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Economic Analysis Procedure

For Local Flood Damage Reduction Projects

AUG 1990

DRAFT

Compiled by the
Flood Control District
of Maricopa County, Arizona

FLOOD CONTROL DISTRICT of Maricopa County

Interoffice Memorandum

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TO: DES, SLS, JER, RGP, GR, TMD

FROM: TLB

DATE: 8/14/90

cc: DAB

The Economic Analysis Procedure (Attached) is in the final draft stage. Comments have been reviewed and incorporated herein. Furthermore, Appendix B has been added — 1989 FEMA Depth-Damage Table. The Table and the information provided in Appendix B were given to me from Ron Conner, Chief Economist @ the Corps, L.A. District. Please review Appendix B & the paragraph referencing it - located on pages 28 + 29 - "3.6.1.1 Residential Damage Functions."

This will be the last "draft" version before the document is ready for distribution outside the District. Please have comments back to me no later than Wednesday, August 29. Thank you,

Tina

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Introduction

Purpose

This procedure is intended to serve as a guide for consultants and staff of the Flood Control District of Maricopa County in the economic analysis of local flood damage reduction projects. It provides limited descriptions of the principles underlying economic analysis and specific instructions for data collection and data summary for benefit-cost analysis.

Performing benefit-cost analyses of flood damage reduction projects enables the District to adhere to its *General Policies Concerning the Allocation of Fiscal Resources to Accomplish the District's Functions and Responsibilities*, which calls for prioritization of flood control projects. In preparation of this procedure, the District has drawn heavily on the *National Economic Development Procedures Manual—Urban Flood Damage*, a publication by the U.S. Army Corps of Engineers' Water Resources Support Center (1988).

Description of Contents

Chapter 1, General Concepts, defines basic terms and concepts used in economic analysis of flood reduction projects and gives a brief description of the basic theoretical principles on which benefit-cost analysis of water resources projects is based.

Chapter 2, Planning Concepts, describes the main steps in the planning process and some of the decisions that must be made before the process can begin.

Chapter 3, Damage Calculations, is a step-by-step guide to defining the extent of flood damage problems in economic terms. In this step, current flood area conditions (and values) must be assessed, and future conditions, with- and without-project, must be estimated.

Chapter 4, Benefit Assessment, describes the process of calculating inundation reduction benefits for both structural and non-structural measures, as well as other benefits that may accrue.

Chapter 5, Discounting Procedures, uses the Corps of Engineers' procedure to demonstrate the use of discounting procedures for converting the estimated value of all future benefits to their present value.

Chapter 6, Minimum Study Requirements, gives guidelines on the minimum areas the report must cover, and the minimum amount of data that must be gathered for a report.

1

General Concepts

1.1 Cost Benefit Analysis

The most widely used approach for evaluating the economic efficiency of a public works project is cost-benefit analysis. Cost-benefit analysis has four major purposes: 1) to help determine the most cost-effective composition and magnitude of an investment; 2) to determine if an investment is economically favorable; 3) to compare and choose between alternative investments; and, 4) to help determine the timing of investments.

The final decision for a public investment in a democratic society is based on political considerations. Cost-benefit analysis is only a tool to help with that decision. There are other social welfare criteria that need to be applied to investment decisions. Thorough investigation and documentation must be made of environmental quality impacts, regional economic development, and other social effects. If decision-makers believe that any of these other considerations are overriding concerns, they can recommend a project other than the one with the highest economic efficiency, including projects where the benefit-cost ratio is less than 1 to 1.

1.2 Bases for Project Selection

In evaluating the flood control projects that are undertaken, water resource agencies follow four principles: 1) willingness to pay; 2) maximum net benefits; 3) separable justification; and 4) basis for project selection.

1.2.1 Willingness to Pay

Assuming that a rational individual would be willing to pay at least the amount equal to restoring flood-damaged property to pre-flood condition, this value, plus a cost equal to time spent preventing damages, the cost of clean-up, evacuation, and time irretrievably lost for production of goods and the delivery of services, becomes an estimated level of willingness to pay.

1.2.2 Maximum Net Benefits

The most efficient use of resources for any one project comes when benefits exceed costs by the maximum amount. The maximum net benefits concept is, therefore, the best measure of investment because it contributes the highest dollar value of

Table 1-1
Net Benefits and Benefit-Cost Ratio Comparison

	Plan A	Plan B
Average Annual Benefits	$660,000	$805,000
Average Annual Costs	$320,000	$425,000
Net Benefits (B-C)	$340,000	$380,000
Benefit-Cost Ratio (B/C)	2.06	1.89

increased output to the economy. The disitinction between maximum net benefits and the highest ratio of benefits to costs is shown in Table 1-1. Plan A has the maximum benefit-cost ratio and Plan B has the maximum net benefits.

It is clear that there is an economic gain for going beyond the scale of the project with the maximum benefit-cost ratio, as marginal benefits continue to exceed marginal costs.

1.2.3 Separable Justification

Each separable component should have a benefit-cost ratio of at least 1 to 1. A separable component is an element of the project that can be left out without disturbing the technical feasibility of the project. A separable component would also have to be technically able to function on its own. A separable component with an unfavorable benefit-cost ratio would reduce the overall net benefits of the project.

1.2.4 Basis for Project Selection

In comparing economically efficient projects, a full accounting should be made of those effects which cannot be measured in monetary terms. It is also important, when considering the implementation of a number of projects, to realize that the implementation of earlier projects could affect the efficiency of later projects being considered for implementation.

1.3 With- and Without-Project Condition

The purpose of making a distinction between with- and without-project conditions is to isolate the changes that are expected to occur as a result of a project from changes that would occur if the project were not undertaken.

The without-project condition is an assessment of the flood problem, assuming no action is taken by the District to alleviate it. If flood control works or any other significant actions are imminent without District action, they should be considered a part of without-project conditions.

Existing structures can be expected to remain in place, unless they are in deteriorated condition or abandoned. Structural assessments should be made of existing flood control works to determine the degree of protection they offer.

Any changes in population, land use, affluence, or intensity of use expected as a result of the project, should be considered in the definition of with-project conditions.

1.4 Period of Analysis

A period of analysis is the time required for implementation of the project, plus the life of that project. For planning purposes, the District uses 100 years for the life of its projects. Planning conditions such as population, land use, and stormwater runoff are usually held constant for the period between 50 and 100 years after implementation. These projections are not generally made beyond 50 years because of the uncertainty of forecasting further into the future. Future development conditions can be assumed in accordance with the projections of the County Planning and Development Department. In some cases, the data of cities and other sources should be used.

1.5 Degree of Protection

The degree of protection is the criterion used to express the flood damage prevention effectiveness of a project. Generally, it is the flood level at which residual adverse effects are considered relatively minor.

Economic analyses of flood control projects will ordinarily be made for 100-year, 50-year, and 25-year flood protection levels. Levee projects on major watercourses in urban or potentially urban areas of development will be designed for protection from the Standard Project Flood (SPF) event. For more information on the District's policy on degree of protection, see page 5 of *General Policies Concerning the Allocation of Fiscal Resources to Accomplish the District's Functions and Responsibilities* (available from the Flood Control District upon request). The Chief Engineer and General Manager should be consulted on the final protection levels to be analyzed.

1.6 Principal Flood Alleviation Benefit Categories

This section defines the categories of benefits attributed to flood damage reduction measures. Procedures for calculating these benefits are found in Chapter 4.

1.6.1 Inundation Reduction Benefits

Most benefits from flood damage reduction projects come from the reduction of inundation damages. Inundation reduction benefits include reduction of both physical and nonphysical costs. These benefits include the saving of structures and contents from flood damage, savings from alleviation of cleanup costs, production losses, the cost of flood fighting, evacuation, and traffic rerouting.

1.6.2 Physical Damages

Physical damages include: structural damages to buildings; loss of contents of a building, including furnishings and equipment; decorations; raw materials; materials used in processing; processed materials; and damage to streets, highways, railways, sewers, bridges, power lines and other infrastructure. Physical damages are evaluated separately for residential, commercial, industrial, agricultural, and public properties; and for utilities, vehicles and roads. Alleviation of physical damages usually accounts for the largest share of flood mitigation benefits.

1.6.3 Non-Physical Damages

1.6.3.1 Income Loss: Income loss is the loss of wages or net profits to businesses over and above physical flood damages. It results from a disruption of normal activities that cannot be recouped from other businesses or from the same business at another time.

1.6.3.2 Emergency Costs: Emergency costs include those expenses that result from a flood and not from just the risk of flooding. Emergency costs include expenses for emergency evacuation, flood fighting, administrative costs of disaster relief, public clean-up costs, and increased costs of police, fire, and military patrol. Emergency costs should be determined by specific survey or research and should not be estimated by application of arbitrary percentages of physical damage estimates. Frequently, data are only available for one significant flood. Applying the same loss to other floods based on the same loss for number of properties affected is usually an adequate approach.

1.6.3.3 Temporary Relocation: Temporary evacuation costs include temporary lodging and the additional costs of food and transportation due to forced evacuation for extended periods of time.

1.6.4 Location Benefits

Location benefits result from new, more profitable activities locating in the floodplain because construction of a project reduces the expected value of flood losses.

1.6.5 Intensification Benefits

Intensification benefits occur when, because of flood protection, a business finds it profitable to modify its operations at its present floodplain location, and that modification results in an increase in net income to the business. In Maricopa County, this often results when a flood protection structure is constructed, the delineated floodplain is reduced in size, and the property is removed from the floodplain. The value of the land is then increased, as is the usability of the land. Furthermore, the cost of developing the land will often decrease as a result of being removed from the floodplain and no longer having to build to the more stringent floodplain requirements.

1.6.6 On-Site Benefits

On-site benefits are those that accrue at the general location of the control measure. Many land stabilization measures produce on-site benefits. For instance, vegetative plantings on critical sediment source areas may increase the net return from cropping, grazing, or wildlife production. Increased net returns that occur on the drainage area of the structure over the amount that could be obtained without structural stabilization measures are creditable to the structural measures. In addition, on-site benefits may be obtainable within the site of a floodwater retarding structure. Such benefits may accrue from fish culture, recreation, and use of the sediment pool for stockwater, irrigation, domestic water supply, or groundwater recharge.

2

Planning Concepts

In preparing for an economic analysis, the first consideration is the type of study and the type of report that the proposed project requires. Below are several options.

2.1 Studies

The measurement of floodwater damages and the benefit from reduction of damage usually is done by one of three methods—Frequency Method, Historical Series Method, and Overland Flow (or some combination of the three). Each of the methods may be specially applicable to particular situations. This section describes each briefly.

2.1.1 Frequency Method

The frequency method used in flood damage appraisal involves the establishment of a relationship between the probable frequency of flood occurrence and economic consequences for given frequencies. The series of curves required to establish this relationship are shown in Figure 2-1.

The frequency series offers a way to compute average annual damages by weighting the effect of all floods without estimating losses separately for each flood in a long series of events, thereby providing an estimate at a savings of work over the historical series method. This document focuses on the frequency method.

2.1.2 Historical Series Method

The historical series method requires somewhat more work for the hydrologist and economist than does the frequency method. Also, it requires that a significant body of data already exist on rainfall and flooding in the area. However, when flooding is frequent and the major damage is to crops and pastures, it allows for the adjustment of damages from recurrent flooding.

In using the historical series method, an evaluation period is selected in which the cumulative annual difference from normal precipitation was low. This method rests on the assumption that a sequence of events that has occurred in the past also may occur in the future.

After each of the various categories of damage have been appraised for each flood during the evaluation period under future conditions without-project, they are

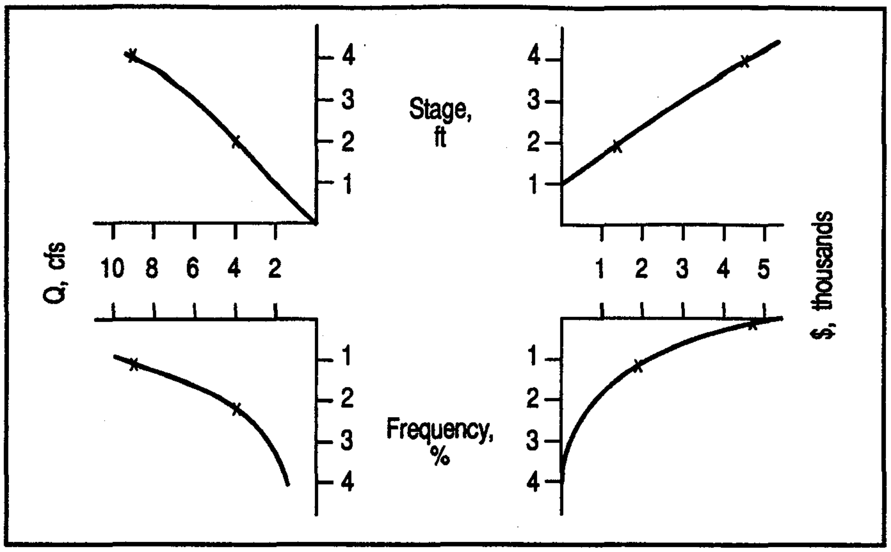

Figure 2-1
Frequency Method Series Curves
(A) Frequency versus discharge.
(B) Discharge versus flood elevation.
(C) Flood elevation versus damage.
(D) Damage versus frequency.

summed and divided by the number of years in the period. The answer is the unadjusted average annual damage. The figure is then adjusted for recurrent flooding, or otherwise as needed, to obtain the average annual damage.

Elevation-damage curves are used in the historical series method. As the dates and sequence of flooding are available, separate curves usually are developed by months or seasons.

2.1.3 Overland Flow

Either the historical series or the frequency method may be used in the overland flow analysis. The distinction between overland flow and the usual methods of analysis is that here the hydrologist provides the economist with a curve reflecting the relationship of flood frequency to volume instead of elevation.

In alluvial areas with no defined channel to the main watercourse, using a volume-frequency curve can be more useful than the elevation-frequency curve. This is especially true in rural areas, where the parameters of floodwater spread determine the degree of damage inflicted on crops. A situation in which there is virtually no channel, or where the possibility of lateral spreading is great, is called overland flooding.

Peak discharge and flood elevation have little meaning in overland floods. When the floodwater emerges from the confined section onto the alluvial fan or plain, the flood peak quickly flattens. As a result, the area flooded is not a direct function of the peak discharge except as it may overtop diversion dikes built to direct its course away from a portion of the floodplain. More often, the area flooded is directly related to the flood volume. The greater the volume, the greater the area flooded.

The White Tanks Watershed illustrates this situation. Floodwater from this watershed debouches from the White Tanks Mountains onto a highly productive, gently sloping floodplain. Once the floodwater breaks through the Highline Irrigation Canal, it spreads out over the farmland in relatively shallow sheet flows, except where it is concentrated or obstructed by railroad or road fills, or other man-made obstacles. It seldom reaches the Agua Fria or Gila Rivers. The relationship between flood volume and acreage flooded is shown in Table 2-1.

A large area of cropland in this watershed lies in the floodplain. Not all would be subject to flooding by a single flood, but most are subject to the flood hazard by slight changes in the paths of flood flows. Even the 100-year flood would inundate only about 25 percent of the flood damage area.

In overland flow situations with relatively little ponding, farm damage per acre flooded appears to be relatively constant, irrespective of the size of the flood. Table 2-2 demonstrates this constancy by using data from two separate floods in the White Tanks Watershed, both of which occurred in August.

Since the 1951 flood was over three times as large as the 1939 flood, it was concluded that flood damage was proportional to the acreage flooded, which in turn was proportional to the flood volume. Hence, it was necessary only for the hydrologist to determine a flood volume-frequency series to provide a basis for determining average annual flood damages over a normal hydrologic period.

Many alluvial fans exhibit a wide variety of damage potential due to differences in kind and extent of development. If a flood strikes the developed area of the floodplain, serious damage may result, whereas if it follows a path through the undeveloped area, little or no damage would occur. It is necessary in such situations to determine the mean damage resulting from a flood of certain size, taking into consideration the probability of the flood following any one of several possible paths. This problem is illustrated in Figure 2-2.

Table 2-1
Flood Volume vs. Acreage Flooded

Flood Date	Volume (In Acre-Feet)	Acres of Crop Land Flooded	Average Acres Flooded per Acre-Foot
August 1939	3,500	4,600	1.3
September 1956	7,000	7,500	1.1
September 1949	2,500	3,000	1.2
January 1951	5,500	7,000	1.3
July-August 1951	11,500	14,100	1.2
Total	30,000	36,200	1.2

Through the use of topographic surveys, aerial photographs, and maps of historical flood flows, flood paths A, B, C, D, and E are traced through the floodplain. Flood damages are determined from known relationships between damages, flood depths, and velocity. If a flood of the magnitude being studied has an equal chance of following each of the flood paths, then the probable damage from such a flood is equal to the mean value of the five alternatives, which in this example is $41,000. Similar studies made for floods of different magnitudes would furnish the basis for damage-discharge curves.

