estimating Economic Rent

The data for estimating the components of economic rent include fixed area development costs, site development costs, transportation costs, amenity values, and social environment effects. In addition, for each component, a rate of change resulting from increased productivity or from increased personal income is specified. In the NED test case, these rates of change were initially assumed to be zero.

1. Fixed Area Development Cost

The required fixed area development cost data consist of a list of subareas included in an area of fixed development costs and the amount of the fixed cost. No data are presented, because no areas with fixed development cost were identified in the NED test case.

2. Site Development Cost Data

The data required for estimating site development cost are divided into three categories: physical characteristics of the site, activity characteristics, and unit cost. The NED test case data are given in Tables V-8 and V-9. The general site data, presented in Table V-8, includes average slope, CBR, clearing requirements, need for disposal of debris, number of new trees to be planted or old trees to be protected per acre, road excavation in cubic yards (if available as independent estimates) and the need for water-proofing

Table V-8

GENERAL SITE DATA

Site Development Zone	Average Slope As %	California Bearing Ratio	Clearing Requirements	Hauling of Debris Needed	Number of Trees Per Acre		Road Excavation	Water Proofing Needed
					New	Old		
1	0	20	Light	Yes	0	0	N.A.	Yes
2	0	30	Medium	Yes	0	0	N.A.	No
3	8	50	High	Yes	0	0	N.A.	No
4	13	80	High	Yes	0	0	N.A.	No

Table V-9

SOIL COMPOSITION DATA IN PERCENTAGES

Site Development Zone	Common Earth	Gravel	Sand	Silts	Clay	Shale Without Blasting	Shale With Blasting	Rock Without Blasting	Rock With Blasting
1	10	20	20	20	20	5	0	5	0
2	30	30	20	5	5	0	0	10	0
3	20	10	5	0	5	0	0	20	40
4	20	10	0	0	0	0	0	10	60

of basements. The soil composition, presented in Table V-9, gives the percentages of different soil types for each site development zone.

The NED test case data on activity characteristics of middle income community development are presented in Table V-10. For each structure, the following data are included: the average ground floor space in square yards, the average excavation requirements in cubic yards, the cost of water proofing in dollars, the average length of connecting trenches in feet, the average linear feet of public road, the number of feet of main utility trench per foot of public road, and the average linear feet of private road. For residential activities these data are given by residence; for local commercial and public buildings, the data are given per acre. Additional data for both the main utility trenches and connecting trenches are required, and include the average width, the average depth, and the added cost per linear foot of main utility trench due to special requirements such as pumping. These data are given for different utility types and depth classes if separate trenches are needed for these utility types and if sections of the trenches fall in different depth classes. The depth classes considered are 1 to 6 feet, 6 to 10 feet, 10 to 15 feet, 15 to 20 feet, and 20 feet or more. For the NED test case, only one type of trench with a depth of 6 feet and a width of 3 feet was considered.

The unit cost data consist of the cost per acre for clearing, grubbing, and disposal; the cost per tree for planting and protection; the cost in cubic yards for highway subbase and base material; and the cost per cubic yard of excavation for different soil types and, in the case of trenches, for different depth intervals. These data may be specified by the planner, or in the absence of such data, the program automatically defaults to internally specified values. These values can be regionally adjusted using the hourly wages for heavy construction labor, tractor-scraper operators and truck drivers; for the NED test case these were \$6.35, \$8.86, and \$5.21 per hour, respectively.

3. <u>Data for Estimating Transportation Cost</u>

The data required for estimating transportation costs are divided into three categories: location, activity types, and unit cost. The NED test case data for middle income community development are presented in Tables V-11 and V-12. Travel distances and travel times for each subarea are presented in Table V-11, where the same centers of destination are assumed for all activity

Table V-10

CHARACTERISTICS OF ACTIVITY TYPES FOR MIDDLE INCOME COMMUNITIES

	Residences		Local Commercial per acre	Public Building per acre
	One Story, w/b*, per residence	Two Story w/b*, per residence		
Average Ground Floor Space in Square Yards	120	83	944	944
Excavation in Cubic Yards	300	215	600	600
Cost of Water Proofing in Dollars	1000	1000	N.A.	N.A.
Average Length of Connecting Trenches in Feet	120	120	50	50
Average Linear Feet of Public Road	150	150	500	500
Feet of Main Trench per Linear Foot of Public Road	2	2	2	2
Average Linear Feet of Private Road	0	0	0	0

* w/b indicates with basement

Table V-11

TRAVEL DISTANCE AND TIME

Subareas	Average Travel Distance in Miles	Average Travel Time in Minutes
1	4	5
2	3	5
3	4	7
4	4	7
5	5	8
6	7	12
7	2	3
8	2	3
9	4	6
10	1	3
11	3	5
12	8	13
13	5	8
14	3	5
15	2	4
16	5	8
17	6	10
18	0	0

types, and where the transportation network is assumed the same throughout the planning horizon. (Separate tables would be needed if transportation characteristics for the activity types differ, or if the transportation network will change over time.) The activity characteristics used to calculate the total number of trips per year are given in Table V-12 for residences and local commercial. The associated unit cost data for running cost and travel time are also presented in this table. If different modes of transportation are to be considered, information similar to that presented above is needed for each mode. The main difference is the need for total travel distances and for unit price rates, as explained in Chapter III, Section E.

Table V-12

ACTIVITY CHARACTERISTICS AND UNIT COSTS FOR TRANSPORTATION

Residences		Local Commercial	
Number of Working Days Per Year	250	Number of Tons Per Acre Per Year	200
Number of Commuters Per Family	1	Number of Tons Per Trip	4
Number of Commuters Per Car	1.2		
Running Cost Per Mile in Dollars	.10	Running Cost Per Mile in Dollars	.20
Value of Travel Time Per Hour in Dollars	1.50	Driver's Wage Per Hour in Dollars	6.00

4. Data for Estimating Amenity Values

The amenity value data is estimated outside of the program. The data required are the land price differences that each community land use would be willing to pay for a location with certain physical amenities, as compared to a location without any special amenities. For the NED test case, a first estimate of these land price differences is presented in Table V-13. The physical amenities considered were a view of Holyoke Range and proximity to the Connecticut River.

Table V-13

AMENITY VALUES IN DOLLARS PER ACRE

Amenity Zone	Middle Income Community
1	1000
2	1500
3	2000
4	1500

5. Data for Social Environment Effect

The data required for estimating social environment effects are information on locations which can potentially influence each others' economic rent, and the reductions in economic rent when activities influence each other. The basic data which is required are illustrated in Table III-1. No values are presented because, for the NED test case, no social environment effects were identified.

6. Agriculture

The economic rent for each combination of agriculture and location is provided as an input to the program. It is equal to the net earnings without subtracting the costs of land or flood damages. For the NED test case, the same economic rent of $35 per acre per year was used throughout the study areas.

7. Data on Land Values

The annual land values for each combination of aggregate activity and subarea are based on corresponding land prices. For the NED test case, the land prices for middle income housing and agriculture are listed in Table V-14. They are based on observed market values and, for testing purposes, they were adjusted to make them in closer agreement with the economic rent differences

Table V-14

LAND PRICES IN DOLLARS PER ACRE

Subarea	Middle Income Community	Agriculture
1	7,000	300
2	7,500	300
3	7,000	300
4	5,000	300
5	4,500	300
6	3,000	300
7	10,000	300
8	10,000	300
9	8,500	300
10	11,500	300
11	10,000	300
12	5,000	300
13	4,500	300
14	10,000	300
15	11,500	300
16	9,000	300
17	8,000	300
18	11,500	300

determined by the SIMULATOR.