Table 2-2
White Tanks Watershed Flood Damage Comparison

Type of Damage	1939 Flood	1951 Flood
Crop	$28.75	$28.60
Land	8.89	10.14
Farm Ditches	3.91	3.60
Miscellaneous Farm Damage	1.69	3.11
Total Farm Damage/Acre Flooded	$43.24	$45.45

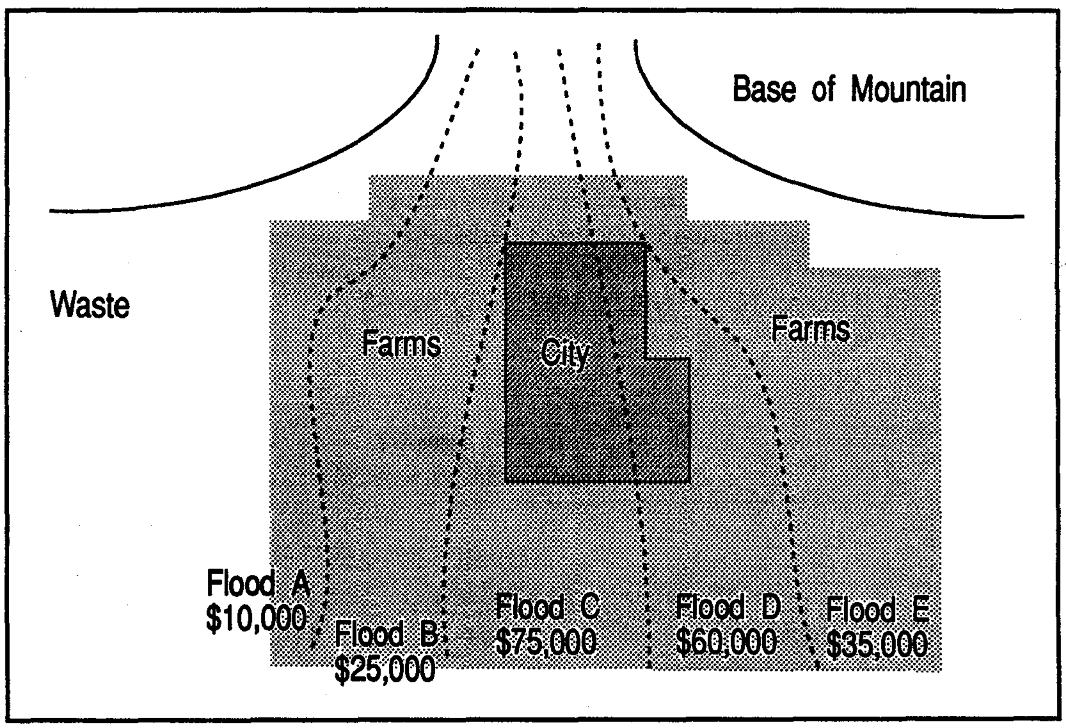

Figure 2-2
Possible Flood Damage Estimates for an Alluvial Fan

2.2 Reports

The District will use two types of reports in the evaluation process, Reconnaissance and Detailed Project Reports.

2.2.1 Reconnaissance Reports

The purpose of the reconnaissance report is to recommend for or against further study. Primary data gathered in this phase can focus on floodplain conditions without project and generating an elevation-damage curve.

2.2.2 Detailed Project Reports

Projects that clear the reconnaissance phase advance to the design phase for preparation of a detailed project report. Work in this phase covers detailed design and an updating of costs and benefits from the material collected in the reconnaissance phase.

2.3 Stages of Planning

The planning process can be broken down into six stages: 1) identification of problems, needs, opportunities, and objectives; 2) establishing the base condition; 3) forecasts of future conditions; 4) formulation of alternatives; 5) evaluating the effects; and, 6) comparing the plans and making a recommendation. Each of these steps is described below.

2.3.1 Identify Problems, Needs, Opportunities, and Objectives

This first step is an overview of the situation. In this step, the flood area is assessed in a general way. A visit to the area can determine whether it is rural or urban, what type of study is needed, and the general categories of damages to be assessed. An examination of historical records, such as reports and newspaper accounts, can determine the extent of the flooding problem. Meeting with community officials and the public can determine concerns and plans for the area. Through this effort, specific objectives of the study are determined and defined as the planning process continues.

2.3.2 Establish Existing Conditions

The second stage begins the detailed level of planning. Existing conditions and resources are inventoried and evaluated on a site-specific basis. Average annual flood damages are estimated after a thorough inventory of properties, analysis of the historical record, and synthetic modeling of existing rainfall, drainage, and streamflow patterns. Consideration is given to the effect of existing flood protection structures.

2.3.3 Forecast Future Conditions

This stage considers the effects of future changes in population, land use, level of economic activities, and drainage structures on every reach of the study area. This is a time to coordinate with other agencies that have their own projections and land use plans, and gather any relevent census information.

2.3.4 Formulate Alternative Plans

Formulating alternatives should include both structural and nonstructural solutions to flood problems, and should include mitigation measures for environmental impacts.

2.3.5 Evaluate Effects

Plans become defined in detail as economic, social, and environmental factors are evaluated. In the economic analysis, benefits should be evaluated against costs (in constant dollars whenever possible).

2.3.6 Compare Alternatives and Recommend a Plan

The final stage of the planning process comes when all plans, given serious consideration and studied in detail, are compared for the selection and refinement of the recommended plan. During this stage, the best compatible elements of plans can be combined to produce a plan that maximizes economic efficiency and other social welfare considerations.

3

Damage Calculations

The following chapter on damage calculations has been taken from the U.S. Army Corps of Engineers' publication, *National Economic Development Procedures Manual—Urban Flood Damage* (1988). Occasional minor changes have been made to reflect District policy where it would diverge from the Corps'. This publication is available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

3.1 Existing Conditions Without-Project

This series traces the steps in defining the existing condition for flood damage analysis. The work described here is generally the most important stage in flood damage analysis. It is also the stage that most clearly uses measurable variables, and thus it supplies the most compelling evidence of whether there is a need for a project.

Flood damages for existing conditions are expressed in terms of expected annual damages. "Expected annual damages" indicates the monetary value of physical loss that can be expected in any given year based on the magnitude and probability of losses from all possible events. Expected annual damages are derived by combining the information from three basic relationships: elevation-discharge and discharge-frequency, which the Hydrology staff work with to compute the elevation-frequency relationship, and the elevation-damage relationship, which is determined by the economist. Figure 3-1 shows how the information in these three functions can be combined to calculate expected annual damage. An eight-step process for calculating expected annual damages is described in detail below. It is the Project Manager's responsibility to ensure that all major tasks for each step are delegated and accomplished. Figure 3-2 shows the division of labor between the economists and hydrologists in computing expected annual damages.

3.1.1 Step One: Delineate the Affected Area

Definition: The affected area is that which is immediately or indirectly affected by the project. This is the geographic area that includes the floodplain and all alternate nearby areas that would attract development by a major activity, such as agriculture or industrial or commercial construction. It also includes the area where development will influence runoff into the floodplain area.

It is during this phase of the study that the flooding problem should really be defined. Records should be consulted as to when damaging floods have occurred in the area; the areal and vertical extent of inundation should be determined; and hydrologists should gather information, for the period of record, on stream gauge and rainfall.

Use: The existing without-project condition must be properly identified since it is the basis for comparison with conditions projected with the plan. Existing flood control works should be taken into account when determining the degree of

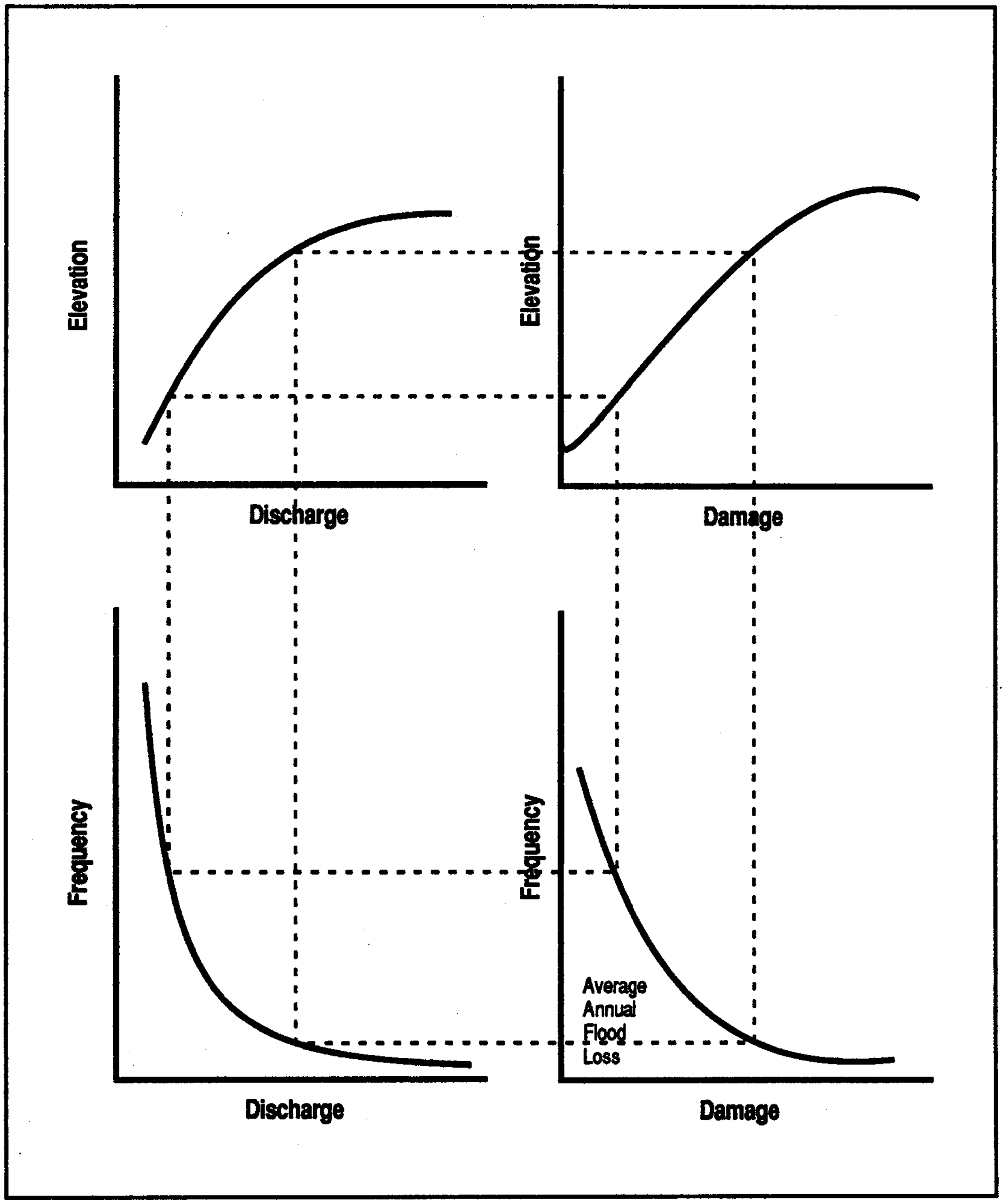

Figure 3-1
Flood Damage Computation

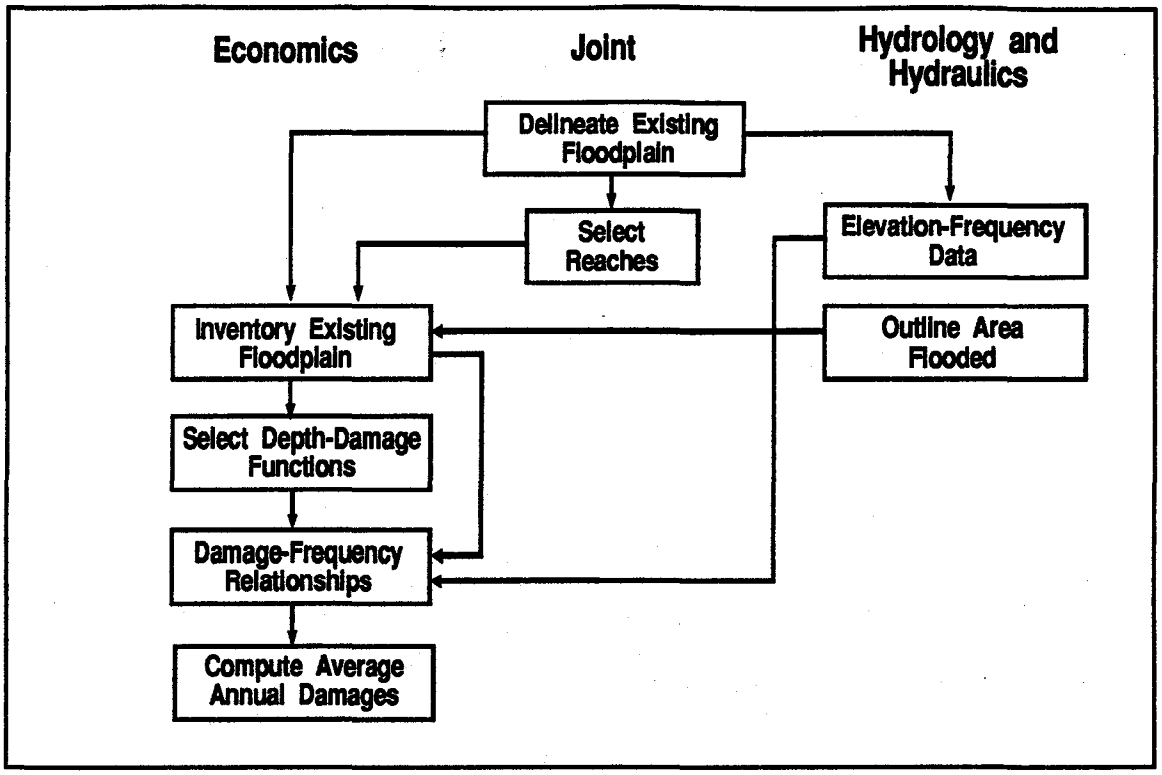

Figure 3-2
Responsibilities in Computing Expected Annual Damages

protection. An evaluation should be made of the effectiveness of any existing protection, and all other relevant systems expected to be implemented before construction.

Procedure: The first step in the process is to delineate the floodplain for detailed hydraulic and economic evaluation. The affected area consists of the floodplain, plus all other areas likely to serve as alternative sites for any activity which might use the floodplain if it were protected. This can be done by observation and recording existing land use, holding public meetings, and reviewing land use plans of area jurisdictions, planners, and citizens' groups. The Economist and the Hydrology staff must perform these tasks as a cooperative effort.

The descriptions of small drainage basins may cover the extent of flooding, land use, and business activities within the entire basin. For larger drainage basins, this description may be limited to the immediate area experiencing flooding problems, and nearby areas that are alternative sites for activities currently located in the floodplain. This description should include a history of the economic and social effects of flooding on the area. Dates, peak discharge, and peak elevations of major flooding events should be given. When the information is available, the economic costs and categories of damages, as well as any figures on deaths and injuries, should be noted. Information on flood events can be obtained primarily from the yearly reports of the U.S. Geological Survey, on file at the District, and the District's newspaper file of flood events. Other reports may be available from the following organizations:

- » Federal Emergency Management Association
- » National Weather Service
- » Corps of Engineers
- » Federal Housing Authority
- » Arizona Department of Water Resources
- » National Resources Council
- » Arizona Department of Transportation
- » U.S. Soil Conservation Service
- » Bureau of Reclamation
- » Arizona State Geological Survey

A critical part of defining the existing "without" condition is a proper evaluation of the degree of protection that existing flood protection can be expected to provide. The assessment involves two major considerations:

1) **The level of protection that existing flood control works actually provide.** In the case of an existing levee, design engineers will determine how much of the levee height is freeboard. Freeboard is the zone between the top of the levee and the design water surface elevation. Freeboard is a safety factor to account for unknowns such as wave action. Levees are generally credited for preventing one half the damages in the freeboard range.

2) **The structural integrity of existing structures.** An existing levee cannot be considered as offering any protection at elevations above which inadequate structural quality would cause it to fail. Likewise, there can be no benefits claimed for flood damage reduction attributable to replacement or rehabilitation of such structures unless it can be shown they are structurally deficient. Channels and interior drainage ditches should be sufficiently maintained so that sediment, logjams, and debris are not likely to cause a significant reduction of capacity. Structural investigations should indicate if levees are free of uneven settlement, inadequate seepage control, or deteriorated construction material.

3.1.2 Step Two: Select Planning Reaches

Definition: The reach is the primary unit of plan formulation. The river length and affected tributaries are divided into "reaches" throughout which the relation between discharge and elevation remains practically constant, and into zones where development or use changes appreciably with elevation. Frequency, flow, elevation and damage data are used for each reach; thus data must be representative of the actual frequency of flood events, flow regime and damage for that reach. A single reach may cover the entire developed area of a small community, in which case it is known as a "damage center." Sub-reaches and zones may be established for the individual consideration of specific areas, particularly when on opposite banks of the stream or when separated by bridges or dams which appreciably affect local elevation-discharge conditions.

Use: Reaches are the primary geographic units for planning. Plans are formulated with components that cover a series of reaches. The hydraulic and hydrologic effects and subsequent benefits of a project are calculated for each reach. Consequently, it is extremely important that reach selection include the joint input of the Project Manager, the Hydrology staff, the Economist, and appropriate Division Heads.

From the Economist's point of view, reaches are established primarily for the purposes of plan evaluation and display. Economists use reaches to determine the smallest breakdown of damages and benefits. Within each reach, breakdowns will be made of damages by land use category and flood zone as defined by flood frequency.

Procedure: Reaches and their subdivisions will be determined by the Project Manager according to District procedure, with input from the Economist as to what areas will provide the most representative cross-sections of damages and benefits.

If technical considerations require that reaches be selected without regard to the Economist's input, the Economist may select his or her own sub-reaches, provided adequate hydrologic data is available for the areas selected. However, permission must be obtained from the Project Manager to do so.

3.1.3 Step Three: Establish Elevation-Frequency Relationships

This step describes three fundamental elements of the hydrologic and hydraulic studies required to establish existing conditions. Step Three includes development of the elevation-discharge curve, which is the basic hydraulic relationship; and the frequency-discharge curve, which is the basic hydrologic relationship. The elevation-frequency (or frequency-damage) relationship is the function derived by combining these two basic relationships. These curves are discussed below and Figures 3-3, 3-4, and 3-5 provide examples of them. *For each of these curves, the procedure below will be followed.*

Procedure: If the project area lies within a defined floodplain, the Project Manager will request the elevation-discharge, frequency-discharge, and elevation-frequency curves from the Floodplain Management Branch of the District. If the project area lies outside a defined floodplain, the Project Manager will request these curves from the Watershed Branch.

While data used for economic analysis requires a high level of detail, it should be noted that the following curves, as used in an economic analysis, will not have the level of detail required for design purposes.

3.1.3.1 Elevation-Discharge Relationships

Definition: Elevation-discharge relationships are functions that relate the amount of stream discharge (Q) to water surface elevations. Elevation is measured by the level of water above mean sea level (msl) or other established datum. Discharge is measured in number of cubic feet of water passing a gauging station in one second (cfs). Elevation-discharge relationships are also known as rating curves. An example of a rating curve is shown in Figure 3-3.

Use: The primary purpose of an elevation-discharge relationship is for analysis to correlate discharge data with specific elevations to determine flooded areas.

3.1.3.2 Discharge-Frequency Relationships

Definition: A frequency is the number of occurrences that can be expected out of some possible number. For example, the exceedence frequency of a 10,000 cfs flood may be 10 times in 100 years. The same frequency can also be expressed as an exceedance probability, 0.1, or a flood with 10 percent chance of occurring in any particular year. Most often, the discharge-frequency relationship is expressed by its recurrence interval, which in this case would be a 10-year event.

Use: Frequency relationships are the key element in the criteria for establishing the magnitude of flood damage. No estimate of damage can be determined without first estimating how often any particular flood is expected to occur. Discharge-frequency relationships can be combined with elevation-discharge to establish the probability of each flood reaching a given elevation in any particular year. Figure 3-4 is an example of a discharge-frequency relationship.

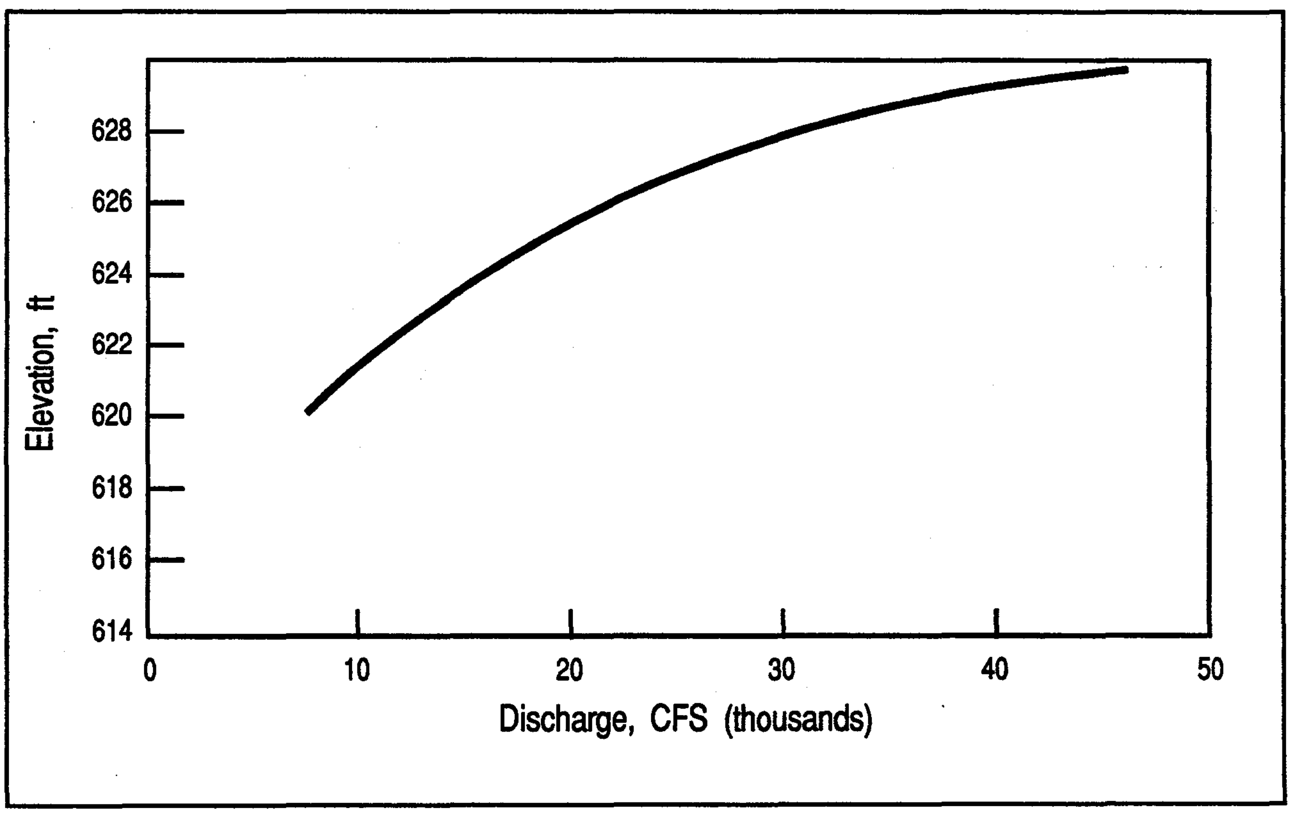

Figure 3-3
Elevation-Discharge (Rating) Curve

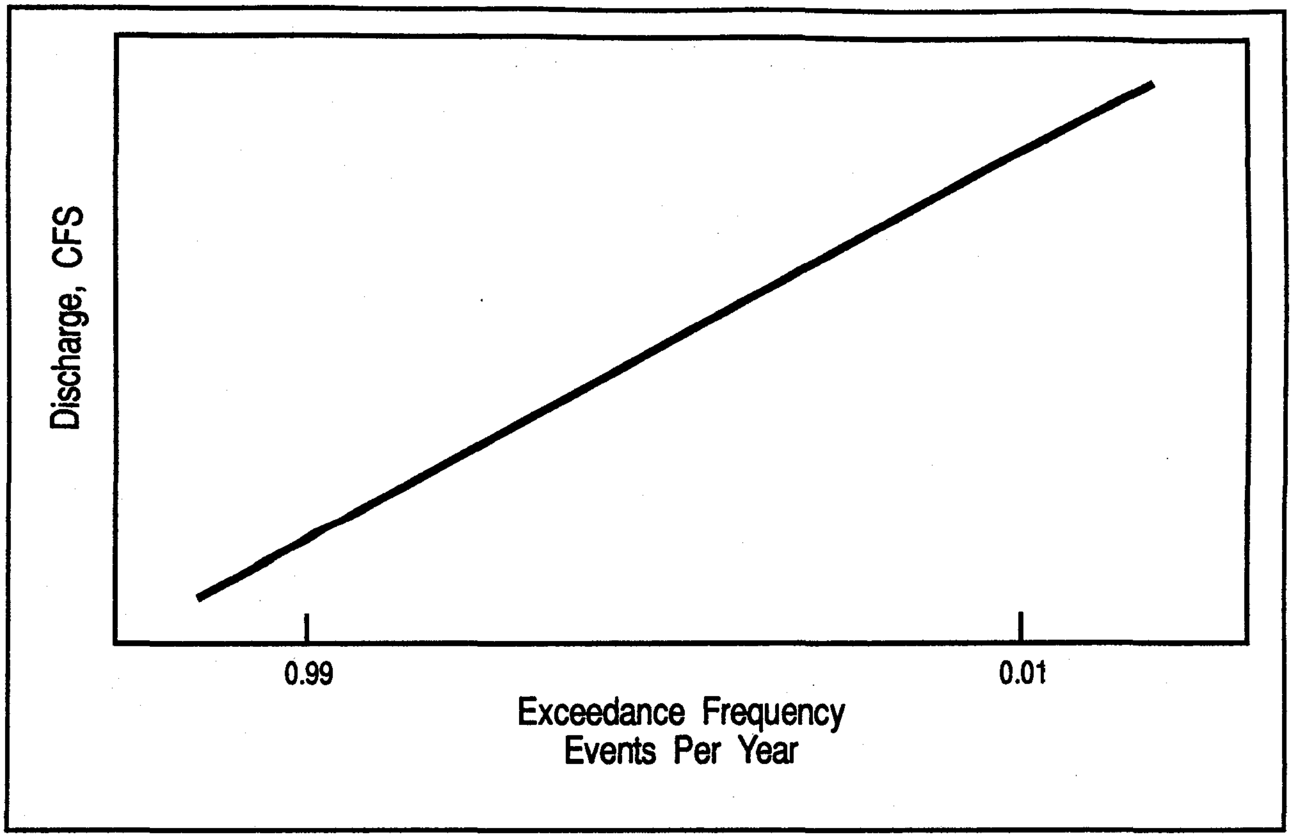

Figure 3-4
Discharge-Frequency Curve

3.1.3.3 Elevation-Frequency Curves

Definition: Hydraulic studies and observed streamflow data form the basis of the elevation-frequency curves, such as the one shown in Figure 3-5, which will be required for each reach for existing conditions and for each plan of local improvement considered, ranging from zero damage elevation to the standard project flood.

Use: The elevation-frequency relationships are primarily tools of economic analysis. Selection of the basic data and derivation of the statistical relationships expressing flood frequency is the Hydrologist's responsibility, but should be formed in consultation with the Economist. From these curves, the Economist is able to calculate the frequency-damage curves.

3.1.4 Step Four: Outline Area Flooded

Definition: The area flooded simply refers to the geographic extent of flood inundation for one particular event or several magnitudes of flooding. At a minimum, the geographic extent of three areas should be shown: 1) the floodway, which is the natural storage area along the river or stream; 2) the one-percent chance (one-hundred-year) flood; and, 3) the SPF flood level. It may also be useful to show the limits of the flood of record (the largest flood recorded) or the most recent major

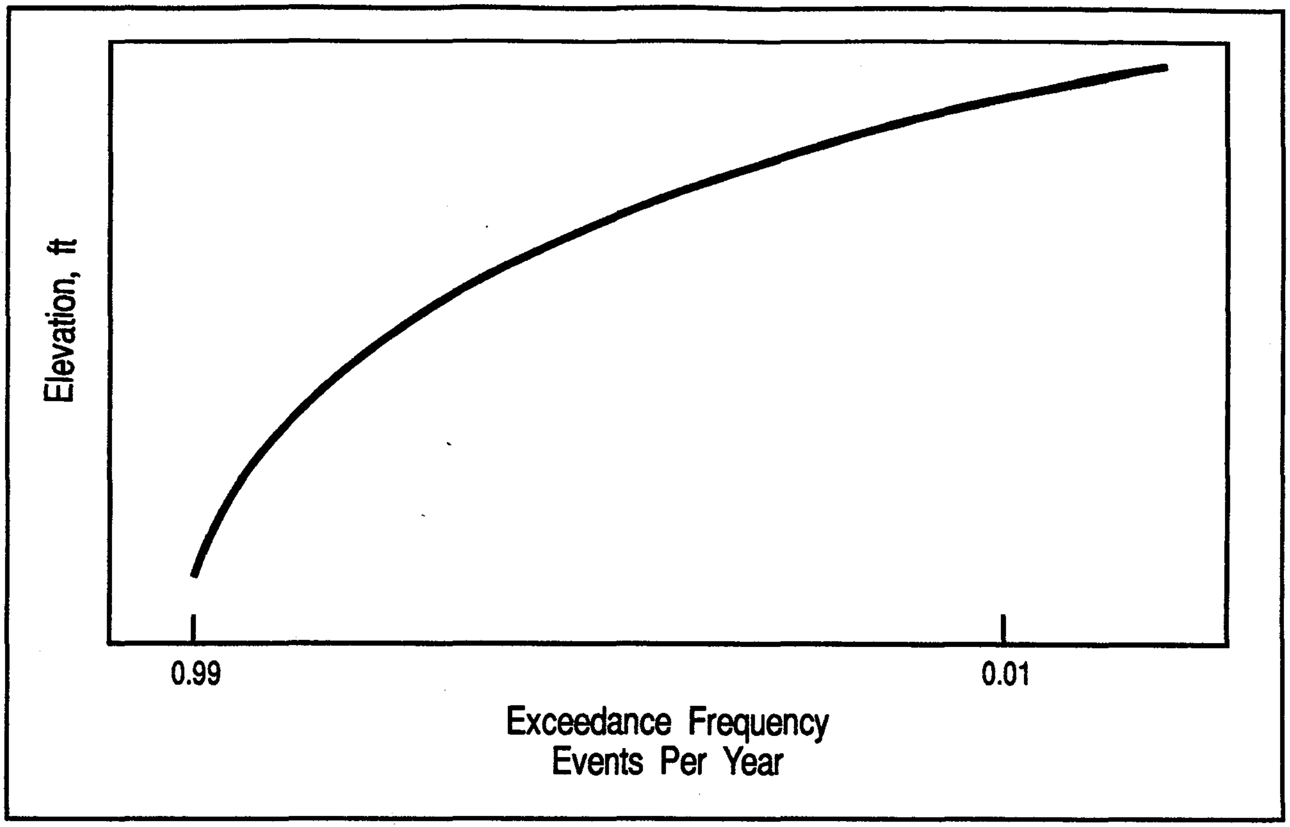

Figure 3-5
Elevation-Frequency Curve

flood. Figure 3-6 depicts an Area Flooded map that designates the three events requested above.

Use: The area flooded is outlined on a map primarily to let the Economist know what floodplain property needs to be surveyed, and the degree of attention to give each area. Effort should not be wasted on surveying areas with too little expected average annual damage to support flood protection. In the early stages of planning, the Area Flooded map can give a general idea of the type of project that might be economically justified by the amount and type of property subject to flooding at various frequencies.

Procedure: Elevation-frequency relationships at each cross section are used to outline the areas flooded at various frequencies of events. These areas should be delineated on topographic maps with a maximum four-foot contour. In most instances, the Floodplain Branch will already have this material available on FEMA maps. If this is not the case, request that the branch that prepared the elevation-frequency curves arrange for preparation of Area Flooded maps as well.