F. Land Use Data and Requirements

The land use allocation model requires, in addition to economic rent differences and flood damages, data on existing land uses in the year of the study, additional land uses by the initial year of the FPM plan, land use requirements over time after the plan is in effect, and ultimate land use plans. For the NED test case, the existing land uses included middle income communities, wholesale and distribution, and industry of type I and II. The acreages used for these activities are listed in the first part of Table V-15 for each parcel. Additional development which is projected between the year of the study, 1972, and the initial year of the FPM plan, 1985, consists of middle income communities only. The additional acreages are listed in the second part of Table V-15. The ultimate land use, for each economic growth area, is presented in Table V-16, and is given by the acreage used for the middle income community in each subarea and is the same with and without the FPM. Finally, in Figure 5.6, the land use requirements for each of the economic growth areas are given in acres at the end of each planning period.

G. Summary

In this chapter the input data required by the SIMULATOR is described in detail. These requirements were illustrated by the data used in the NED test case in Reach 13 of the Connecticut River Basin. The importance of using initial gross estimates to reduce the total data collection effort was emphasized.

Table V-15

LAND USES AT INITIAL YEAR OF FLOOD PLAIN MANAGEMENT PLAN IN ACRES

Subarea/Parcel		Middle Income Community					Whole-sale and Dis-tribution	Industry	
		Residen-tial	Local Commer-cial	Public	Open Space	Streets		I	II
1	1		1		3	4			
	2	2		10		6			
2	1		2		4	7			
	2	42	8			20			
3	1	70	7	2		26			
5	1	60				20			
6	4	13	3			5			
	5	20	4			7			
	6	4	1			3			
	7	4				6			
7	1	2			4	12			
	2	6				3			
8	1	11				3			
	2	10				6			
9	1	5				30			
	2	12	4			2			5
	3		2			1			
	4	3		1		2			
10	1	6				2			
	2							55	
11	1	9							
	2	6				5			
	3	11				4			
	4	20	3		4	8			
18	1						80		
	2	86	5	5		40			
		Additional Land Uses by 1985							
1	2	6				2			
2	1	2							
2	2	15	4			6			
3	1	70	7			26			
5	1	10				3			
6	5		3			1			
6	6	2	1						
7	2	3				1			
11	1	3				1			

Table V-16

ULTIMATE LAND USE FOR MIDDLE INCOME COMMUNITY IN ACRES

Sub-area	Economic Growth Area #1		Sub-area	Economic Growth Area #2		Sub-area	Economic Growth Area #3		Sub-area	Economic Growth Area #4	
	w/o	w		w/o	w		w/o	w		w/o	w
1			7			4	230	230	11	130	130
2	160	160	8			5	625	625	16	210	210
3	282	282	9			6	300	300	17	280	280
12	960	960	10	154	154	13	1190	1190			
			14	280	280						
			15	120	120						
			18								
Total	1402	1402		554	554		2345	2345		620	620

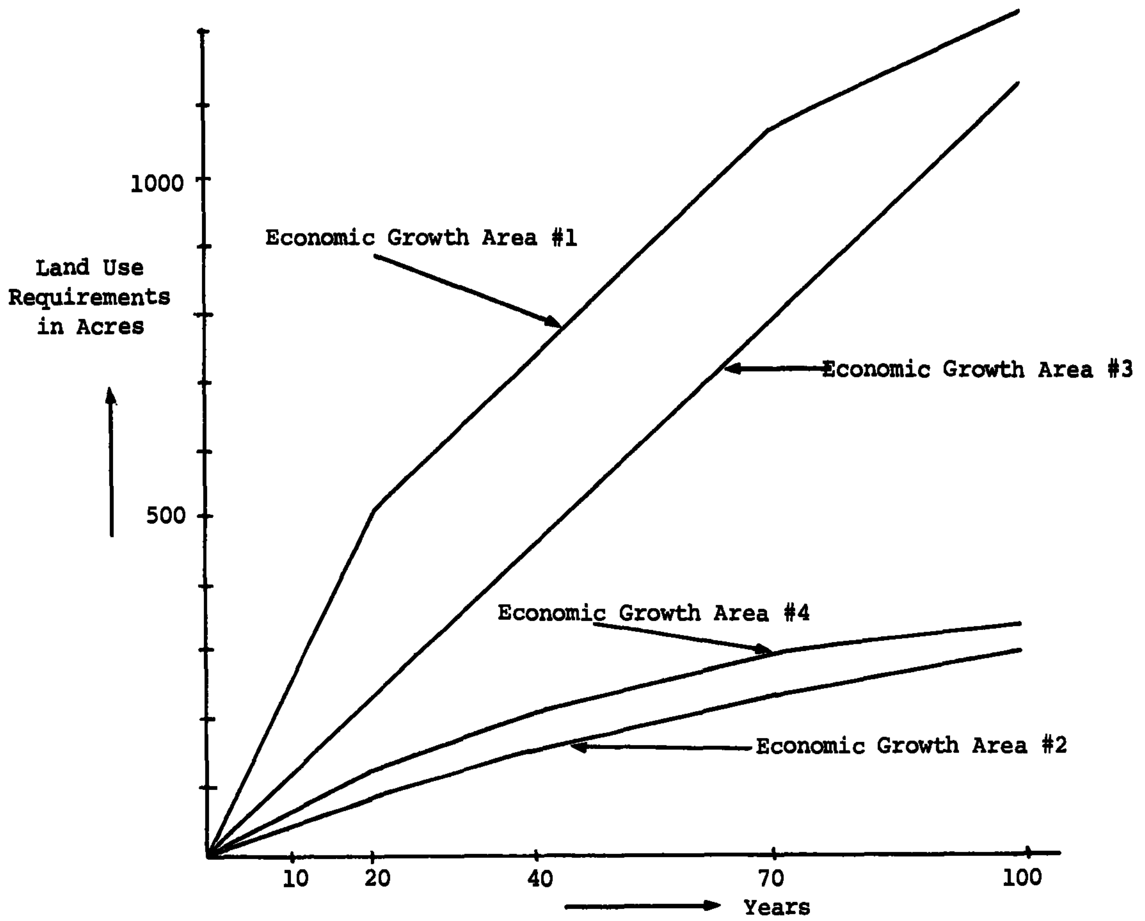


Figure 5.6 LAND USE REQUIREMENTS OVER TIME

Chapter VI

RESULTS OF NED TEST CASE

A. Introduction

The program was tested on Reach 13 of the Connecticut River Basin. Basic input data for this test case were described in the previous chapter. In this chapter the results are presented. Section B describes the basic run, together with results from initial test runs. Section C presents the results of several sensitivity runs, and Section D illustrates the use of the SIMULATOR in studying alternative zoning regulations. The chapter is summarized in Section E.

B. Basic Run

Future land use in Reach 13 of the Connecticut River Basin is expected to consist primarily of middle income housing, and in describing the output of the SIMULATOR, only the results for middle income housing are presented. However, the SIMULATOR also provides information on all other activity types specified in the study. Results of the basic run are described in detail, since this run is used as a reference when studying sensitivities to input data or to flood plain zoning and related assumptions about locational behavior of activities.