In addition, a field investigator should check the location of the overflow areas defined on the map. Taking this step now can insure a greater degree of certainty later in the study. Some sources of uncertainty are unavoidable and can only be

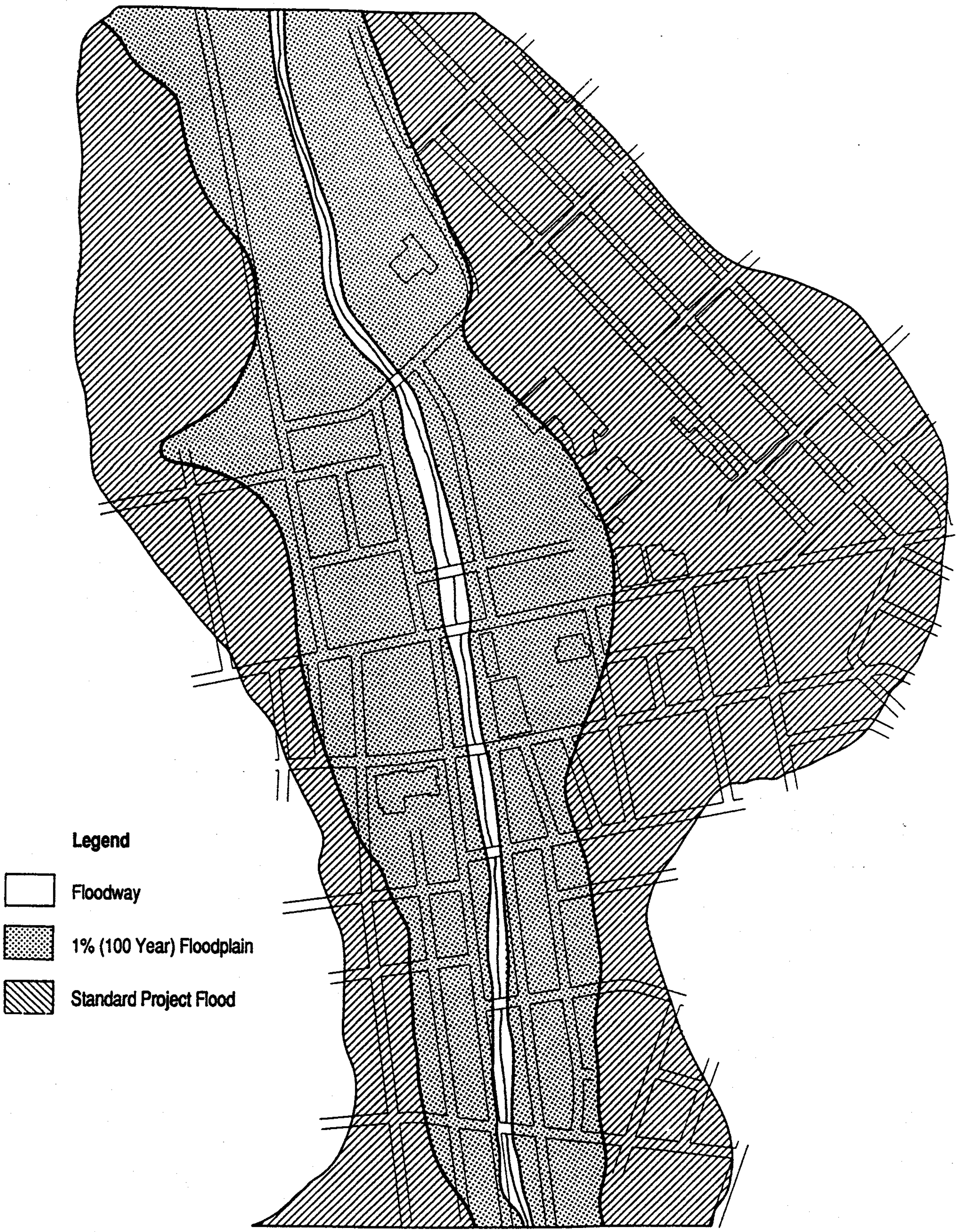

Figure 3-6
Outline of Floodplain

acknowledged. The following conditions may be found to affect the limits and extent of overflow areas and damages, contributing to a more accurate assessment:

» Duration of flooding.

» Filling and scouring of stream channels, outlets, and confluences during floods, to either increase or decrease channel capacity.

» Observed or anticipated synchronization of flood peaks from several tributary areas.

» Effects of buildings, streets, embankments, other obstacles, and cuts on the course of flood flow.

» Diversion of flood flows at various stages to other courses or channels, and the probability of erratic or unpredictable paths.

» Contribution of sediment, debris, and other blockages.

» Local aggravating circumstances affecting overflow, such as dams, inadequate or clogged waterway openings, obstructions in channels, pervious and impervious embankments, pervious substratum, adequacy of local drainage and sewerage, inadequacy of existing levees, and backwater conditions in channels.

» A major stream or a tributary changing course and causing the flow of the water to take a different path.

3.1.5 Step Five: Inventory Existing Floodplain

This section illustrates the general procedures for inventory and appraisal of the floodplain. The inventory assesses existing conditions and estimates the potential effects of any future growth. The procedures described here are applicable to residential, commercial, industrial, and public buildings, as well as transportation facilities and utilities.

Definition: Inventorying is the surveying of floodplain properties to determine expected damage. Three types of information are needed for all property to be evaluated: susceptibility classification, value, and elevation.

Use: The purpose of making an existing floodplain inventory is to learn what structures and other property are in the floodplain, the value of the structures and associated contents, and at what elevation they are susceptible to flooding. This information is then used as a basic step in the computation of flood damages and flood damage reduction benefits. Structures include residential, commercial, industrial, and public. Physical damage estimates should also be made for transportation facilities, public utilities, vehicles, communications and other outside property. The following sections will describe procedures for making damage inventories for each type of property.

Procedure: The information collected in the floodplain inventory should be tabulated for easy coding and processing by the District's computer flood damage analysis program. All forms should be checked for accuracy, completeness, and legibility. Major steps in the inventory process include:

1) Reconnaissance determines the representative property types or categories of properties in the floodplain.

2) Basic data from such sources as topographic maps or surveys, aerial photography, floodplain information reports, and flood insurance maps are consulted and summarized for referencing properties to flood elevations.

3) An inventory or count of all properties is made and data recorded to facilitate application of sample data for the derivation of the elevation-damage relation by reach and zone.

4) Representative properties for adequate coverage of all property types in each flood reach and zone are selected, inspected, and appraised for real value and for damage potential.

5) Office analysis includes review of the field appraisals and inventories to obtain the elevation-damage relations.

3.1.5.1 Defining Structure Type: Structure is defined here as a permanent building and everything that is permanently attached to it. For the purpose of floodplain inventory, categories of property are defined by similar susceptibility to flood damage. Both structural use and physical characteristics can be useful areas for categorization. The Economist should make these distinctions based on the availability of existing elevation-damage relationships of flood property with similar patterns of susceptibility to flood damage. Single family residential building categories generally include the following: 1) one story, no basement; 2) one story, with basement; 3) two or more stories, no basement; 4) two or more stories, with basement; 5) split-level, no basement; 6) split-level, with basement; and, 7) mobile homes.

These categories can be further subdivided into: wood, masonry, steel, or adobe structure; good, fair, or poor condition; and categories of size, in square feet. The variable of building condition should have operational definitions for each classification. For example, good condition might be any property with visible repairs of less than 10 percent of the structure value. Poor condition would be anything needing major structural repair of greater than 25 percent of the structure value. Fair condition would be anything between. Similarly, square footage categorizations of small, medium, and large should have operational definitions with number of square feet used as breaking points between size classifications.

Single family residential structures generally include single story with or without basements, two or more stories with or without basement, split-level with or without basement, and mobile homes. Further differentiations have been made for the type of foundation the building has, and extent to which the basement is finished and whether the basement might be more appropriately classified as being crawl space.

Multi-family residential structures can be divided by high-rise (more than ten stories), mid-rise (four to ten stories), garden apartments (one to three story walk-up units), duplexes, and townhouses.

Commercial structures have the largest number of building use types. For structural damage potential inventories, it should be sufficient to have breakdowns by number of stories and relative size. These factors are often consistent for types of commercial enterprise, i.e., fast food restaurants are mostly one story buildings without basements, and have brick or block construction.

Industrial structures also vary by number of stories, building material, size and permanently attached equipment. The value of individual industrial plants, variability of structural characteristics, operation, and output usually warrant detailed surveys of individual properties. Detailed surveys are also required in instances of unique structures and conditions.

Public buildings are defined here as public-use, rather than publicly-owned. Public property includes public offices, schools, recreation facilities, hospitals, churches, and nursing homes. Public offices, primary and secondary schools, and small churches are all housed in similar types of buildings, and should only require a brief windshield survey. Other public use facilities require detailed interviews and inspections to ascertain value and susceptibility.

3.1.5.2 Sampling: It is recommended that every property be inventoried, at least by a windshield survey, to establish the approximate values and elevations, as well as the appropriate elevation-damage relationships to use. Industrial property and larger commercial businesses require on-site inspections to determine the value and location of equipment, inventory, and outside property. For other types of property, sampling is an efficient means to verify windshield estimates of structure and content value as well as storage locations.

When proper field sampling procedures are used, variances, confidence interval, and other statistical measures can be derived from the collected data. This information can assist the planner in developing sensitivity analyses, in determining optimal solutions, and in evaluating the confidence that can be placed in study results. If care is not maintained in the development and implementation of survey design and sampling procedures, biases can be introduced that can lead to spurious results. Some common sources of bias that need to be considered when conducting sample surveys of floodplain properties include:

» Sampling with unequal and unknown stratifications (e.g., only conducting household surveys during the daytime, excluding those households from the sample where no one is at home during this period);

» Measurement error (e.g., asking for only the replacement price paid for a damaged furnace, rather than obtaining all the information needed to estimate the depreciated replacement value of the damaged unit);

» Non-response (e.g., individuals who refuse to participate in a survey having different income levels than those who do participate); and

» Interviewer error (e.g., a particular interviewer who consistently overestimates structure values).

Concise delineation of study objectives and data needs, careful consideration of questionnaire design and sampling plans, and the provision of training and supervision to interviewers can minimize the potential for obtaining biased results.

The degree of precision of floodplain inventory depends on the resources available for the project, the availability of data, and the precision of other study components. Accurate appraisals and elevation in computing flood damage estimates, and considerable effort, should go into making and verifying estimates. Stratification of floodplain properties (e.g., by building use, construction type, and elevation) before sampling, can generally provide increased precision for a given sample size needed to provide a specified level of precision.

3.1.5.3 Value of Structure: Building values should be evaluated as an estimate of depreciated replacement value of the structure. Outside building values and land values should be considered separately. Estimating actual replacement values, determining an expected life, and depreciating by deterioration can be a time-consuming and costly job. If resources are limited, depreciated replacement values of buildings can be approximated by market values. Market values can be obtained from the following sources of information:

Real Estate Assessment Date: The Land Management Division has a microfiche file of property values assessed for the previous year's real estate tax levy. This file is updated annually by REDI, and lists property values for Maricopa County. There are also corresponding maps, which identify parcels, and rolls of ownership. The District receives an update of ownership listings twice yearly from the County Assessor.

Property values are assessed as a percent of market value. Usually, the Total Full Cash Value listed on the REDI microfiche is 80 percent of the market value. However, these values can be tested against the recent sales prices (see next paragragh) also available through the Land Management Division. For various reasons, the ratio of assessed value to actual market value can vary considerably. Recent sale prices, opinions of real estate sales people, and first-hand appraisals, can all be used to test the validity and consistency of real estate assessments. Assessment-to-value ratios, and structure-to-land ratios can be used to estimate the value of buildings.

Recent Sales Prices: The Land Management Division also receives a monthly update from REDI of all recent property sales. These values are recorded as a matter of public record for property assessment and for establishing deeds, mortgages, and liens. In addition, realtors are usually very willing to offer their knowledge of recent sale prices and the asking prices of property currently on the market.

Depreciated Replacement Values: Another source for making appraisals is the Marshall Valuation Service, published by Marshall and Swift. Marshall and Swift books can be found in the Land Management Division. They are used to obtain replacement costs for building construction in various parts of the country. Local construction cost multipliers are given by type of construction material. Square and cubic foot construction costs are given for foundations, flooring, walls, roofing, heating systems, plumbing, and built-in appliances, as well as garages and outside property. The guides are updated quarterly. Care should be taken to limit valuation estimates to the depreciated conditions, otherwise benefits might be over estimations of values.

3.1.5.4 Elevation for Each Structure: Building elevations are as important as hydraulic information for establishing project benefits, and they are also much easier to accurately establish. Often, this crucial variable is given too little attention.

3.1.5.5 Sources of Topographic Information

Topographic Maps: The U. S. Geological Survey maintains complete topographic maps of the United States. These maps vary in age, scale, and contour intervals. The maps are continually updated, but they can be as much as 50 years old. Urban areas are most frequently updated. For most urban areas, maps are at a scale of 1 to 24,000, where one inch equals 2,000 feet. Urban areas in terrain with flat or moderate slope are usually mapped with five-foot contours. The GIS/CADM Section of the Information Systems Branch, Administrative Division, is likely to have these maps on file, or can order them on request. Be aware that some verification work must always be done to ensure that subsequent development has not changed elevation data for the area.

Permanent Bench Marks: Permanent elevation bench marks can be fixed by circular metal disks hammered, bolted, or set with masonry into a street, bridge, or building. Reference elevations may also be recorded for positions on permanent structures such as a spot on a bridge or the top of a fire hydrant. Bench marks are kept by the U. S. Geological Survey, the Corps of Engineers, the USDA Forest Service and Soil Conservation Service, the Bureau of Reclamation, and state and local agencies including municipalities. It is important to be aware, however, that some verification must always be done to ensure that subsequent development hasn't changed elevation data.

Aerial Photography: Aerial photos are a commonly used tool for creating detailed contour maps. The maps can be used with stereoscopic equipment and field checking to create four-foot contour maps (or, in flat or shallow areas, two-foot contours). The GIS/CADM Section may have aerial photos available, or can order them through commercial photographers.

Survey Crews: The District has several survey firms under contract. Survey crews are the most accurate way to determine elevation. The costs of survey crews can be reduced by combining their structure elevation surveys with cross-section survey, and by limiting their work to spot elevations or reference marks every few blocks.

Hand Levels: Hand levels are simple devices for estimating the elevations of structures. This small hand-held instrument can be used to take readings off bench marks and determine the first floor elevations of surrounding structures. The user needs no assistance, but simply uses the level to find a spot on the nearby building at eye level. Hand levels should be used in circuits to tie back into the original bench marks.

This will serve to verify readings along the circuit. The Construction & Operations Branch of the Operations & Maintenance Division can supply hand levels.

Architectural Drawings and Site Plans: Architects, developers, and community building permit officers may keep building records with first floor, ground, and foundation elevations.

3.1.5.6 Content Inventory Procedures

Definition: Categories for single-family residential content inventory should be much the same as the structural categories described above. These include one story without basement; two or more stories with basement; split-level without basement; split-level with basement; and mobile home. Subcategories within these can be made on the basis of income for consideration in setting content-to-structure value ratios.

Content-to-structure value ratios are also of major importance in setting categories for apartments. See discussion of content-to-structure ratios below.

3.1.5.7 Content-to-Structure Value Ratios: The inventory of building content requires a good deal more site-specific inspection and interviewing than structural inventory. Nearly all industrial property and many types of large commercial establishments require detailed interviews or on-site inspections to determine the value and elevations of flood-prone inventory, equipment, and raw material. At least some sampling is required to determine content-to-structure value ratios for all types of commercial property. No standard commercial content ratio can be applied across types of commercial enterprises.

Even for residential property, where standard elevation-damage relationships can be applied, it may be desirable to have a sampling to establish a content-to-structure value ratio. Insurance companies generally use a flat rate of 50 percent for a residential content-to-structure value ratio. Residential insurance customers have the option of claiming higher content values if they have highly valued furniture, clothing, electronic equipment, appliances, or art work. The affluence factor calculation, which is described later in this procedure, is based on the principle that the content-to-structure value ratio increases with household income—with or without a project. It can also be assumed that the basic necessities, such as clothing and appliances, and modest luxuries, such as televisions and stereos, make the ratio above 50 percent for very poor households. Apartment and small condominium dwellers can also be expected to keep mostly highly valued items, when space becomes a limiting factor.

Determining Content Value: Appraisal of content value requires far more detailed work than structural appraisal. While the depreciated value of a building can be easily approximated through the market, content appraisal is much more complicated. There is little market information that can be used to evaluate the real value of residential or business contents. Used household goods are not universally found in top condition, and then the uncertainty of quality tends to limit the value. Business content inventory is best left to the manager of the facility. When there is a property of major consequence or the manager is in doubt, an insurance appraiser can be contracted to estimate the depreciated replacement value. Industrial and commercial inventory should be valued at the cost to the business for acquisition and processing.

Establishing Content Elevations: Estimation of content elevation in relation to the first floor of structures is generally only required for synthetically constructed elevation-damage functions, as described in Step Six. In other cases, the content location is already considered in the depth-damage relationship. When any home or business has made a special effort to elevate the storage location, that factor should be considered in the inventory.

3.1.5.8 Inventory of Outside Property: Damage to outside property can be very significant, particularly in flash floods and other high velocity situations. Even so, outside property is seldom given thorough evaluation. Consequently, no commonly used procedures have been established for estimating loss to outside property.

The following is a list of considerations for determining the value and susceptibility of outside property:

Outside Buildings: Garages, sheds, and other small buildings are particularly vulnerable to collapse or being washed away by swift current. The building material and value of these structures should be noted. Residential garages are often storage areas for electrical and mechanical equipment, subject to shorting out, corrosion, and rust.

Vehicles: In many cases, vehicles receive a major portion of flashflood damage. Expected vehicle damage potential should be given special attention where the flood warning lead time is six hours or less. It is important to not only consider the lead time, but the potential evacuation routes and likelihood that people are available to move the vehicles. Motor vehicles can suffer extensive damage from floods that barely reach the first floor level of nearby buildings. Even in situations where there is a sophisticated warning and preparedness system, there may not be enough lead time to move vehicles.

Sources of information on the number and age of vehicles in a community include:

1) The U.S. Census, which gives the percent of families with one vehicle, the percent of families with two or more vehicles by income group, and the average prices paid for these vehicles new and used;

2) R.L. Polk & Co. of Detroit, Michigan, which keeps records on the number of cars and trucks in operation by age group; and,

3) The U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*, which gives the number of automobiles and other vehicles registered by state, and per 1,000 population by state.

Aggregated national figures for the Census and Polk Company data as well as the statewide Highway administration data are published annually in the U.S. Bureau of Census, *Statistical Abstract of the United States*. Average value of vehicles are published annually in *Ward's Automotive Yearbook*. The number and value of vehicles parked in commercial and industrial areas can only be determined by on-site inventory. In any case, the average number of vehicles at any place is dependent on time, day, and season. The analyst should attempt to find an appropriate average.

3.1.5.9 Public Utilities: Public utilities can best be inventoried after review of any previous flood damage. It is important to determine what facilities might be particularly vulnerable. Otherwise, facilities might be too numerous to consider. When there is no record of previous flooding, then inventory should concentrate on above-ground facilities that are sealed. Sewage treatment and water treatment plants are particularly vulnerable, as are electric power substations, gas regulator stations, and storage facilities.

3.1.5.10 Transportation Facilities: Highways, streets, and bridges are particularly vulnerable to washing out or suffering wave damage. Bridges are vulnerable to damage by debris, particularly when the debris is being carried by very heavy current. The locations and elevations of especially vulnerable facilities should be determined after interviews with local public works and state highway managers. Railway beds and track are subject to being washed out when the track is overtopped. The elevation, length and number of tracks, particularly in low-lying areas, need to be identified. An effort should also be made to inventory rail yard facilities and cars that might be kept in low-lying areas.

3.1.6 Step Six: Select Elevation-Damage Relationships

After the inventory and appraisal of flood-prone property, the computation or selection of elevation-damage relationships is the most important job the Economist has. This section will deal with the process of selection of appropriate elevation-damage functions to meet the requirements of a particular situation. This section also includes a discussion of when it is appropriate to use generalized elevation-damage relationships and when it is necessary to compute site-specific functions. There will also be emphasis on the process of verifying and adapting depth-damage functions to serve as reliable predictors of specific flood problems.

Elevation-damage relationships are based on the premise that water height, and its relationship to structure height, is the most important variable in determining the expected value of damage to buildings. Similar properties, constructed, furnished, and maintained alike, and exposed to the same flood elevations and forces, may be assumed to incur damages in similar magnitudes or proportion to actual values. However, there are many factors that can explain the variations in the extent of flood damages. There is no widely accepted, quantified relationship in the United States between any of these factors and the extent of flood damage.

In prior steps, floodwater elevations for various discharges were derived, along with the frequency with which to expect these flows. In this step and the next, the objective is to determine how much damage occurs at various flood elevations. There are two basic approaches. The most accurate approach is to determine the damages that occurred during a recent flood, usually by conducting extensive interviews with floodplain residents and business proprietors. During the interviews, damages are also estimated for elevations above and below the flood of reference. This is still the preferred method of determining the elevation-damage curve. However, it is a time-consuming and expensive process for most large floodplains. Consequently, it is not unusual to obtain elevation-damage data by using generalized data in a computer-oriented analysis. This approach is described below.

Application: Predictable elevation-damage relationships can be used to estimate the amount of damage from any given level of flooding and, consequently, to assess the benefits of flood damage alleviation. Elevation-damage functions are used to compute the probable damage for a given level of flooding. Functions are computed separately for structure and content for various categories of enterprise. The functions are predictors of either direct-dollar loss or percent of value lost through a flood event. Damage functions can be applied to structures on an individual basis or applied over a large number of properties with similar susceptibility.

Major Criterion for Selection: The major criterion in selection of elevation-damage functions is the similarity of susceptibility relationships. Damage functions are influenced by a number of variables. Variables found to be significant in regression analysis can be used in computing reliable elevation-damage relationships. Table 3-1 summarizes the major factors (hydrologic, structural, and institutional), that significantly influence the amount of damage. While most people involved in flood damage assessment are aware of most of these factors, it has been rare that any of these factors have been isolated as part of a predictive function. It is less difficult to apply functions where the factors are reasonably close to the situation to which they are being applied. For example, elevation-damage functions computed for one section of the Colorado River may be very applicable to damage from flooding along another section of the Colorado where there is similar velocity, duration, and sediment load.

Sources: Generalized damage functions are computed for either post-flood surveys or synthetic estimates. Generalized functions are sometimes as accurate as building-by-building estimates of susceptibility, but they should be field-checked whenever they are applied. Knowledge is required of the critical variables that could influence damages in the area where the generalized curves were derived, and in the area where they might be applied.

Post-flood damage surveys are the most accurate way to determine the susceptibility of any property to various levels of inundation. Limited availability of study funds and lack of specific authorization to study an area often result in the delay of survey for some time after a major flood. Post-flood surveys should use the questionnaires found in Appendix A. Synthetic damage functions are estimated flood values, calculated at hypothetical flood levels and conditions. Synthetic estimates are often necessary for areas with no recent flood experience. Any number of flood damage levels can be estimated. Because synthetic damage relationships are hypothetical, they should be done by people experienced in post-flood surveys, who are familiar with what is damaged in a flood.

3.1.6.1 Residential Damage Functions: Depth-damage (or elevation-damage) relationships for residential property, commercial property, and mobile homes have been established by the Federal Emergency Management Administration (FEMA).

Table 3-1
Variables that Influence the Elevation-Damage Relationship

Hydrologic Variables	
Velocity	Velocity is a major factor aggravating structure and content damage. It limits time for emergency flood proofing and evacuation. Additional force creates greater danger of foundation collapse and forceful destruction of contents.
Duration	Duration may be the most significant factor in the destruction of building fabric. Continued saturation will cause wood to warp and rot, tile to buckle, and metal objects and mechanical equipment to rust.
Sediment	Sediment can be particularly damaging to the workings of mechanical equipment and can create cleanup problems.
Frequency	Repeated saturations can have a cumulative effect on the deterioration of building fabric and the working of mechanical equipment.
Structural Variables	
Building material	Steel frame and brick buildings tend to be more durable in withstanding inundation and less susceptible to collapse than other material.
Inner construction	Styrofoam and similar types of insulation are less susceptible to damage than fiberglass and wool fiber insulation. Most drywall and any plaster will crumble under prolonged inundation. Waterproof drywall will hold up for long periods of inundation. Paneling may be salvageable when other wall coverings are not.
Condition	Even the best building materials can collapse under stress if the construction is poor or is in deteriorated condition. Building condition should be a major determinant of replacement value.
Age	Age may not be a highly significant factor in itself, except that it may serve as an indicator of condition and building material. It would be more accurate to survey the other factors separately.
Content location	Arrangement of contents is an important factor in determining elevation-damage relationships. These relationships could be expected to be somewhat homogenous for commercial business, particularly chain stores. Industrial property should be surveyed individually to determine how the arrangement of contents will affect the elevation-damage relationship.
Institutional Factors	
Flood warning	Major reductions in both content and structural loss can be made through flood fighting and evacuation activities when there is adequate warning.

The Corps of Engineers has been directed to use these curves when estimating damages unless a site-specific curve is available. Currently, there are no regional curves available for Maricopa County. Reportedly, the Corps of Engineers has plans to download FEMA's nation-wide data to produce regional curves sometime toward the end of 1990 or the beginning of 1991. Until those curves are available, however, FEMA's Depth-Damage table contains the data to be used (see Appendix B).

Standard relationships are more common for residential structures than other types of property, because residential property is considered to be more homogenous in susceptibility and layout of contents, and in the types of building materials used, than other kinds of property.

Any damage function must be tested for reasonableness—in the office on the basis of theoretical assumptions and in the field on the basis of empirical tests—to determine how well specific data are matched. The theoretical check should meet the following assumptions:

» Physical damage can begin when floodwaters reach the lowest levels of a building, even if floodwaters are below the ground level.

» Basement or cellar damage may occur when flood elevation rises above the floor due to backing up through drains, seepage through foundation walls, or when flow through doors and windows occur. The primary factors will be the design of the sewer system, the soil types (soils with high clay content will absorb and filter water much slower than soils with high sand or loam content), and building material (concrete foundations will be subject to less infiltration than cinder blocks). Water pressure can also cause cracks or collapse of building walls and foundations, especially if water has not entered the building.

» Damages at the same elevation in different floods may vary with seasonal flood characteristics. There may be seasonal differences in velocities, duration, silt, debris, and ice content. Estimated damages might be tied to these seasonal factors and the probabilities of floods occurring at any particular time of the year.

» Changing trends in property use, such as the more intense use of properties (game rooms in the basement and the accumulation of residential electronic equipment) will affect the elevation-damage relation, and produce significant differences in estimates of current and future conditions.

» Generally, for low and moderate velocity flood occurrences, the magnitude of damages on furnished levels will increase most rapidly to 3 or 4 feet above floor level, with an appreciably slower rate of increase to the next floor level.

» The mobility of some personal property should tend to reduce losses, particularly when there is sufficient warning time. However, some damages, even of mobile property, will probably be inevitable due to lack of warning lead time and variations in judgement.

3.1.6.2 Business Elevation-Damage Functions

Definition of Building Type: The computation of elevation-damage functions for business structures can vary a great deal from residential computation. The variation in building size, number of stories, and construction material can lead to a greater number of structure type definitions. Although permanently installed equipment is considered real estate and consequently would be treated as a permanent part of the building, equipment is most often treated as a separate damage category. Industrial building construction is often highly specialized, and may not lend itself to general classification, but may need to be treated strictly on an individual basis. Otherwise, business structure categories might include one story without basement; one story with basement; two stories without basement; two stories with basement; multiple stories without basement; and multiple stories with basement. Further breakdown could be made for masonry, frame, and metal structures.

3.1.6.3 Evaluation of Commercial Losses: Reconnaissance of the flood area will indicate the nature of commercial development, and the extent to which sampling procedures may be applicable or specific inspection and appraisal required. For interviews and inspection, the forms in Appendix A may be used for, or adapted to, commercial properties.

Sampling and Specific Appraisal Requirements: To the extent that reliable, generalized, simple elevation-damage relationships can be established for specific commercial activities, they may be used—if reliable adjustments can be based on readily available parameters such as size or value of store, stock, turnover, number of employees, etc. Sampling should be limited or not used where wide variations in property characteristics exist; direct methods of appraisal should then be employed. Appraisors may need to pay special attention to large individual establishments that constitute a major part of the total damage in the reach. Advance contact with these individuals is advised, particularly because it will enable the appraisors to assemble data on property characteristics and damages, and to arrange to review these with company officials. As with evaluation of residential damages, but more so in the case of business and industry, it is critical to estimate reasonable periods for rehabilitation of property and return to normal operating conditions.

Evaluation of Direct Physical Commercial Damages: Actual or potential damages can be estimated by the normal methods of estimating construction costs. Where available, repair bills, company records, etc., also provide an independent source. As in other cases of direct physical damages, losses attributable to floods must be separated from repair costs that restore accrued depreciation. Shortened physical life (accelerated depreciation) of damaged items, non-recurring damages, and those preventable by good housekeeping, prudent management, or prompt action upon receipt of flood warning, can be eliminated from estimates of prospective damages.

3.1.6.4 Industrial Property: Industrial property includes the facilities for extracting, producing, manufacturing, and processing of commodities, where labor on and working of materials creates new products and new wealth. Direct physical flood damages to industrial property include the net physical losses of economic value to land, buildings, machinery, equipment, materials, supplies, and other items used in the industry. Direct physical damages to industrial property include all net losses from deterioration or spoilage of raw material, processing material or completed goods.

In general, the magnitude of industrial activity, with respect to other values in a flood area, and the generally unique nature and features of each industrial enterprise, require that separate and specific appraisals be made for each industrial plant or property. Sampling procedures and comparisons with other similar plants cannot be relied upon to give an accurate basis for evaluation of flood control projects, and may be used only when similar small industries constitute a representative group comparable with sample conditions and do not make up a critical portion of the total damage estimate. The specialized nature of each industry and its operations ideally requires both the cooperation and assistance of the industry itself in appraising potential flood damages, and an impartial and independent appraisal and review. Where specialists familiar with major types of industrial property involved in a study are not available on staff, the Project Manager should seek consultative service by independent, qualified experts in appraising industrial damage. These consultants should be familiar with the principles and criteria of project formulation and evaluation of the District, the effects of floods on the specific types of industries involved, and the physical and economic aspects of the industry. The Project Manager must be the judge, in the course of field investigation, as to the admissibility, soundness, accuracy, and completeness of estimates of industrial flood damages for use in project formulation and evaluation. Estimates by industry or consultants need not be fully accepted. Satisfactory reporting requires that adequate explanations be given for differences in assumptions and appraisals, so that proper consideration and review can be given to the major and determining items in an estimate.

3.1.6.5 Evaluation of Public Damages: Public property, for purposes of damages appraisal, can be considered to include all property owned by the various agencies of government or by charitable associations for the service of the public. Public property damages are principally apparent in the form of direct physical damage, or in the physical costs associated with preventing cessation or insuring continuation of public services. Some loss of public income may be found in interruption of services provided on a reimbursable basis other than taxation. Other than streets which are classed with transportation facilities and public power stations, public goods and services that may be adversely affected by floods include all public buildings, churches, schools, libraries, museums and other educational facilities, hospitals, institutions, water supply systems, sewerage systems and treatment plants, pumping stations, fire and police protection facilities, parks, recreational facilities, etc. Specific inspection and appraisal of damage potentials is required in each case.

Physical damages to public property can be readily evaluated by the restoration method of appraisal. Estimates of such damages and the costs of related emergency and normal services should be prepared in cooperation with the governmental or other agency involved. The highly variable nature of other public facilities makes use of a standard form generally impracticable, and notes thereon and appraisal computations should be adapted to each case. It may be found that many public facilities or services overlap several flood reaches or zones and that damages cannot readily be assigned to specific locations.

Thus, breaks at any one or several points in water supply or sewerage systems may produce equivalent associated losses to customers or taxpayers in other reaches or on high ground. Damage to public property such as streets, sidewalks, lighting, water and sewer connections, etc., may duplicate part of the appraisal of specific properties served.

3.1.6.6 Elevation-Damage Function Calculation: Elevation-damage functions can be calculated to various degrees of precision. The simplest method is merely to take the mean value of percent damage for each water height. The problems with this procedure include:

» Limitation of variation in percent damage to one variable: water height.

» Limited information provided on the effect of outliers or extreme values of percent damage on the sample mean.

» No level of dispersion determined for the data.

» No parameter to show the strength of the independent variable, water height, in explaining variation in the dependent variable, percent damage.

The advantages of this approach are that it is easy and quick; water height has always been believed to have the most influence on physical damage; and the effect of outliers can still be limited by setting reasonable limits on the values to be used in the calculations.

Regression analysis can measure the effects of several variables on percent damage. The strength of any one variable can be estimated along with the strength of the entire model in explaining the variance of percent damage. Regression analysis with elevation-damage data is difficult because of the problems in obtaining good measurements of all the important variables that influence percent damage.

3.1.7 Step Seven: Calculate Damage-Frequency Relationships

Definition: The damage-frequency relationship is a simple relationship that is represented by the probability that could be associated with any level of flood damage. This relationship is derived from elevation-damage, elevation-discharge, and discharge-frequency relationships.

Use: The damage-frequency relationship is the last step in the process before computing average annual damages. By applying a frequency interval to each level, a weighted average for each of these events can be computed. Damage-frequency relationships are basically an interim step used in computing average annual damages. However, the breakdown of information by damage reach is particularly useful for identifying the areas of most severe economic damage.

Categories: Damage-frequency relationships are aggregated for display by damage category and reach. Major land use categories can include: residential, commercial, industrial, agricultural, public use, utilities, and transportation.

Procedure: This relationship is derived after the elevation and flow relationships have been combined with flow-frequency relationships to produce the elevation-frequency relationship, and the elevation-frequency relationship is combined with the elevation-damage relationship for each flood reach, zone and damage category. Figure 3-7 gives the aggregated damage-frequency relationships for various damage categories.