1. Intermediate Results

Following the procedure outlined in Chapter III, flood damages for each detailed activity/flood damage zone combination were calculated for middle income residences, average annual damages to both structures and contents are presented in Figure 6.1 for different damage zones. Damage zones are identified by depth of the reference flood above ground level. Damages are given with the existing protection (21.6% reduction TTCF) and with additional protection (47.5% reduction TTCF). Flood damages for each aggregate activity/subarea combination were obtained as the weighted sum of flood damages for detailed activity/damage zone combinations. The results are presented in Table VI-1, which gives the average annual damages to structures and contents in dollars per acre, both with

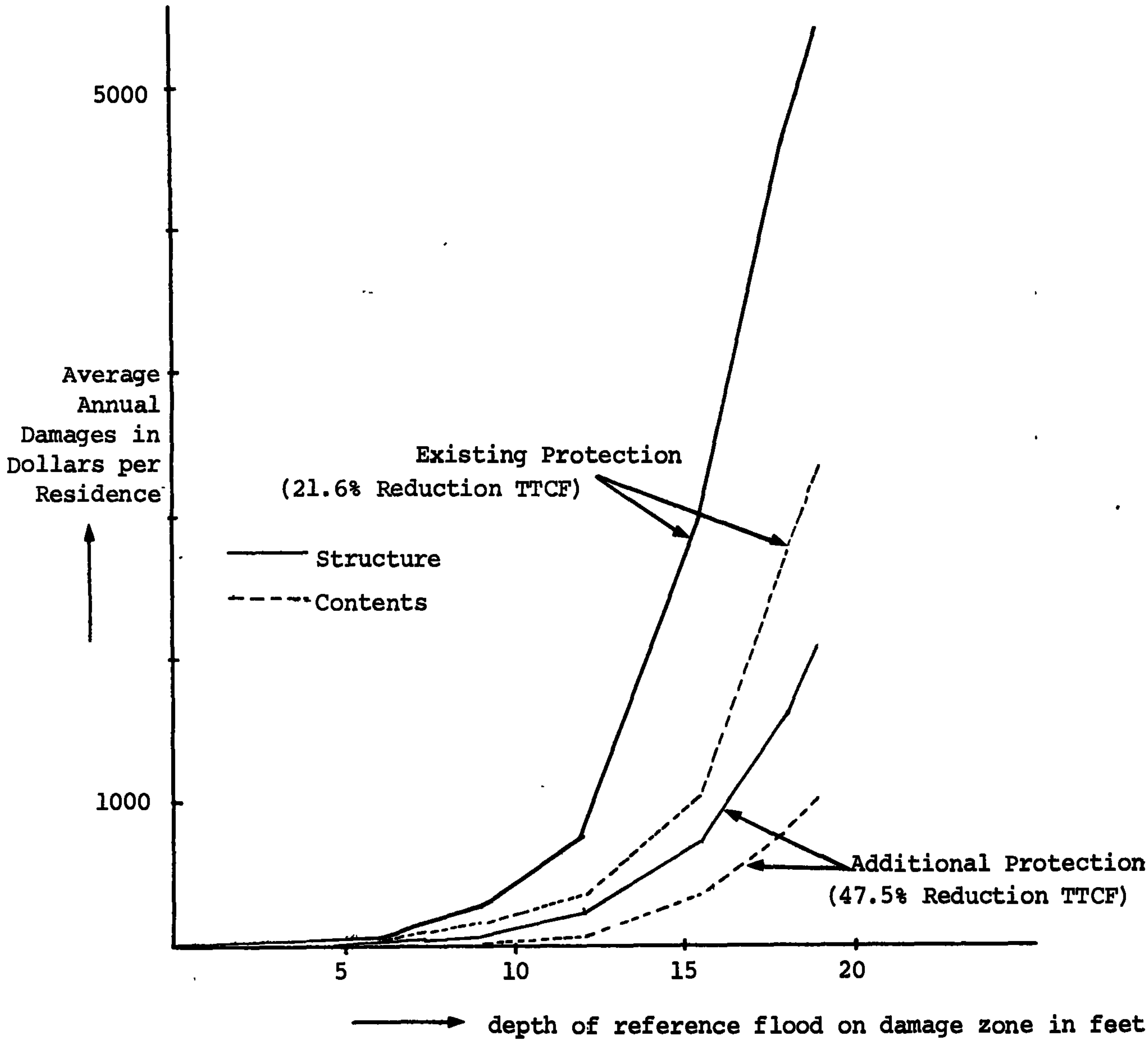


Figure 6.1 AVERAGE ANNUAL DAMAGES FOR MIDDLE INCOME RESIDENCE WITH TWO STORIES AND BASEMENT

and without additional protection.

Table VI-1

AVERAGE ANNUAL FLOOD DAMAGES FOR MIDDLE INCOME COMMUNITIES IN DIFFERENT SUBAREAS, IN $/ACRE

Subarea	Structures		Contents	
	w/o*	w*	w/o	w
1	886	122	780	110
2	79	4	73	4
3	10	0	9	0
4	257	31	227	28
5	41	0	38	0
6	1400	229	1253	205
7	2094	319	1878	286
8	596	79	525	72
9	2757	466	2668	417
10	18	0	16	0
11	75	4	67	4
18	58	20	44	16

* Stand for with and without additional protection

Similarly, following the procedure described in Chapter III, site development cost, transportation costs and amenity values were calculated for each detailed activity type/zone combination. For site development cost, the results are presented in Table VI-2. Zone 1 is in the flood plain, where the site development cost is larger than for zone 2 which is flat and outside the flood plain. The reason for this cost difference is that water proofing of basements is required inside the flood plain. Zone 3 consists of land with an average slope of 8% and soil with an increased level of rock content compared to zones 1 and 2. Thus, site development cost in zone 3 is larger than in zones 1 and 2. Based on values for the detailed activities and zones, economic rent components were calculated for each aggregate activity/subarea combination. The resulting values for the economic rent components were used in the land use allocation model and are presented in Table VI-3. Values for site development costs are substantially higher than values for transportation cost and amenites because the site development cost is incurred only once when an activity locates on a site, while the other costs are incurred on an annual basis.

Table VI-2

SITE DEVELOPMENT COST FOR DETAILED ACTIVITY/ZONE COMBINATIONS IN $/ACRE

Activity Type	Site Development Zone		
	1	2	3
Middle Income Community			
Residence, One Story, with Basement	4817	3059	5789
Residence, Two Story with Basement	4695	2936	5601
Local Commercial	5561	5288	10700
Public Building	5561	5288	10700

The criterion for land use allocation is the present value of net economic rents, using a private discount rate and market horizon. For the basic run, land use requirements included middle income housing, which will displace non-urban land use. Thus, present value of economic rent, flood damages and associated net economic rents for middle income housing and non-urban land use were needed. They are given for each subarea with and without additional protection in Table VI-4a and VI-4b. The present values of flood damages for middle income housing were obtained as the present value of annual flood damages given in Table VI-1, using a discount rate of 10%, a planning horizon of 20 years, and assuming that flood damages are incurred at the beginning of each year.