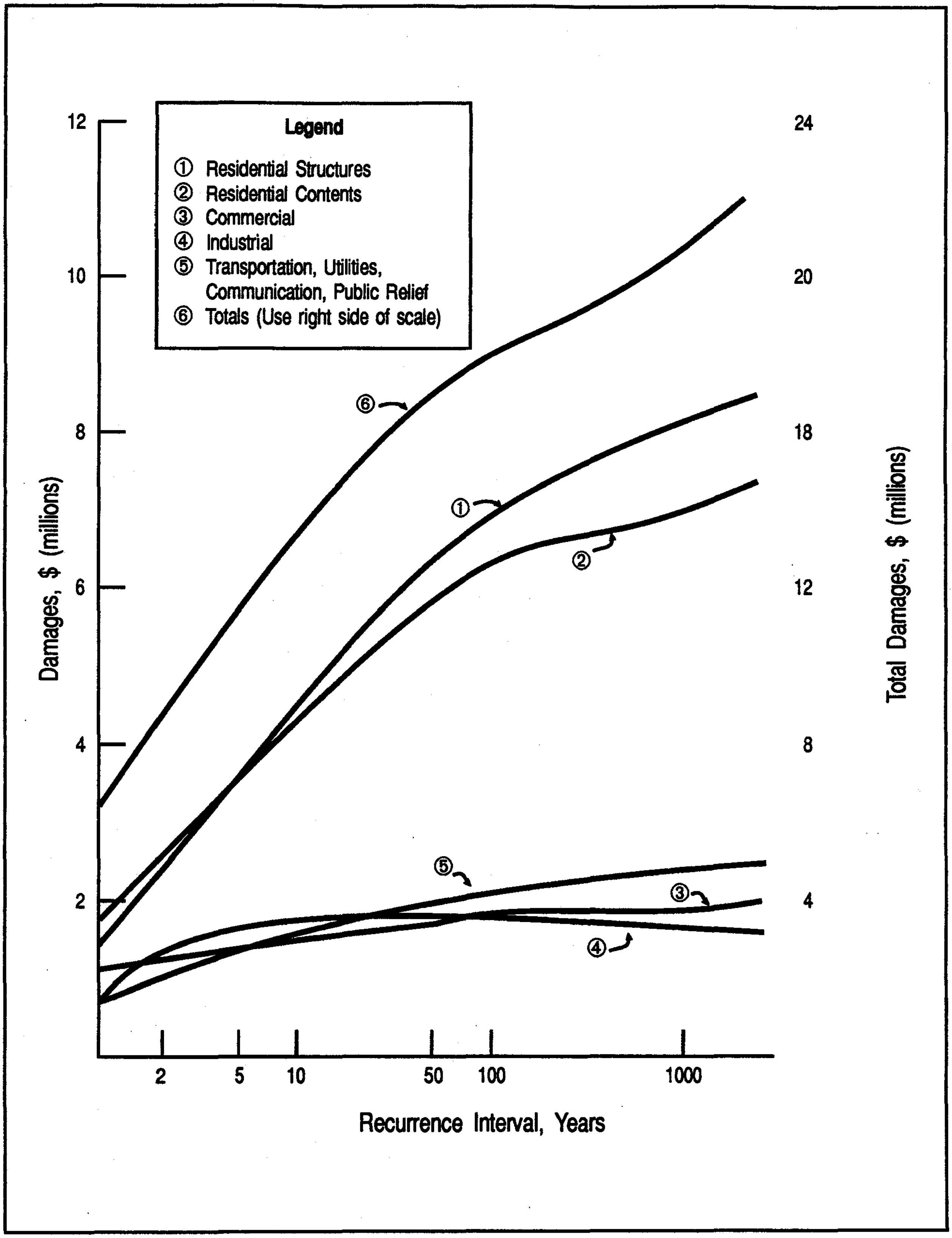

Figure 3-7
Damage-Frequency Curves

3.1.8 Step Eight: Calculate Expected Annual Damages

Definition: The expected annual damage (EAD) is the expected value of flood loss in any given year.

Use: Expected annual damages are the most tangible measure of the severity of the existing flood problem. Generally, any project that is economically justified on the basis of existing conditions will be justified in the future—if the area is built out. If the area is not yet built out, the drainage review process should decrease the possibility of flood damages.

Procedure: Expected annual damages are calculated by computing the area under the damage-frequency curve. This is done mathematically by taking an integral of the function. It does not mean that this amount of damage will occur in any particular year, but rather that over a long period of time, the average amount of damage will tend to approach that amount.

Assessment of existing conditions includes the consideration of any structure that is already in place (See Section 3.1.5 for an explanation of this process). There is no projection involved.

Expected values computed for frequencies in Step Eight are weighted by their exceedance probability. In most floodplain areas, the high frequency events usually account for the major share of the average annual flood damages. Damages for specific floods not computed in the damage frequency relationship are interpolated to create the function for expected annual damages.

Derivation, general: This is the method most frequently used by the Corps of Engineers to compute expected annual damages. As will be seen later, it involves the combining of three basic functions: elevation-damage, elevation-discharge, and discharge-frequency, to define a fourth function, the damage-frequency relationship. It has already been established how these functions are developed. Suffice it to say that the elevation-damage curve, which relates dollar damage to each stage of flooding, is usually the responsibility of the economist and/or planner while development of the other two curves is usually the responsibility of the hydraulic and hydrologic engineer. This is not to imply that responsibilities should be performed independently of each other. On the contrary, as explained in earlier sections, team effort is necessary to insure internal consistency and consideration of all relevant economic and hydrologic factors.

Figure 3-8 shows the relationships discussed above and the schematic for deriving expected annual damages. Elevation-damage Curve A is combined with elevation-discharge Curve B to generate damage-discharge Curve D by picking a damage point and relating it to a discharge estimate on Curve B, and, finally, using the estimates identified for discharge and damages as a new point on Curve D. This process is repeated until Curve D is traced out.

The tracing of Curve D is an intermediary step that is not necessary, but is included here to add clarity to the process. Curve D is then combined with Curve C to generate Curve E, the damage-frequency curve. The area under this curve repre-

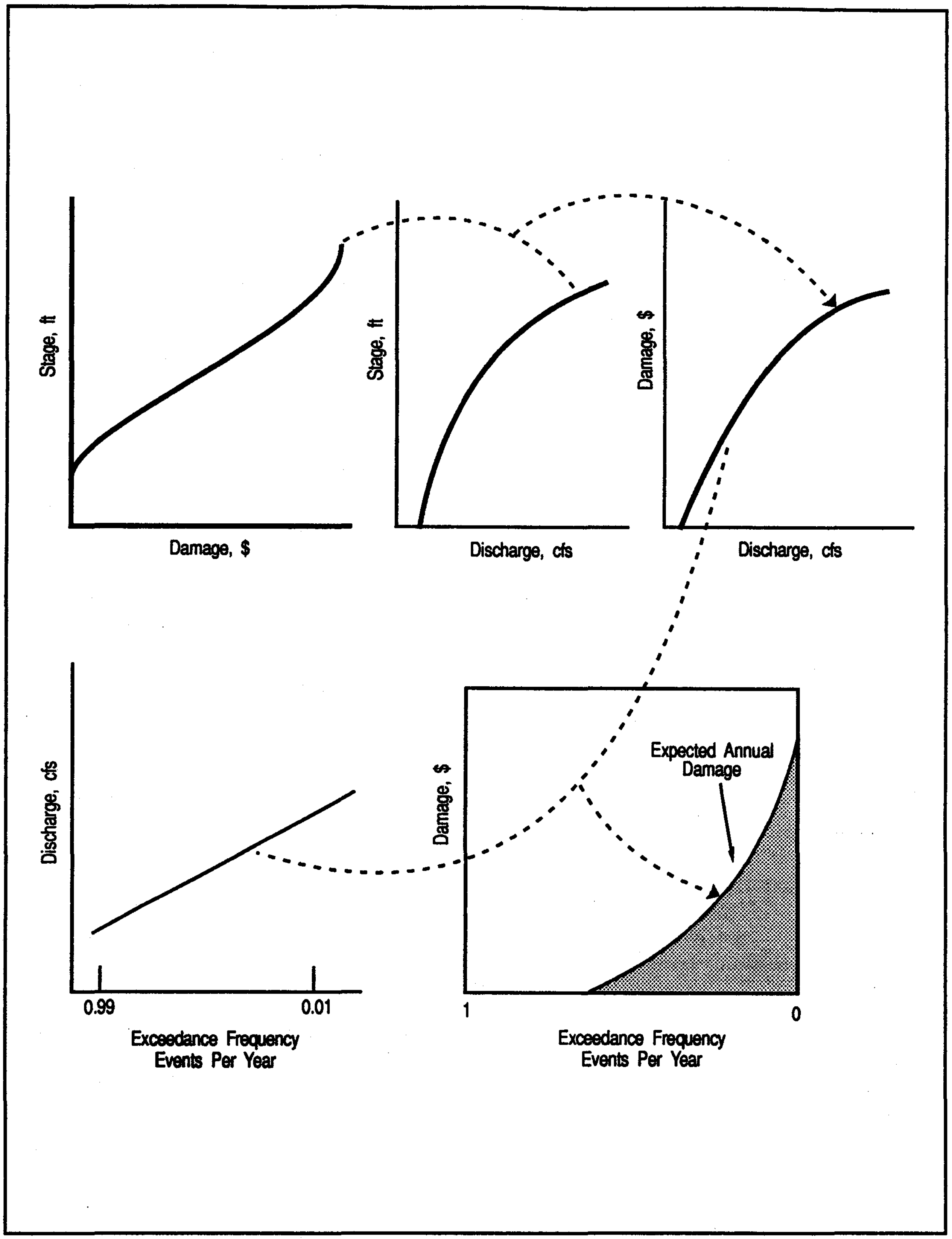

Figure 3-8
Schematic for Computation of Expected Annual Damage

Table 3-2
Expected Annual Flood Damage Computation

Flood	Discharge, cfs	Stage, ft		Frequency		Damages, $		Expected Annual Damages	
		RF	MSL	%	Interval	at stage	average	Interval	Summation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SPF	26,300	+4.2	713.0	0.1		669,800			42,645
					0.00035		652,200	228	
	22,750	+3.7	712.5	0.135		634,600			42,417
					0.00040		616,100	246	
	19,500	+ 3.2	712.0	0.175		597,600			42,171
					0.00065		578,600	376	
	16,600	+ 2.7	711.5	0.24		559,600			41,795
					0.0006		539,100	323	
	14,300	+ 2.2	711.0	0.3		518,600			41,472
					0.001		196,350	496	
	12,200	+ 1.7	710.5	0.4		474,100			40,976
					0.002		446,050	892	
DESIGN	10,000	+ 1.1	709.9	0.6		418,000			40,084
					0.0025		389,950	975	
	8,400	+ 0.6	709.4	0.85		361,900			39,109
					0.0045		328,500	1,478	
NOV '87	6,800	RF	708.8	1.3		295,100			37,631
					0.005		267,850	1,339	
	5,800	- 0.4	708.4	1.8		240,600			36,292
					0.008		211,150	1,689	
	4,900	- 0.8	708.0	2.6		181,700			34,603
					0.015		157,500	2,363	
SEPT '38	4,000	- 1.3	707.5	4.1		133,300			32,240
					0.059		112,550	6,640	
	3,100	- 1.8	707.0	10		91,800			25,600
					0.10		71,450	7,145	
	2,450	- 2.3	706.5	20		51,100			18,455
					0.23		38,950	8,959	
	1,850	- 2.8	706.0	43		26,800			9,496
					0.37		19,800	7,326	
	1,400	- 3.3	705.5	80		12,800			2,170
					0.15		11,500	1,725	
	1,300	- 3.4	705.4	95		10,200			445
					0.049		8,975	440	
	1,250	- 3.5	705.3	99.9		7,750			5
					0.0009		5,150	5	
	1,240	- 3.6	705.2	99.99		2,550			0
					0.0001			0	

sents expected annual damages. Subsequent paragraphs will show a sample computation, and will address the justification for both the procedure used and the conclusion that the area under the damage-frequency curve represents the expected annual value.

Sample Computation: Table 3-2 displays a comprehensive picture of all the relationships used in damage evaluation. This is a standard calculation sheet that is designed to provide all relevant information. For example, if one wanted to know about a particular flood, e.g., the design flood, by reading across that row, it can be readily observed that the discharge is 10,000 cfs, the elevation is 709.9 feet, the frequency is 0.6 percent, or a recurrence interval of 167 years (derived by dividing 100 by 0.6), and damages are $418,000. However, only the frequencies and damages, columns (5) and (7), enter directly into the computation of expected annual damages. Let us, therefore, concentrate on these columns, and the mechanics of computing expected annual damage.

1) Column 6 represents the intervals between frequencies. For example, in the first row, 0.00135 (0.135 percent) - 0.001 (0.1 percent) = 0.00035, the first entry in column 6. This is done for successive pairs of frequencies, through the entire range.

2) Next, we concentrate on column 7. The average damage between successive damage estimates is determined and shown in column 8, and results entered correspondingly with those in column 6. The entry of $652,200 in the first row is the average of $669,800 and $634,600.

3) Corresponding values in columns 6 and 8 are then multiplied to give column 9.

4) Values in column 9 are then added cumulatively, starting from zero, to give the summation of the EAD of $42,645 shown in column 10.

Conceptual Framework for Computation: Ideally, the area under a continuous curve with a known function, yk=f(x), can be determined by integrating over the limits of the intervals of that function. The concept of integration is based on breaking down the area under the curve into rectangles, and summing the results. The smaller the width of the rectangles (or the greater the number of rectangles), the closer this summation is to the actual area. A logical consequence of this is that if the number of rectangles approaches infinity, the area under the curve is essentially defined. This, then, is the basis for integration, and the justification for the procedure used to compute EAD.

The concept can be grasped more readily by examining Figure 3-9. Damage-frequency points, taken from the simplified sample estimates shown in Table 3-3, are used to construct the curve shown on this chart. The heights of the rectangles represent the average damages shown in column 4. For example, the heights of the first and last rectangles are 600,000 and 3,225,000, respectively. The widths of the rectangles are the frequency intervals shown in column 2. Consequently, the summation of the areas of all rectangles, i.e., the summation of all the heights times the bases, yields the same result as in the sample computation. However, remember that since the number of rectangles is limited, the estimate derived is only an

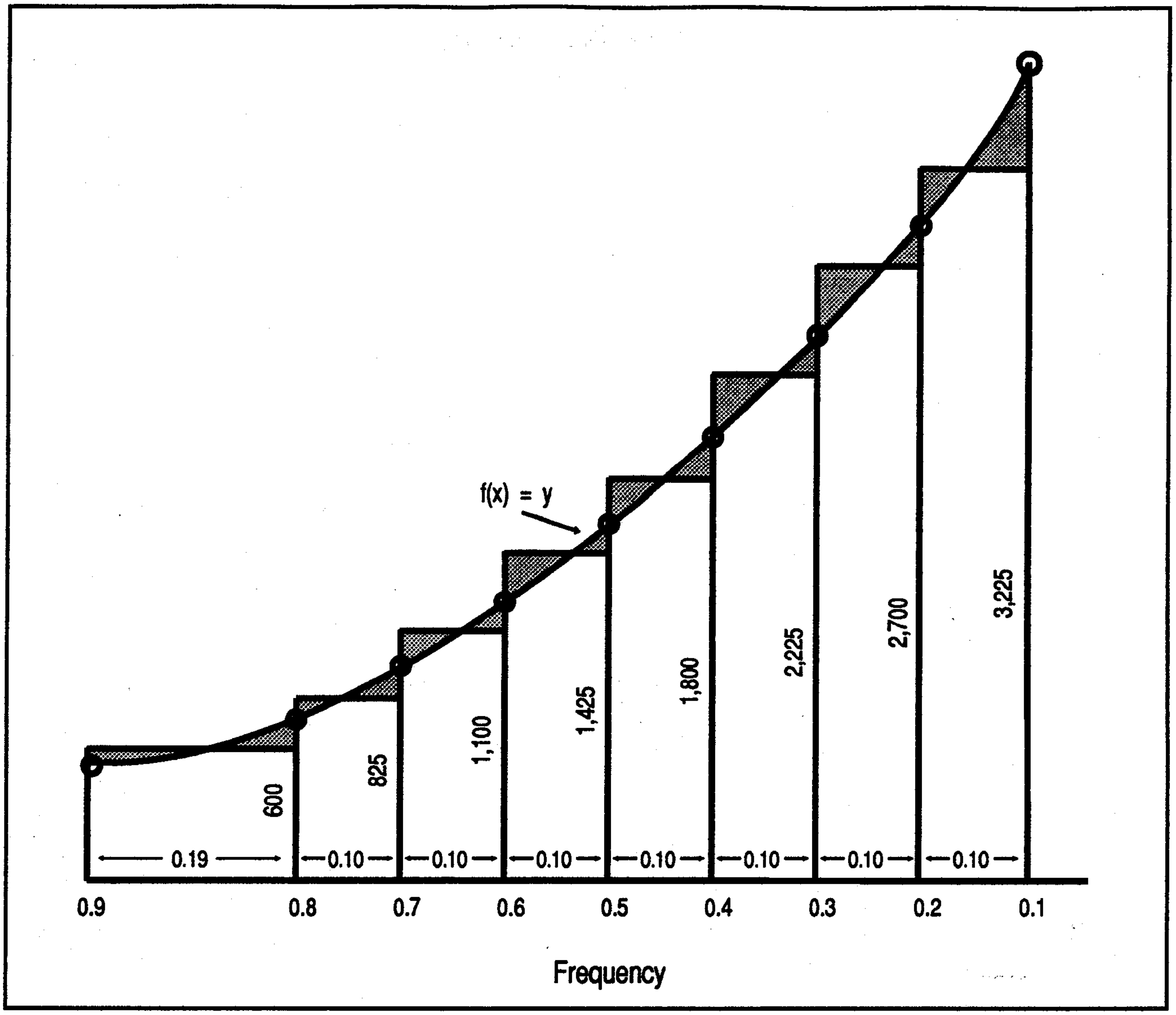

Figure 3-9
Integration of Damage-Frequency Curve

approximation of the area under the curve. Estimates can be distorted, based on the number of input points, and on the shape of the curve, except where the damage-frequency curve is a straight-line. The straight-line damage-frequency curve is an unlikely occurrence and is used here for illustrative purposes only. The simplified graph, shown on Figure 3-10, has been further distorted to demonstrate the principles discussed above. Note that, by definition, frequencies range from zero to one. This figure should not, therefore, be construed to represent a realistic situation. It does, however, serve the intended purpose.

The area under the curve is determined by three methods: by direct integration, by the frequency interval calculation method, and by directly computing the area from rectangles. Examples follow (refer also to Figure 3-11):

Table 3-3
Sample Computation of EAD

		Damages, $ (thousands)		Expected Annual Damages	
Frequency	Interval	At Stage	Average	Interval	Summation
(1)	(2)	(3)	(4)	(5)	(6)
0.10		3,500			1,445
	0.10		3,225	322	
0.20		2,950			1,123
	0.10		2,700	270	
0.30		2,450			853
	0.10		2,225	223	
0.40		2,000			630
	0.10		1,800	180	
0.50		1,600			450
	0.10		1,425	143	
0.60		1,250			307
	0.10		1,100	110	
0.70		950			197
	0.10		825	83	
0.80		750			114
	0.19		600	1140	
0.99		500			
1					

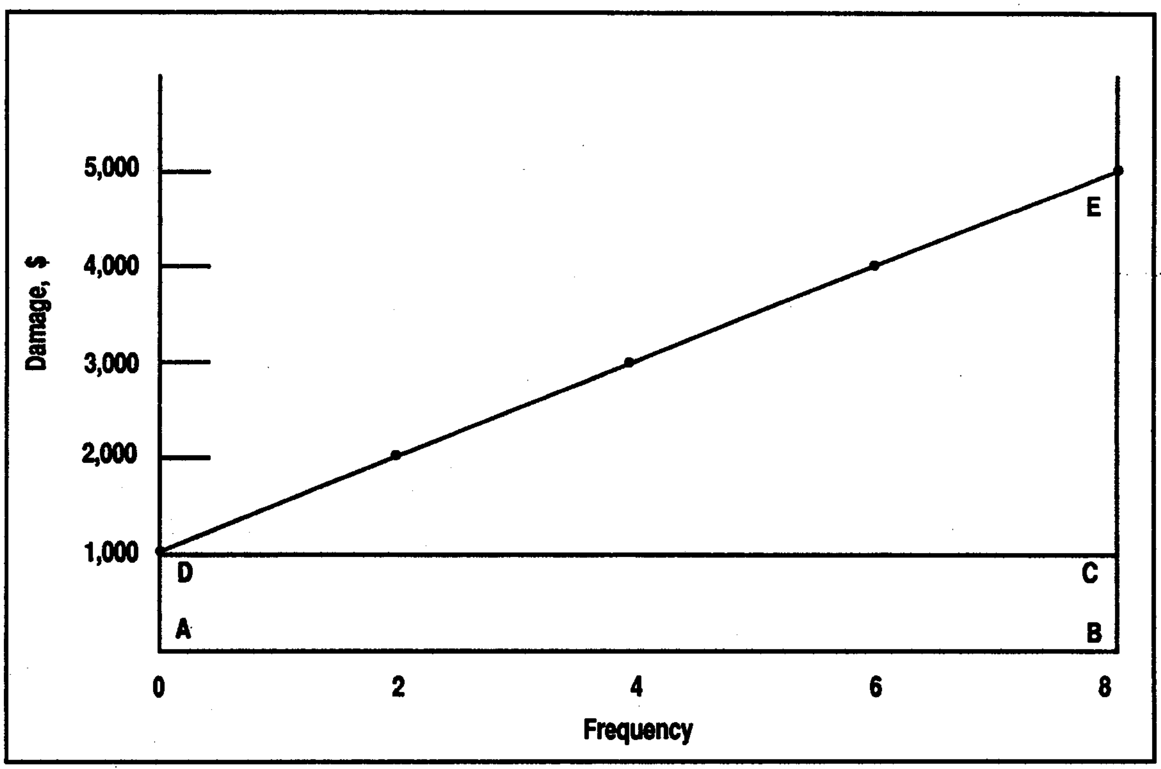

Figure 3-10
Straight Line Damage-Frequency Curve

a. Direct Integration:

$$y = f(x) = bx + a$$
$$= 500x + 1{,}000$$
$$\int_0^8 (500x + 1{,}000)\,dx = [250x^2 + 1{,}000x]$$
$$= [250(8)^2 + 1{,}000]^8 - 0$$
$$Area = 16{,}000 + 8{,}000 = 24{,}000$$

b. Frequency Interval Calculation Method:

x-Value Summation	Interval	Y-Value	Average	(2) x (4)	Total
(1)	(2)	(3)	(4)	(5)	(6)
0		1,000			24,000
	2		1,500	3,000	21,000
2		2,000			
	2		2,500	5,000	16,000
4		3,000			
	2		3,500	7,000	9,000
6		4,000			
	2		4,500	9,000	0
8		5,000			
			Area = 24,000		

c. Direct Computation:

Area of rectangle ABDC	=	height (h) × base (b)
	=	1,000 × 8 = 8,000
Area of triangle CDE	=	1/2 (hb)
	=	1/2 (4,000 × 8) = 16,000
Total area	=	8,000 × 16,000 = 24,000

The three methods yield identical results for the straight-line situation. However, for the typical non-linear situation, the closeness of results will depend on the number of input points and, therefore, on the number of rectangles defined by these points.

The second concern, regarding distortions from use of the frequency interval calculation method, can be demonstrated from an inspection of Figure 3-11. Curve 4a duplicates the straight-line situation such that, by inspection, the area excluded from rectangle ABCD, under the curve, is equal to the area included, above the curve. This, of course, is consistent with previous findings. Curve 4b is convex, and is more typical of the shape of damage-frequency curves encountered. Rectangle ABCD is fitted to the last two points. By inspection, it is observed that the area included in the rectangle, above the curve, is significantly larger than the area excluded, under the curve, such that the estimate for this part of the curve appears to be overstated. It appears, then, that the accuracy of the estimate is increasingly

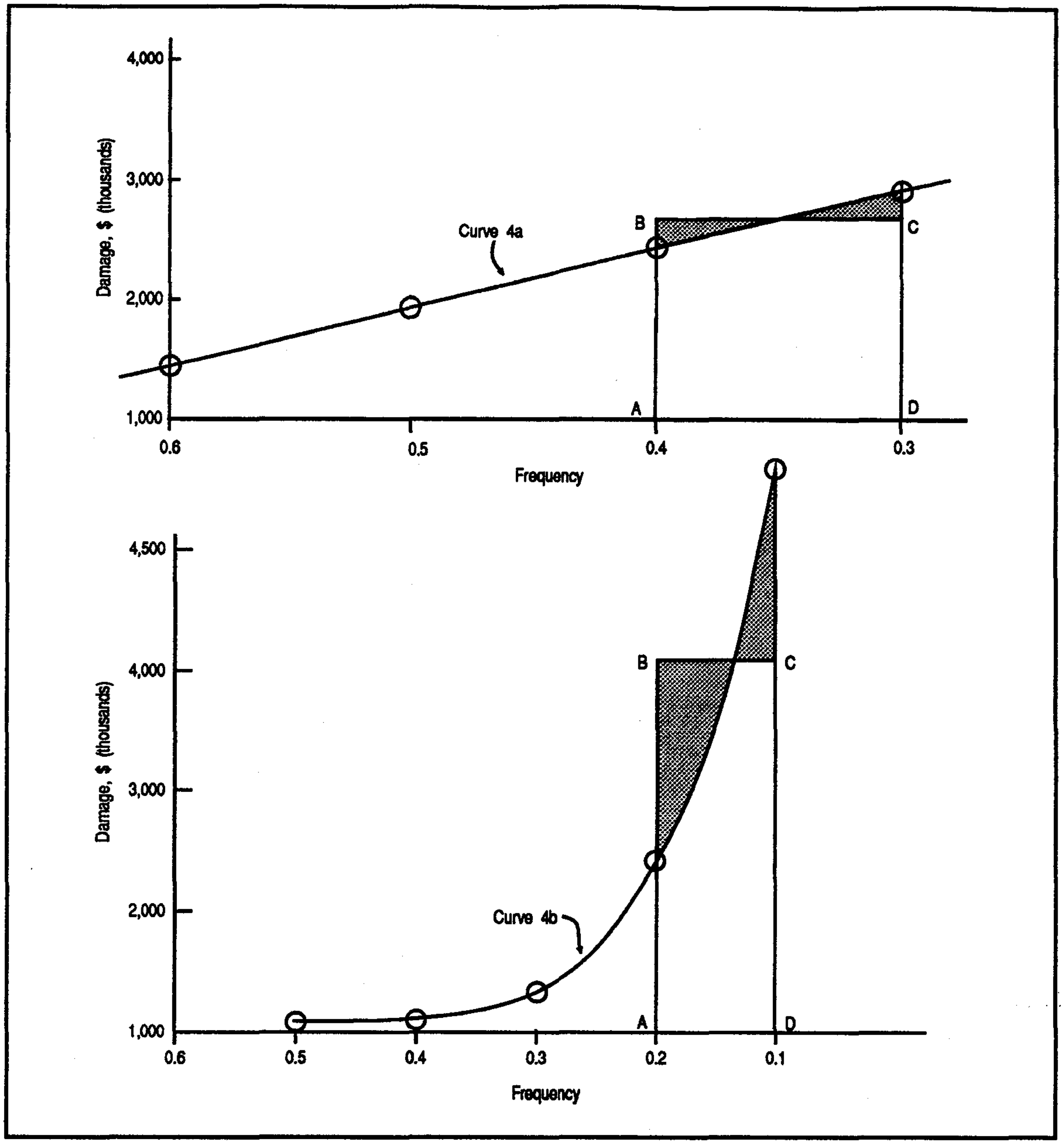

Figure 3-11
Damage-Frequency Curves

compromised the more convex the curve becomes. It can, therefore, be concluded that, typically, the frequency interval calculation method yields more accurate results for the lower end of the curve, which is usually flatter, and represents less frequent flood events, than for the upper part, which is usually more convex, and represents the more infrequent events. Even if it could be argued that, over the entire range of the curve, the pluses and minuses of areas tend to cancel each other out, EAD would still be distorted since the component of EAD contributed by more frequent events is more heavily weighted by the higher probability than those for the more infrequent events. Even so, we can conclude that if sufficient data points are used, the frequency interval calculation method will yield reasonably accurate results, since distortions occur primarily for the more remote events.

3.1.8.1 Why Expected Annual Damage? It is important to know why the computed value is considered to be an annual value over the study period. The three basic functions used to determine the damage-frequency relationship (the elevation-damage, elevation-discharge, and discharge-frequency curves), under existing conditions, are derived based on existing hydrologic and economic conditions. The damage-frequency curve, employed in EAD computation, was generated from these curves. In other words, the probability of occurrence of each event, in a given year, was used to define the probable damages in that year, based on the conditions that prevailed at that time. For example, the probable damages associated with a 100-year and a 10-year event are, respectively, 0.01 and 0.1 times the damages estimated for each of these events in that year. The summation of all probable damages, over the range of events, defines expected damages for that year. This summation of probable damages is the same as EAD computed from the damage-frequency curve. However, to be considered an annual damage estimate over the period of analysis, essentially the same hydrologic and economic conditions must prevail over the period of analysis.

3.1.8.2 HEC EAD Program: Many planners use the HEC EAD program to compute annual damages. This can be done by directly inputting either the damage-frequency function, or the three basic functions from which the damage-frequency curve is derived. It is recommended that planners become familiar with the HEC Users Manual before using this program. This will help to reinforce your knowledge of the subject, will give an insight into how the program works, and will make you aware of some pitfalls to avoid when using the program. A word of caution is in order. The program inserts points between successive input points to more properly define a curve. For example, in the case of a damage-frequency curve, nine points are inserted between successive input points. It is important to emphasize that both the curve, and the EAD computed therefrom, vary according to the number of input points, consistent with the previous discussion. It is, therefore, incumbent on the planner to insure that sufficient points are inputted to define the relationship properly. This is especially critical where the study area has unusual characteristics that should be captured in the analysis. Additionally, program output should always be carefully checked for reasonableness. One way is to check the results against recent flood events.

3.1.8.3 Computer-Calculated Bias: Figure 3-12 was taken from the 1984 HEC Users Manual. The dotted line shows the damage-frequency curve plotted by the HEC program from the nine input points. Note that for segment AB, the curves coincide; for segment CD, they almost coincide; but that for segment BC, there is a wide disparity. By inspection, the segment generated by the program does not seem to represent the best fit between points B and C. It appears that a better fit would be a curve somewhere between the hand and computer computations. This bias in the computer computations could be the determining factor in project feasibility. The planner would be justified in making an adjustment to the curve and to EAD in this analysis. Note, however, that this cannot be done without careful examination of the output.

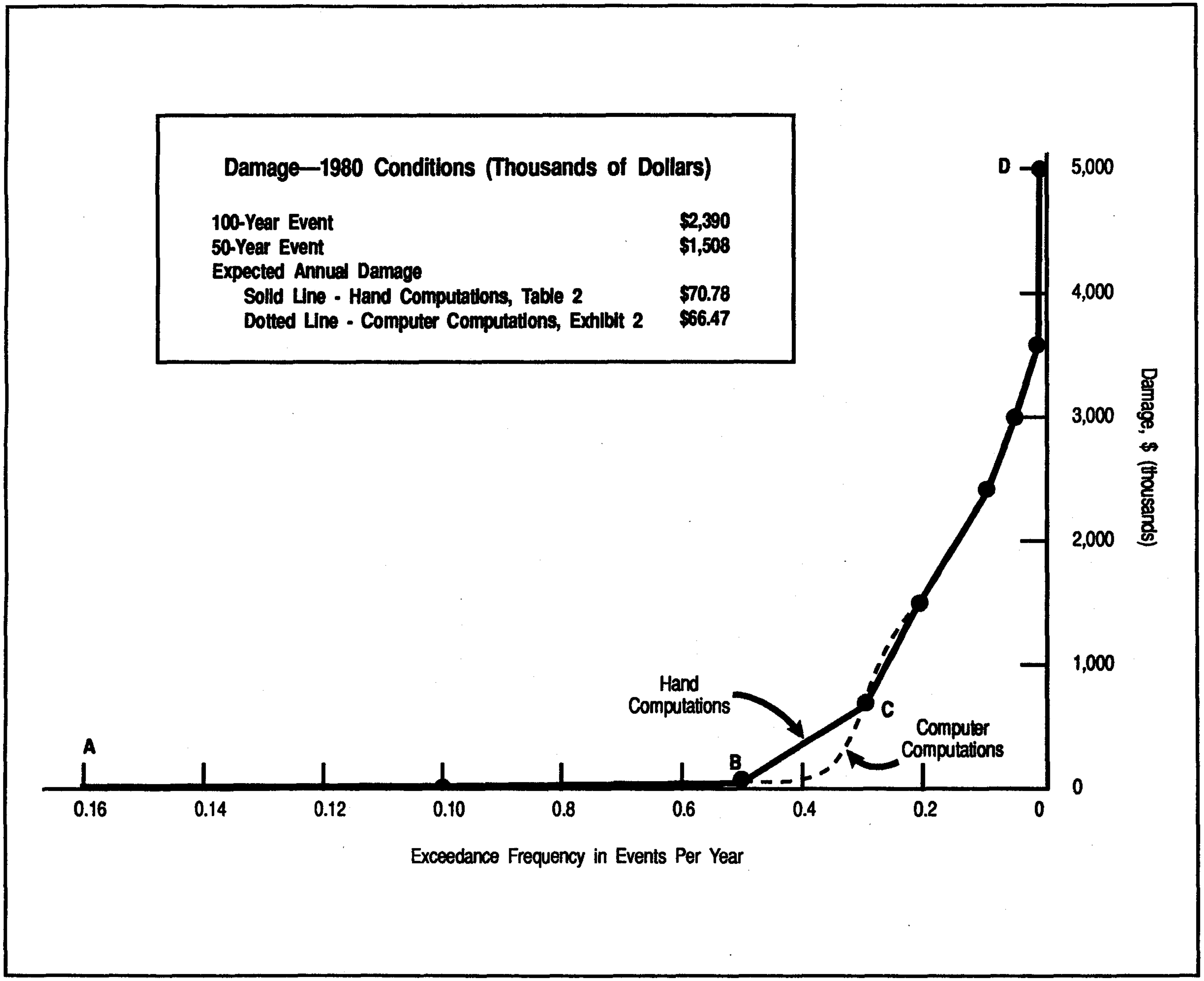

Figure 3-12
Damage-Frequency Relationship
Damage Category: Residential Structures
Reach 1 Plan 1 1980 Condition
(Reference: HEC User's Manual)

3.2 Physical Flood Damage under Future Conditions Without-Project

This section outlines the procedures used to account for all changes that would occur during the period of analysis if no project were undertaken in response to the study. The term "future" is used here to denote any time period after the year in which the study is completed. The period of analysis is defined as the project life, which is usually 50 or 100 years, depending on the type of flood damage reduction measure being considered. The period of analysis begins with the base year, when the project becomes fully operational. Due to the high degree of uncertainty over time, all economic activity, demographic, and hydraulic characteristics are held constant after the 50th year. All benefits are discounted to the base year. A large discount rate can greatly reduce the effect of any future changes on the overall project benefits.