Table VI-3

ECONOMIC RENT COMPONENTS FOR MIDDLE INCOME COMMUNITY IN DOLLARS PER ACRE

Subarea	Amenity Values	Site Development Cost	Transportation Cost	
			Running Cost	Value of Travel Time
1	100	5059	209	65
2	100	5059	157	65
3	100	5059	209	91
4	200	5059	209	91
5	200	5059	261	104
6	200	5059	366	157
7	0	5059	104	39
8	0	5059	104	39
9	0	5059	209	78
10	150	5059	52	39
11	0	5059	157	65
12	0	3284	419	170
13	0	3284	261	104
14	0	4185	157	65
15	0	3284	104	52
16	0	4486	261	104
17	0	3584	314	130
18	0	5059	0	0

Table VI-4a

SEQUENCE OF SUBAREA DEVELOPMENT WITHOUT ADDITIONAL PROTECTION

Economic Growth Area	Subarea	Present Value in Dollars per acre Using 10% Discount Rate and 20 years Horizon							First Year of Development
		Middle Income Housing			Non Urban Use			Total Net Economic Rent	
		Economic Rent	Flood Damages	Net Economic Rent	Economic Rent	Flood Damage	Net Economic Rent		
1	1	-6,688	15,601	-22,289	309	43	266	-22,555	-
	2	-6,201	1,422	- 7,623	309	0	309	- 7,932	11.7
	3	-6,932	177	- 7,109	243	0	243	- 7,352	0.0
	12	-8,799	-	- 8,799	280	-	280	- 9,079	18.1
2	7	-6,397	37,197	-43,594	280	112	168	-43,762	-
	8	-6,397	10,497	-16,894	280	32	248	-17,142	-
	9	-7,746	52,677	-60,423	243	149	94	-60,517	-
	10	-4,506	317	- 4,823	280	0	280	- 5,103	31.2
	14	-6,263	-	- 6,263	0	-	0	- 6,263	91.4
	15	-4,743	-	- 4,743	103	-	103	- 4,846	0.0
	18	-5,059	955	- 6,014	0	0	0	- 6,014	-
3	4	-5,996	4,531	-10,527	309	8	301	-10,828	-
	5	-6,604	738	- 7,342	206	0	206	- 7,548	-
	6	-8,084	24,844	-32,928	309	80	229	-33,157	-
	13	-6,701	-	- 6,701	280	-	280	- 6,981	0.0
4	11	-5,733	1,329	- 7,062	0	0	0	- 7,062	44.4
	16	-6,499	-	- 6,499	309	-	309	- 6,808	0.0
	17	-7,741	-	- 7,741	299	-	299	- 8,040	-

Table VI-4b

SEQUENCE OF SUBAREA DEVELOPMENT WITH ADDITIONAL PROTECTION

Economic Growth Area	Subarea	Present Value in Dollars per Acre Using 10% Discount Rate and 20 Years Horizon							First Year of Development
		Middle Income Housing			Non Urban Use			Total Net Economic Rent	
		Economic Rent	Flood Damages	Net Economic Rent	Economic Rent	Flood Damages	Net Economic Rent		
1	1	-6,688	2,172	- 8,860	309	0	309	- 9,169	-
	2	-6,201	74	- 6,275	309	0	309	- 6,584	0.0
	3	-6,932	0	- 6,932	243	0	243	- 7,175	6.7
	12	-8,799	-	- 8,799	280	-	280	- 9,079	18.1
2	7	-6,397	5,665	-12,062	280	15	265	-12,327	-
	8	-6,397	1,413	- 7,810	280	0	280	- 8,090	-
	9	-7,746	8,269	-16,015	243	21	222	-16,237	-
	10	-4,506	0	- 4,506	280	0	280	- 4,786	0
	14	-6,263	-	- 6,263	0	-	0	- 6,263	91.4
	15	-4,743	-	- 4,743	103	-	103	- 4,846	41.9
	18	-5,059	336	- 5,395	0	0	0	- 5,395	-
3	4	-5,996	552	- 6,548	309	0	309	- 6,857	56.5
	5	-6,604	0	- 6,604	206	0	206	- 6,810	0.0
	6	-8,084	4,063	-12,147	309	8	301	-12,448	-
	13	-6,701	-	- 6,701	280	-	280	- 6,981	77.0
4	11	-5,733	74	- 5,807	0	0	0	- 5,807	0.0
	16	-6,499	-	- 6,499	309	-	309	- 6,808	23.2
	17	-7,741	-	- 7,741	299	-	299	- 8,040	-

The present value of economic rents for middle income housing was derived similarly from Table VI-3 by combining site development cost with the present value of operating cost for the automobile, value of travel time, and amenity value. The present value of economic rent and flood damages for non-urban land use was obtained by using the economic rent and flood damages for agriculture, and the percentage of each subarea in agricultural use.

The change in total net economic rent associated with location of one acre of middle income housing in a subarea is equal to the net economic rent of middle income housing minus the net economic rent of displaced non-urban land use. With no additional protection, the result for each subarea is given in the next to last column of Table VI-4a. It was assumed here that agriculture, once displaced, goes out of production. Furthermore, the net economic rent for middle income housing included only the location dependent cost components as explained for site development cost in Chapter III, Section E. As a result, the changes in total net economic rent are generally negative. The last column in Table VI-4a gives the first year of development for each subarea where the order in which subareas are used was based on total net economic rent, and where land use requirements for each economic growth area were as given in Figure 5.6. Similar results are presented in Table VI-4b when additional protection is provided. In this case, flood damages are reduced, total net economic rent for subareas in the flood plain is increased, and the sequence in which areas develop is changed.

The results of allocation of land uses over time with and without additional protection are summarized in Figure 6.2 for the four economic growth areas, where the line segments indicate time periods during which each subarea is being developed. In economic growth area 1, under existing conditions, subarea 3 is developed first and then subarea 2. With additional protection this sequence is reversed. In both cases, subarea 12 is used after 20, and subarea 1 is not used at all. The situation is similar in economic growth area 2. Under existing conditions, subarea 15 develops first and then subarea 10, while, with additional protection, this sequence is reversed. The difference with economic growth area 1 is that, whereas subareas 2 and 3 are both in the flood plain, in economic growth area 2 subarea 10 is in the flood plain and subarea 15 is outside the flood plain. Furthermore, subarea 14 develops after year 91 both

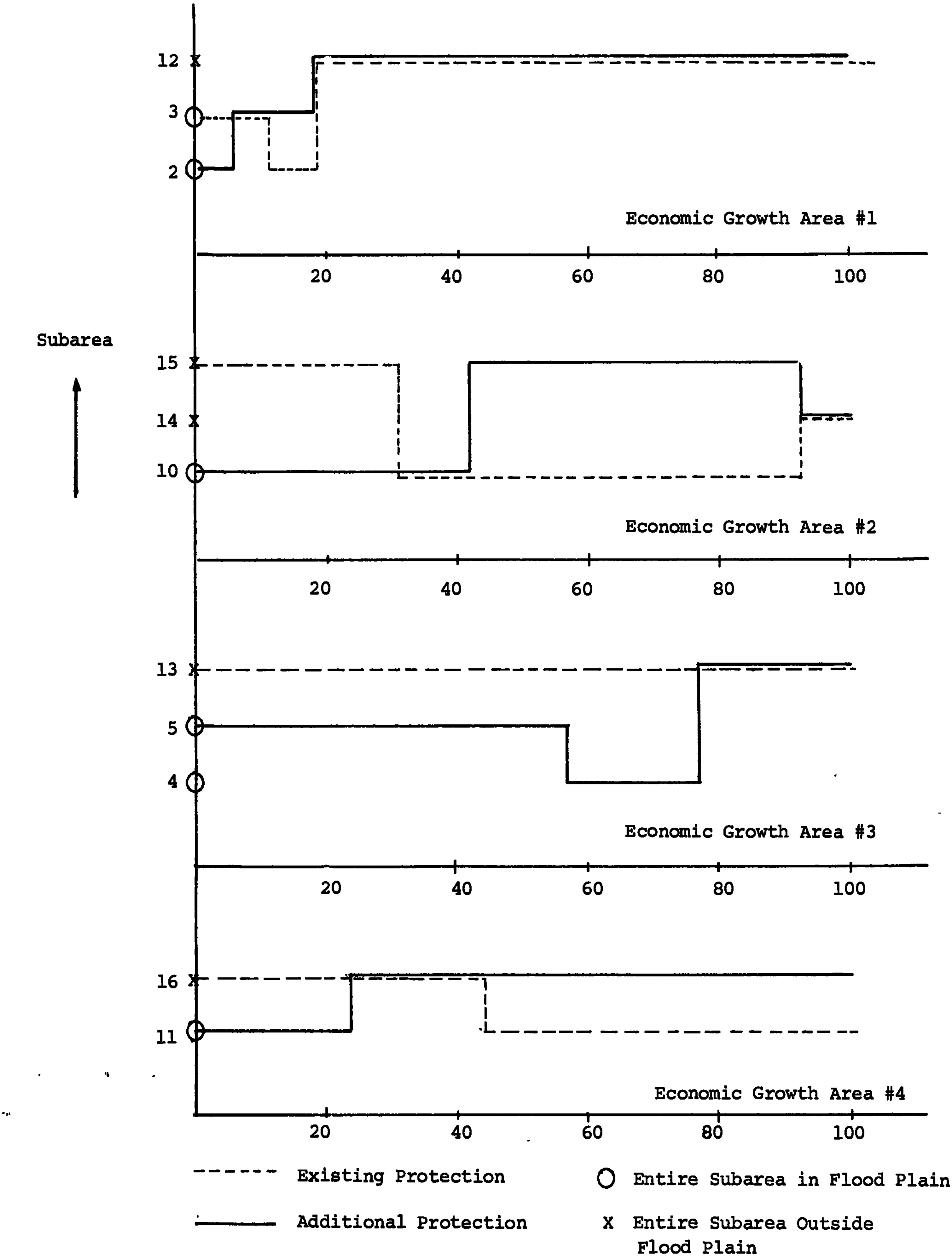


Figure 6.2 ALLOCATION OVER TIME WITH AND WITHOUT ADDITIONAL PROTECTION

with and without additional protection, while subareas 7,8,9 and 18 are not used at all. In economic growth area 3, subarea 13 is used throughout the planning period under existing conditions, while with additional protection, subareas 5 and 4 are used instead during the first 77 years. Subarea 6 is not used at all. Finally, in economic growth area 4 under existing conditions, subarea 16 is used and then subarea 11, while with additional protection, the order is reversed. Subarea 17 is not used.

2. Benefits from Additional Flood Protection

Damage reduction and locational advantage, making up the benefits from additional flood protection are presented in Table VI-5. Damage reduction is given for activities existing in 1972, and for future middle income community development locating the same with and without additional protection. Locational advantage, measuring the benefits from activities locating differently with and without additional protection, was estimated independently by the three alternative formulas discussed in Chapter II, Section E. The economic rent formula was selected to calculate the total benefits. Estimates for locational advantage provided by these different formulas differed widely.

Damages to activities existing in 1972 make up about 80% of the total benefits. They are composed of a $7.0 million damage reduction to middle income communities, $1.0 million to wholesale distribution and industry, and $1.2 million to agriculture. Damage reduction to future activities makes up about 10% of the total benefits, while locational advantage of middle income housing accounts for the remaining 10%. Damage reduction benefits due to existing and future middle income community development accounts for about 73% of the total benefits. Thus, one of the conclusions of this basic run is that improved estimates of the benefits from FPM plans can be obtained principally by increasing the accuracy of the damage reduction estimate for middle income communities.

Locational advantage, estimated by the economic rent/land value formula, is about $44,000 lower than the estimate obtained by the economic rent formula. This difference is due to the fact that subareas 2 and 3, which are used differently with and without additional protection, are both located in the flood plain and only the damage component of locational advantage is included in the economic rent/land value formula. Additional deviations result because the

Table VI-5

FLOOD CONTROL BENEFITS: BASIC RUN

Damage Reduction		
Existing Activities (1972)	9,157,717	
Future Activities	1,183,961	10,341,678
Locational Advantage		
Economic Rent Formula	1,078,173	1,078,123
Economic Rent/Land Value Formula	1,034,000	
Land Value Formula	456,123	
Land Value Formula (Flood Plain Only)	5,064,873	
Total Benefits		11,419,801

difference in agricultural land use is evaluated using land values. The purpose of the economic rent/land value formula is to reduce data requirements. However, in this case, no reduction in data requirement resulted when this formula was used.

The estimate obtained using the land value formula is more disparate. Only crude estimates of land prices were available, and these were adjusted to conform to within $500 to the differences in present values of the economic rents in Table VI-4a and 4b in order to test the formula assuming land prices and economic rents are reasonably consistent. In this case, however, a closer agreement between economic rents and land values was needed in order to arrive at the same locational advantage as the economic rent formula. The danger of using land enhancement as a measure of benefits based only on land values in the flood plain is illustrated by restricting application of the land use formula to the flood plain.

Components of locational advantage, locational advantage and the upper bound are presented in Table VI-6 for the study area and for each economic growth area. Locational advantage was obtained using the economic rent formula. The site development cost component includes differences in economic rent to agriculture, and is negative for all areas. The reasons for this negativity are that the site development cost is higher in the flood plain due to water proofing requirements for basements, and the economic rent of displaced non-urban use is also generally higher in the flood plain. Since subarea 2 and 3 are in the same site development zone, the site development cost component for economic growth area 1 is totally due to agriculture. The transportation cost component is positive for each economic growth area because subareas in the flood plain are closer to the points of destination. The amenity value component is also positive because generally physical amenity is associated with areas in the flood plain. For economic growth areas 1 and 4, the contribution of amenity value is zero because both subareas 2 and 3 and subareas 11 and 16 have the same amenity values. (The non-zero entry in the table for economic growth area 1 is a result of round-off.) Finally, the total residual damage reduction is positive for the entire study area as well as in economic growth areas 1 and 2 while it is negative in economic growth areas 3 and 4. Thus, in these last areas, residual damages to the middle income community with additional protection exceed damages to agriculture without additional protection. The last row in Table VI-6 lists the upper bound on locational advantage, as described in Section C of Chapter II. The upper bounds are violated for the entire study area and for economic growth area 1 and 3. The reason is that allocation of activities is performed on the basis of a private discount rate and market horizon, while the benefit evaluation uses a social discount rate and planning horizon. The implications of the difference in criteria for allocating activities are discussed in more detail below.

Table VI-6

LOCATIONAL ADVANTAGE BY ECONOMIC GROWTH AREA

	Study Area	Economic Growth Area			
		1	2	3	4
Site Development Cost*	-449,667	-8,070	-85,850	-325,090	-30,496
Transportation Cost	335,375	79,721	64,619	7,873	183,032
Amenity Value	956,956	- 116	161,010	795,897	0
Residual Damage Reductions	235,459	246,458	3,098	-7,633	-6,408
Locational Advantage	1,078,123	317,993	142,877	471,047	146,128
Upper Bound	1,076,081	465,712	40,365	312,919	248,304

* includes economic rent difference due to agriculture

3. Allocation Based on Social Discount Rate and Planning Horizon

In the basic run, the allocation of activities over time uses a private discount rate of 10% and a market horizon of 20 years, while the benefit evaluation uses a 5 3/8% discount rate and a 100 year planning horizon. The results of using the same social discount rate and planning horizon in allocation as in evaluation are presented in Table VI-7. Damage reduction to future activities has increased substantially indicating that more activities locate the same with and without additional protection. Thus, based on the social discount rate and planning horizon, more activities locate in the flood plain without additional protection. Increased present value of the annual contributions of transportation and amenity values is, in many cases, large enough to overcome the disadvantage of larger site development costs and flood damages incurred in the flood plain. Thus, on the basis of the social discount rate and planning horizon, more activities locate in the flood plain without additional protection because of the heavier weight given to future benefits compared to the initial payments for water proofing of basements.

Table VI-7

FLOOD CONTROL BENEFITS USING DISCOUNT RATE OF
5 3/8% AND 100 YEAR PLANNING HORIZON FOR ALLOCATION

Damage Reduction			
Existing Activity (1972)	9,157,717		
Future Activities	1,785,096		
Total Damage Reduction		10,942,813	
Locational Advantage			
Site Development Cost	-20,874		
Transportation Cost	87,599		
Amenity Value	25,286		
Residual Damages	238,800		Upper Bound
Total Locational Advantage		330,811 <	466,699
Total Benefits		11,273,624	

Changes in the time profile, given in Figure 6.2 for the basic run, are as follows when the social discount rate and planning horizon are used. In economic growth area 1, the allocation does not differ from that of the basic run. In economic growth areas 2 and 4, the allocation is the same with and without additional protection, and equal to allocation with protection in the basic run. In economic growth area 3, subarea 5 is used for the first 56 years both with and without additional protection; for the remainder, the allocation is the same as in the basic run. As a result of the above changes, the larger part of locational advantage is now due to economic growth area 1, as can be seen by comparing Tables VI-6 and VI-7. The remainder is the result of economic growth area 3's contribution to locational advantage from year 56 through 77.

The upper bound is satisfied when using the same criterion for allocation as for benefit evaluation, as was expected. Violations of the upper bound may occur if the basis for allocation is different from that of benefit evaluation. In the above case, the difference was related to discount rate and planning horizon. Other instances of violations of upper bounds would be expected if the allocation procedure accounted for the loss of life or the cost of uncertainty, and if the evaluation analysis did not take these into account.

4. Results of Initial Test Runs

During the initial test runs it was assumed that, with additional protection, apartment communities, region-serving retail, and warehouse and distribution would locate in subarea 7. The result was a large locational disadvantage of about four and a half million dollars, indicating that the location of some activities was not as good with as without the additional protection. The breakdown of locational advantage by components and by aggregate activity type is shown in Table VI-8. As expected, the component is negative for site development cost and positive for transportation cost and amenity value. However, damage reduction is heavily negative and is the major reason for negative locational advantage. This negativity results from the large residual damages to apartment community development, regional serving retail, and warehousing and distribution in subarea 7.

The initial test run shows that, by specifying an improper ultimate land use for the study area, the benefit estimate will be off by a large amount.

Table VI-8

LOCATIONAL ADVANTAGE OF INITIAL TEST RUN BY AGGREGATE ACTIVITY TYPE
(BENEFITS IN $1000)

	Total	Middle Income Community	Apartments Community	Region Serving Retail	Wholesale and Distribution	Agriculture
Economic Rent Differences						
Site Development Cost	-532	-437	-11	3	14	-101
Transportation Cost	583	335	109	28	111	
Amenity Value	957	957	0	0		
Social Environment Effect						
Damage Reduction	-5,400	236	-2,256	-696	-2,784	40
Locational Advantage	-4,452	1,091	-2,158	-665	-2,659	-61

The undesirability of the ultimate land use plan could also have been identified at an earlier stage by studying a table similar to Table VI-4a and 4b of present values of net economic rents for relevant activity types. This table would show that all subareas outside the flood plain are superior to subarea 7. As a result, apartment communities, region serving retail and warehousing and distribution were assumed to locate outside the flood plain irrespective of additional protection, and these activities were excluded from the basic run.

C. Sensitivity Study

Sensitivity of the benefits to several problem parameters are presented in this section. The results are grouped together on the basis of related parameters in Tables VI-9 through VI-13.

1. Social Discount Rate and Planning Horizon

The sensitivity of benefits to the social discount rate and planning horizon are shown in Table VI-9. Discount rates considered are 5 3/8%, 7% and 10%, and planning periods considered are 100 and 50 years. As expected, benefits decreased rapidly with an increased discount rate. By using a 10% discount rate instead of 5 3/8%, benefits were reduced by a factor of about 2, indicating that the choice of discount rate is crucial for benefit evaluation. The use of a 50 year planning horizon reduced benefits by a relatively small amount, becoming smaller with an increased discount rate. Thus, events in the second half of the 100 year planning period are not very important for benefit evaluation.

2. Level of Protection and Stage-Frequency Curve

Benefits resulting from different levels of protection are presented in Table VI-10. For the basic run, TTCF was reduced by 47.5%. A lower level of protection, corresponding to a reduction of 35% in the TTCF, results in a decrease in benefits measured by damage reductions. It also decreases the economic rent compoents of locational advantage, because, with decreased portection, economic growth area 3 will use subarea 13 both with and without additional protection. Thus, the benefit contributions, indicated in Table VI-6 for economic growth area 3, are eliminated for the case of a 35% reduction in TTCF. With

Table VI-9

SENSITIVITY TO DISCOUNT RATE AND PLANNING HORIZON (BENEFITS IN $1000)

	100 Year Planning Horizon			50 Year Planning Horizon		
Discount Rate	5 3/8%	7%	10%	5 3/8%	7%	10%
	Basic Run					
Damage Reduction						
Existing Activities	9,158	7,062	4,948	8,535	6,830	4,907
Future Activities	1,184	909	634	1,101	878	628
Total	10,342	7,971	5,582	9,636	7,708	5,535
Locational Advantage						
Site Development Cost	-450	-374	-285	-434	-368	-284
Transportation Cost	335	246	157	310	236	156
Amenity Value	957	605	318	768	536	305
Damage Reduction	236	149	74	199	135	71
Total	1,078	626	264	843	539	248
Total Benefits	11,420	8,597	5,846	10,479	8,247	5,783

Table VI-10

SENSITIVITY TO LEVEL OF PROTECTION AND STAGE-FREQUENCY CURVE
(BENEFITS IN $1000)

	Reduction in TTCF		Complete Pro-tection	Increased Stages At Low Frequency	First Floor 4 Feet Above Ground
	47.5%	35%			
	Basic Run				
Damage Reduction					
Exiting Activities	9,158	6,513	10,837	9,397	6,205
Future Activities	1,184	797	1,354	1,411	862
Total	10,342	7,310	12,191	10,808	7,067
Locational Advantage					
Site Development Cost	-450	-125	-554	-38	-437
Transportation Cost	335	327	992	263	315
Amenity Value	957	161	1,016	0	953
Damage Reduction	236	12	254	316	98
Total	1,078	375	1,708	541	929
Total Benefits	11,420	7,685	13,899	11,349	7,996

Table VI-11

SENSITIVITY TO ECONOMIC RENT COMPONENTS
(BENEFITS IN $1000)

	Basic Run	Travel Time From $1.50 to $2.50/Hour	Change In Transportation Net Work At Year 20	Increased Distances Outside Flood Plain	Increased Site Development Cost
Damage Reduction					
Existing Activities	9,158	9,155	9,158	9,158	9,158
Future Activities	1,184	1,184	1,184	1,785	1,785
Total	10,342	10,339	10,342	10,943	10,943
Locational Advantage					
Site Development Cost	-450	-468	-563	-21	-1
Transportation Cost	335	579	387	97	88
Amenity Value	957	953	1,097	25	25
Damage Reduction	236	80	19	239	239
Total	1,078	1,144	942	340	351
Total Benefits	11,420	11,483	11,284	11,283	11,294

	Increased Acres of Desirable Subareas	No Amenity Values	Amenity Values Half of Basic Run	Amenity Values Double of Basic Run
Damage Reduction				
Existing Activities	9,158	9 158	9,158	9,158
Future Activities	1,152	1,181	1,187	1,536
Total	10,310	10,339	10,345	10,694
Locational Advantage				
Site Development Cost	-556	-97	-39	-51
Transportation Cost	823	401	263	271
Amenity Value	1,005	0	0	51
Damage Reduction	77	229	240	232
Total	1,349	533	464	503
Total Benefits	11,659	10,872	10,809	11,197

Table VI-12

SENSITIVITY TO INCREASE IN FLOOD DAMAGES AND ECONOMIC RENTS OVER TIME
(BENEFITS IN $1000)

	Basic Run	Increase in Value of Structure Etc.	Depre-ciation	Increase in Values and Depre-ciation	Increase in Economic Rent Component	Increase in Economic Rent Component & Value of Structure	Increase All Components by 2%
Damage Reduction							
Existing Activities	9,158	10,278	7,618	8,770	9,158	10,278	11,662
Future Activities	1,184	1,320	953	1,094	1,840	1,876	1,639
Total	10,342	11,598	8,571	9,864	10,998	12,154	13,301
Locational Advantage							
Site Development Cost	-450	-437	-450	-437	-18	3	-543
Transportation Cost	335	328	335	327	69	421	1,426
Amenity Value	957	931	957	931	52	52	1,741
Damage Reduction	236	317	201	274	246	312	182
Total	1,078	1,139	1,043	1,095	349	788	2,806
Total Benefits	11,420	12,738	9,614	10,959	11,347	12,942	16,107

Table VI-13

SENSITIVITY TO LAND USE REQUIREMENTS OVER TIME
(BENEFITS IN $1000)

	Basic Run	Future Land Use Until 1985		Future Land Use After 1985	
		Half	Double	Half	Double
Damage Reduction					
Existing Activities	9,158	9,159	9,155	9,158	9,157
Future Activities	1,184	608	2,336	1,169	1,200
Total	10,342	9,767	11,491	10,327	10,357
Locational Advantage					
Site Development Cost	-450	-450	-449	-283	-631
Transportation Cost	335	337	336	290	318
Amenity Value	957	958	956	527	1,499
Damage Reduction	236	231	235	79	459
Total	1,078	1,076	1,078	613	1,645
Total Benefits	11,420	10,843	12,569	10,940	12,002

complete protection, benefits due to damage reductions increased, as did the economic rent components of locational advantage. This last increase is the result of changes in land use; such as the use of subarea 1 instead of subarea 12 in economic growth area 1, and the change in sequence of subareas 4 and 5 in economic growth area 3.

Sensitivity of benefits to the estimated stages for low frequencies was investigated by increasing the stage for the 100,200,400 and 1000 year floods by 1,2,3 and 4 feet, respectively. These increases in stage were made both with and without additional protection. As a result of this change, land use in economic growth areas 2 and 3 with additional protection becomes the same as without additional protection. As expected, damage reduction increases, while locational advantage decreases. Overall benefits remain about the same as in the basic run.

In the basic run, the first floor is assumed to be two feet above ground level. Increasing this to four feet reduced damage reduction benefits as well as locational advantage. Only a small part of this change in locational advantage is the result of change in economic rent components related to different land use allocation.

3. Sensitivity to Parameters of Economic Rent Components

The sensitivity of benefits to various parameters of economic rent components is presented in Table VI-11. The value of travel time in the basic run is $1.50 per hour. Using a value of $2.50 per hour, the transportation cost benefit increases, and also the sequence in which subarea 4 and 5 develop is interchanged. This results in minor changes in other economic rent and damage reduction components. In the next run, the transportation network was changed after year 20, such that travel distance and time from subarea 12 were reduced by a factor of about 3. As a result, land use in economic growth area 1 without additional protection changes and subarea 2 is not used. Instead, the decision is made to start using subarea 12 in year 12 because of the reduction in transportation cost from this subarea starting in year 20. As a result, locational advantage from additional protection as well as overall benefits decrease.

The travel distances of several subareas outside the flood plain were in creased in order to study the influence of less desirable alternative locations on benefits. Increases made were as follows:

Subarea 13: distance from 5 to 6 miles, travel time from 8 to 10 minutes.
Subarea 15: distance from 2 to 3 miles, travel time from 4 to 6 minutes.
Subarea 16: distance from 5 to 8 miles, travel time from 8 to 12 minutes.

With this condition, more activities locate in the flood plain irrespective of additional flood control, resulting in an increase in the damage reduction benefit. However, total benefits are reduced. This is possible because land use, and therefore net earnings, may change both with and without additional protection as a result of increased transportation cost. Thus, total benefits will increase if, due to the new land use, total net earnings decrease without additional protection, and it will decrease if the total net earnings decrease with additional protection. Depending on which of these decreases dominates, benefits will increase or decrease. A similar result was obtained when the site development cost to subareas outside the flood plain was increased. Site development zones 2 and 3 are given the characteristics of site development zones 3 and 4, respectively. Again, damage reduction benefits increase, because more activities locate the same, and total benefits decrease because the total net earnings without additional protection decrease less than with additional protection.

In each economic growth area the sizes of the subareas with the highest net economic rent both with and without additional protection were increased so that each could absorb the entire growth during the 100 year planning horizon. Resulting benefits were about the same as for the basic run, indicating that, for the case study, the spread in desirability of subareas is not large enough to warrant a more detailed division of the study area.

Finally, the case of zero amenity values, amenity values equal to half of those assumed in the basic run, and amenities equal to double those assumed in the basic run were considered. The damage reduction benefit increases, while locational advantage and total benefits fluctuate up and down as the amenity value increases. This can be expected, because benefits depend on the relative increases of total net earnings with and without additional protection. In the case study fluctuations in benefits associated with large variations in the amenity values were relatively small, so an accurate estimate of these amenity values is not needed.

4. Sensitivity to Increases in Flood Damages and Economic Rent Over Time

Sensitivity to increases in values of structures, contents and non-physical damages, to depreciation of structures, and to increases in economic rent components is presented in Table VI-12. First, it was assumed that the values of structures, contents and non-physical losses increase by 1 percent annually for the first 50 years, and by 1/2 percent thereafter. Next, values of structures were depreciated, based on a 40 year lifetime and a 20% depreciation over each of the first three decades. Finally the changes of the two previous runs were made simultaneously. As expected, the damage reductions increase in the first case, decrease in the second case, and are in-between in the last case.

Next, amenity values, value of travel time and agricultural productivity were assumed to increase by 3 percent annually for the first 50 years, and by 1 1/2 percent thereafter. These changes result in a substantial increase in damage reduction to future activities, and a corresponding reduction in locational advantage. Overall benefits are lower than in the basic run for reasons similar to those mentioned in the previous section. This last increase in economic rent components was applied simultaneously with the increase in value of damageable components. The combined effect results in an increase in total benefits. Finally, all components were increased by 2% annually over the entire planning period. Increase in total benefits is considerable, but violates the upper bound of $1,872,000 on locational advantage. This is the result of using a private discount rate and market horizon in the allocation procedure. Because of the 20 year market horizon, all future increases are not accounted for in allocation decisions but they are included in benefit evaluation.

5. Sensitivity to Land Use Requirements Over Time

The sensitivity of benefits to future land use requirements is presented in Table VI-13. First, sensitivity to future land use requirements until 1985 was considered by using half and double the requirements estimated for the basic run. As expected, damage reduction to future activities decreases in the first case and increases in the second case. Changes are roughly in proportion to the changed requirements. Furthermore the effect on locational advantage as the result of changes in available acres in year 1985 is negligible. Next, sensitivity to future land use requirements after 1985 was considered by using half and double of the requirements estimated for the basic run. The effect on the damage reduction benefit is very small in both cases. The locational advantage, however, decreases by about 40% when land requirements are halved and increases by about 60% when land requirements are doubled. Overall benefits from additional protection do not change appreciably as a result of the drastic changes in land use requirements because the damage reduction benefits to existing activities still dominate the benefits.

D. Study of Zoning Regulations

In the basic run it was assumed that decisions are made on a rational basis, given complete information about damages. The SIMULATOR can be used to investigate the reduction in benefits when irrational behavior is not prevented by sound zoning regulations. The effect of irrationality is illustrated with two examples, one for existing conditions and the other assuming additional protection. In both cases it was assumed that the ultimate land use plan is changed such that undesirable, flood-prone land is used. Changes are indicated in Table VI-14, where subareas 1,7 and 8 are assumed to develop. In addition, the sequence in which subareas will be used was specified, thus forcing the use of subareas 1,7 and 8 in the early part of the planning period.

Benefits from zoning regulations are obtained by comparing the development specified in the basic run with the irrational behavior assumed above. These benefits are presented in Table VI-15. Under existing conditions, the benefits from zoning are about three million dollars, and, as expected, result primarily from the prevention of damages which are not balanced by economic rent advantages. With additional protection, benefits from zoning are about a quarter of a million dollars. Therefore zoning is still desirable with additional protection in order to prevent the use of certain subareas in the flood plain. Otherwise the use of these subareas could reduce the benefits realized from the flood control. In some cases this may even result in the actual benefits being less than the costs of the project.

E. Summary

In this chapter results of the test case study were presented. First, for the basic run, the intermediate results for flood damages, economic rent components, and sequence of subarea developments with and without additional protection were described. Second, benefits for the basic run were discussed in detail.

This included the breakdown of locational advantage by economic growth area; the implications of using an allocation based on a private discount rate and market horizon versus a social discount rate and planning horizon; and results of the initial test runs locating activities such as apartment buildings, region-serving retail, and warehouse and distribution in the flood plain. Next, the sensitivity of benefits to several problem parameters were presented to illustrate the scope of sensitivity studies which can be performed, and the kind of information which can be obtained. Finally, the results of studying flood plain zoning were presented, and the reason for zoning both with and without protection emphasized.

Table VI-14

IRRATIONAL BEHAVIOR WITHOUT ZONING

Subarea	Basic Run	Irrational Behavior	Economic Growth Area	Forced Sequence of Subarea Development With and Without Protection
1	-	200	1	2, 3, 1, 12
12	960	760	2	10, 8, 7, 15, 14
7	-	40		
8	-	60	3	5, 4, 13, 6
10	154	54		
			4	11, 16, 17

Table VI-15

BENEFITS FROM ZONING REGULATIONS IN $1000

	Basic Run Compared With Irrational Behavior	
	Without Protection	With Protection
Damage Reduction		
Existing Activities	-	-
Future Activities	0	0
Total	0	0
Locational Advantage		
Site Development Cost	537	88
Transportation Cost	-621	-286
Amenity Value	-937	- 31
Damage Reduction	4,123	476
Total	3,052	247
Total Benefits	3,052	247

REFERENCES

1. Arvanitidis, N.V., Lind, R.C., Rosing, J., and Johnson, G.P., Preliminary Review and Analysis of Flood Control Project Evaluation Procedures, Final Report, prepared for U.S. Army Corps of Engineers under Contract No. DACW07-70-C-0050, INTASA, Inc., Menlo Park, California, May 1970, and published as IWR Report 70-2.

2. Arvanitidis, N.V., Rosing, J., Petropoulos, D.P., Luenberger, D.G., and Lind, R.C., A Computer Simulation Model for Flood Plain Development, Part I: Land Use Planning and Benefit Evaluation, Final Report, prepared for U.S. Army Corps of Engineers under Contract No. DACW07-71-C-0026, INTASA, Inc., Menlo Park, California, June 1971, and published as IWR Report 72-1.

3. Interim Memorandum I. "Data Requirements for the Flood Control Benefit Simulator," INTASA, Inc., Menlo Park, California, October 1971.

4. Interim Memorandum II. "Procedure for Obtaining First Estimates of Locational Advantage," INTASA, Inc., Menlo Park, California, November 1971.

5. Interim Memorandum III. "Refined Data Collection," INTASA, Inc., Menlo Park, California, January 1972.

6. Interim Memorandum IV. "Flood Control Benefit Simulator: Work Outline for Remainder of FY '72," INTASA, Inc., Menlo Park, California, March 1972.

7. Interim Memorandum V. "Areas of Research and Development Related to the Flood Control Simulator," INTASA, Inc., Menlo Park, California, March 1972.

8. User's Manual and Programmer's Manual for SIMULATOR, INTASA, Inc., Menlo Park, California, to be published in February 1973.

9. Input Data Collection Guide for SIMULATOR, INTASA, Inc., Menlo Park, California, to be published in February 1973.

10. Lind, Robert C., "Flood Control Alternatives and the Economics of Flood Protection," Water Resources Research, Vol. 3, No. 2, 1967.

11. Day, John C., A Recursive Programming Model for the Selection of Nonstructural Flood Plain Management Systems, Thesis, University of Wisconsin, 1969.

12. Day, John C., Progress Reports, Corps of Engineers Contracts DACW73-71-C-0018 and DACW73-71-C-0030, Institute for Water Resources, U.S. Army Corps of Engineers, January 1, 1971.

13. Day, John C., and Weisz, Reuben N., Econometric and Mathematical Programming Techniques for Flood Plain Management: A Discussion Paper, University of Arizona, Tucson, Arizona.

14. Sumrall, Clinton L., Jr., Guidelines for Flood Insurance Studies, Lower Mississippi Valley Division, U.S. Army Corps of Engineers, January 1970.

15. "New Techniques in the Computer Analysis of Flood Damage Prevention," Los Angeles District, U.S. Army Corps of Engineers, July 1971.

16. McKeever, J.R., ed., The Community Builder's Handbook, Urban Land Institute, Washington, D.C., 1968.

17. Merritt, F.S., Standard Handbook for Civil Engineering, McGraw-Hill, New York, N.Y., 1968.

18. Dodge Estimating Guide for Public Works Construction, McGraw-Hill Information Systems Company, New York, N.Y., 1969.

19. Herbert, John D. and Stevens, Benjamin H., "A Model for the Distribution of Residential Activity in Urban Areas," Journal of Regional Science, Vol. 2, No. 2, 1960.

20. Chapin, F. Stewart, Urban Land Use Planning, University of Illinois Press, Urbana, Illinois, 1965.

21. Beckmann, Martin, Location Theory, Random House, Inc., New York, 1968.

22. Comprehensive Water and Related Land Resource Investigation: Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

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13. ABSTRACT

This report presents a simulation model for the evaluation of national economic efficiency benefits of various levels of flood protection and alternative land use plans. The model has three major components: 1. Calculation of flood damages and economic rent components. 2. Allocation of land use requirements. 3. Benefit calculation based on locational advantage and damage reduction. The report also presents the results of a test case in Connecticut River Basin.

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