This section describes how changes in land use, economic activity, and physical setting can affect flood damages. Projections have two major purposes: 1) to determine how changes in development and economic activity will affect elevation-damage relationships; and, 2) to determine how changes in drainage patterns that occur as a result of physical development will affect elevation-frequency relationships. These two relationships are combined to estimate damages under future without-project conditions. Hydrologic, demographic, and economic changes are forecasts that are necessary for the base year, and for 10-year increments up to 50 years beyond the base year.

There are five steps in the process of analyzing future damages. These include:

» Establishing the economic and demographic data base;

» Projecting land use;

» Establishing new economic inventory;

» Estimating new elevation-frequency relationships; and

» Calculating equivalent annual damages.

Each of these stages are described in detail below.

3.2.1 Conditions For Assessment

Any analysis of future conditions for with- or without-project conditions are subject to the following conditions:

1) All communities should be assumed to belong to the National Flood Insurance Program and to be in compliance with the following rules:

   a) No new development in the floodway, which is considered to be the natural storage area of the stream.

   b) The first floor of all new residential development must be above the one percent flood elevation.

c) All new non-residential development must be above, or effectively floodproofed to, the one percent flood elevation.

d) No major reconstruction or additions (equaling 50 percent or more of the structure value) to an existing property can occur without complying with rules b and c above.

2) The Flood Control District will not take actions that will promote development in the 100-year floodplain.

3) Decision makers are presumed to act rationally by assuming the most likely conditions that would occur under each measure. Rationality is based on the premise that individuals will continually act to maximize their net income. Irrational use, such as continued occupancy in frequently flooded areas, will not be perpetuated. The rationality test for continued floodplain occupancy is whether the floodplain location offers advantages sufficient to offset the costs of any land use or building regulations, plus the costs of any residual flood damages.

4) Development conditions are never static. Property can be added to or removed from the floodplain. Frequently flooded property may be abandoned and removed over a period of years.

5) Other flood control projects that are planned or authorized and not yet constructed, should be evaluated according to the likelihood and projected date of their implementation.

6) If local action is planned to occur only as the result of no District action, the project should not be assumed as part of the "without" condition. Local interests should not be penalized for their own incentive.

The remainder of this section outlines the five basic steps used to calculate inundation reduction benefits for future conditions without-project.

3.2.2 Step One: Establish the Economic and Demographic Base

The analysis of future benefits without-project begins with a detailed study of population characteristics and the level of economic activity in the region. Projections for population and economic activity are made for several points into the future. Values for the intervening years would then be interpolated, with the values displayed for the 10th, 20th, 30th, 40th, and 50th year beyond the base year.

For the District's purposes, there are several potential sources of information on population and economic development. Use of any one source should be determined by recency of figures, applicability to the situation and location, and availability of data. Sources to be considered include:

» The Valley National Bank publishes the Arizona Statistical Review annually. This is an extremely reliable source of information, and can be obtained at any branch, free of charge. It is published by the Economic Planning Division.

- » The Arizona State University College of Business has a Bureau of Economic Research which compiles data useful to economic planning.
- » The Arizona Department of Economic Security has two divisions which compile statistical data relevent to economic planning: The Labor Market Division and the Population Statistics Division.
- » For national figures, the Office of Business Economics publishes a set of projections called OBERS (Office of Business Economic Research Service) every five years. OBERS projections are published for the Nation, each of the 50 states, the District of Columbia, and each of the 330 Standard Metropolitan Statistical Areas (SMSA). The 1985 publication includes figures for 1969, 1973, 1978, 1983, 1990, 1995, 2000, 2005, 2015, and 2035. The state figures include population and personal income, as well as earnings and employment for 57 industrial groups. Metropolitan earnings and employment figures are limited to 14 industrial groups. Further breakdowns of county data can be developed under contract to the Bureau of Economic Analysis (BEA).

Projections of economic activity within the study area are based on three major factors: 1) the attributes of the study area; 2) the attributes sought after by potential activities; and, 3) the availability of sought-after attributes in the surrounding area.

Possible future use should first be specified by broad categories including: residential, commercial, industrial, public use, open space, recreational, and agricultural. Sufficient area should be included to insure that the affected area covers as many of these major categories of potential future uses as possible. When the potential use of the floodplain includes industrial use within a metropolitan statistical area, the entire metropolitan statistical area is the affected area; for residential areas, even within a metropolitan statistical area, a much smaller area may be envisioned.

All problems and characteristics of the study area should be evaluated in terms of existing conditions and the base year. The base year can be estimated by the amount of time for the process of authorization, funding, and implementation. The period from submission of a plan to implementation can vary considerably, and delays are commonly part of the approval and funding process.

Several other attributes are critical for projecting the floodplain inventory when land use changes take place. These attributes are generally assumed to remain constant, unless there is strong reason to expect demographic changes: 1) population per single or multi-family housing unit; 2) distribution of activities over the floodplain area; and 3) natural population increase and net migration.

3.2.3 Step Two: Project Land Use Changes

Land use patterns within the basin form the basis for economic and hydrologic change. Any planning study must contain estimates for past, existing, and future land uses. The scale of land use mapping will be dependent on the nature of the project. The following describes seven steps in the land use projection and allocation process:

1) **Review Federal Projections:** The Office of Business Economics (OBE), which is part of the Bureau of Economic Analysis of the U.S. Department of Commerce, and the Economic Research Service (ERS) of the U.S. Department of Agriculture calculate projections for states and metropolitan statistical areas.

2) **Review State and Local Projections:** Projections made by state or local agencies should be used in place of Federal projections when there is reason to believe that the local projections are more accurate by virtue of better localized or more up-to-date information.

3) **Identify New Information:** Any locations of specific development commitments, where a developer or potential occupants have made a financial investment, should be considered as part of the base year conditions.

4) **Adopt Population and Employment Projections:** Population and employment projections should be determined for the study area to determine the approximate number of acres required for each of the major land use categories.

5) **Establish Land Use Classifications:** In general, land use categories will follow those established for existing conditions unless major changes in categories are anticipated. A major influx of new development may require the designation of new categories. Some land use categories may be consolidated if it is found that a more detailed breakdown makes little difference in the calculation of benefits.

6) **Establish Land Use Requirements:** The existing land use pattern should, in general, be assumed to continue in similar proportion to current patterns. Growth in demand for land can be determined by the projected change in population and employment. The change in the number of acres required for each type of land use should be determined by the projected change in population and employment. The change in the number of acres required for each type of land use should be determined by applying conversion factors to the projected changes in population and employment. For example, it might be assumed that residential development will occur at the same density as established residential development. If this is the case, the projected population increase can be divided by the current population per residential acre to determine the acreage requirement for new residential development.

7) **Allocate Land Use Among Classifications:** Land use allocation requires determining a set of requirements or attractiveness factors for each land use and matching these factors with the attributes of available land in the affected areas, in and outside the floodplain. The desired attributes for each land use should be based on economic location theory, observation of past development trends in the area, and interviews with local developers and other business leaders. Once this initial research is completed, there are several models to allocate land use requirements among classifications.

One such model is the Alternative Land Use Forecasting (ALUF) program, developed by the Institute for Water Resources. (ALUF is not operational at the time of this publication.) The following describes how ALUF employs user-determined attractiveness factors for allocating land use.

Major attractiveness criteria include:

- **Access:** Distance to interstate highways and other major roads, distance to the central business district or other major commercial centers, distance to sources of supply and markets, and availability of public transportation.
- **Physical and Land Attributes:** flood hazard, slope, drainage, ground cover, and soils.
- **Infrastructure:** water supply, sewer system, electricity, and natural gas.
- **Local Prerogatives:** zoning, land use plan, transportation, and infrastructure plans.
- **Land Prices.**
- **Land Ownership.**

Once these factors are identified for each of the potential land use categories, it is necessary to establish the importance of each of these variables and build that into the allocation equation either by giving each variable a weight or factoring it in as a constraint. The planner can then apply these factors to determine the predominant land use or the proportion of land use distribution for each designated planning area. Planning areas can be defined as grid cells of uniform sizes.

The ALUF program requires that the existing land use information be entered in a spatial data base of uniform grid sizes. The predominant land use is indicated for each grid cell. Residential, commercial, and industrial land use may be found to be the predominant land use in 900, 800, and 200 grid cells, respectively.

3.2.4 Step Three: Establish New Floodplain Inventory

Analysis of future benefits is based on the projected level of economic activity in the study area and its spatial distribution. The analysis entails reestablishing a projected inventory for each damage reach and floodzone so that elevation-damage functions can be applied.

Once land use is established, there are three tasks in establishing the future floodplain structure inventory. These are: estimating the number and elevation of physical units, estimating the future value of those units, and determining the susceptibility of those units to flood damage. It can generally be assumed that land use patterns identified in Step Two will be the same, unless there is an impending development or recent change in the pattern of development that breaks with the existing land use.

3.2.4.1 Affluence Factor: Increases in residential content-to-structure value ratios are believed to increase with income over time. The affluence factor concerns the extent of increase in the content-to-structure value ratio over the 50 year horizon for projection of economic activity. The affluence factor is assumed to be in effect with or without a project.

Prevention of damages to future increases in content value of residential structures is a legitimate benefit when a flood control project protects residential development. The following steps should be followed in calculating increases in residential content value over time:

1) Determine average content value of existing homes and compare them with average structural values. This is often in the 35 to 55 percent range.

2) Use OBERS (Volume 1 and 2) regional growth rate for per capita income as the growth rate for increasing the value of residential contents in the future (or whatever local resource provides the most reliable data for the current study).

3) The future value of contents cannot exceed 75 percent of structural value nor can the growth period be projected beyond 50 years.

4) Assume damages (and benefits) will increase at the same rate as content value.

5) Determine average annual benefits for protecting existing residential contents. Then, calculate the benefits for protecting projected increases in content value.

An example of benefit calculations using the affluence factor procedure is given in Section 4.3.

3.2.5 Step Four: Establish New Elevation-Frequency Relationships

Land use changes may cause major alterations in drainage characteristics, particularly surface runoff. Hydrologic changes should be projected up to the first 50 years of the project life, and will primarily be based on land use changes. It is important that hydrologic change be noted by time interval to reflect changes in the degree of protection over time.

Hydrologic changes are critical when determining the level of protection afforded by any particular measure. Consequently, conditions should not be presented as averages, but rather shown as incremental changes that are staggered over the period of analysis.

3.2.5.1 Calculate Land Use Changes Effect on Runoff: The rooftops, streets, and parking areas that come with urbanization can greatly reduce the amount of water that infiltrates the ground. All jurisdictions in Maricopa County require that additional runoff be reduced by retention and diversion schemes. However, retention requirements vary from one jurisdiction to another. In calculating future conditions, local retention requirements should be taken into account.

3.2.5.2 Identify Other Physical Changes: Changes in the conveyance system that carries stormwater runoff can also affect elevation-frequency relationships. Cleared and otherwise smooth channels convey water more quickly and sustain fewer runoff losses than channels with vegetation and other obstructions. Storm sewers also cause more rapid conveyance, unless temporary storage is provided.

3.2.5.3 Re-do Hydrologic Analysis: The total amount of discharge for a given frequency of storms can be estimated by calculating the combined effects of the hydrographs for each sub-basin. The rainfall/frequency relationship is held constant. The new hydrograph is computed for each sub-basin by use of a simulation model that calculates and applies new runoff coefficients.

3.2.5.4 Review Hydraulic Analysis: For without-project conditions, hydraulic changes will be limited to any impending physical change, such as a bridge replacement, or anticipated long-term physical processes that would affect the geometry of the channel and consequently affect the elevation-discharge relationship.

3.2.5.5 Calculate New Damage-Frequency Relationships

1) Update land use information.

2) Apply new elevation-frequency relationship.

3.2.6 Step Five: Calculate Equivalent Annual Damages

Equivalent annual damages are the discounted values of damages after the mandated interest rate has been applied. While projections are limited to 50 years, equivalent annual damages are based on the entire project life, up to 100 years.

The elevation-damage relationship is calculated by the same procedure illustrated in Section 3.1.7. Elevation-damage curves change as a result of work done in the previous four steps.

Equivalent annual damages are calculated using established procedures similar to calculating average annual damages as illustrated in Section 3.1.8. An important difference between expected annual damages and equivalent annual damages is discounting. The effect of discounting is to lower the average annual expected value of future flood damages. For example, the equivalent value of flood damages seven years into the future might be worth 50 percent of the same damages if they were to occur this year.

Figure 3-13 shows some of the possible growth trends that could occur. Between existing and base year conditions, damages could increase, remain constant, or decline. Evaluation of the most probable future condition will determine which growth trend occurs. However, it is important to emphasize that existing conditions must first be clearly defined. Without knowing "what is," it is unlikely that "what will be" can be properly defined. Curve II represents constant conditions over the entire study period. Damages computed for existing conditions, therefore, represent annual damages over the entire period considered. If, on the other hand, conditions change significantly between existing and base year conditions, as suggested by Curve I or Curve IV, existing EAD must be adjusted to establish a new base year estimate. Generally, however, because of changed economic conditions, Curve III represents the future growth path of damages. This curve is isolated and shown in Figure 3-14. Damage estimates represented by this curve are based on future economic and hydrologic changes, generally categorized as future urbanization. These future values are discounted and annualized in accordance with the procedures outlined in Chapter 5.

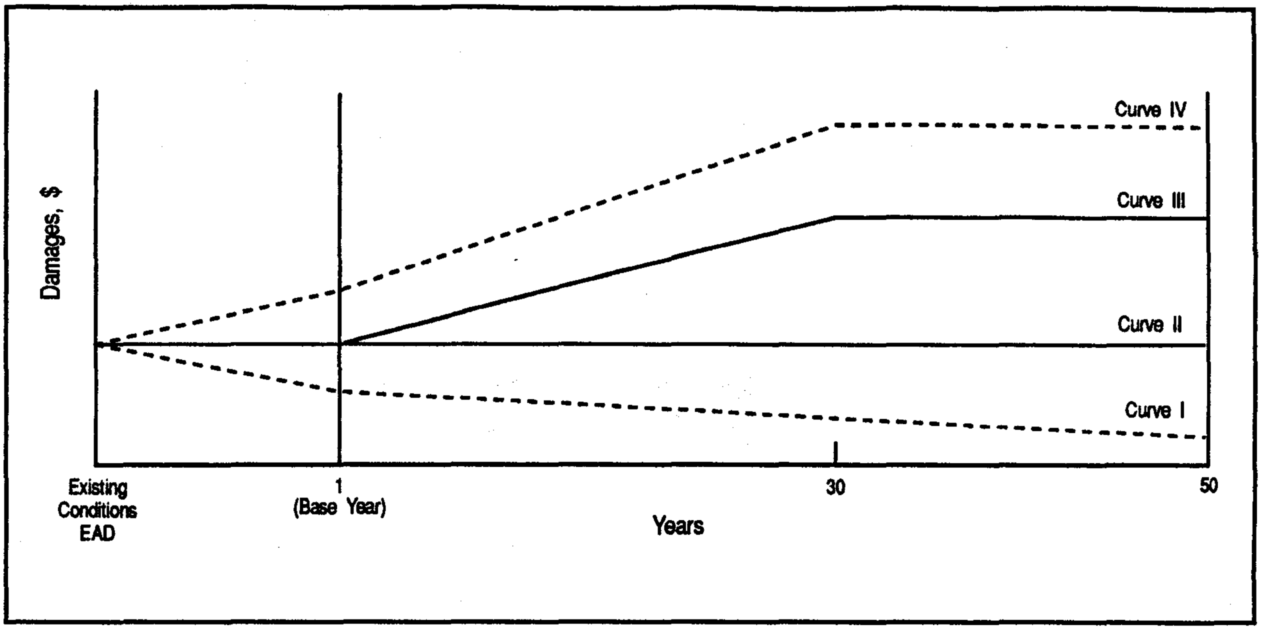

Figure 3-13
Expected Annual Damages with Alternative Growth Trends

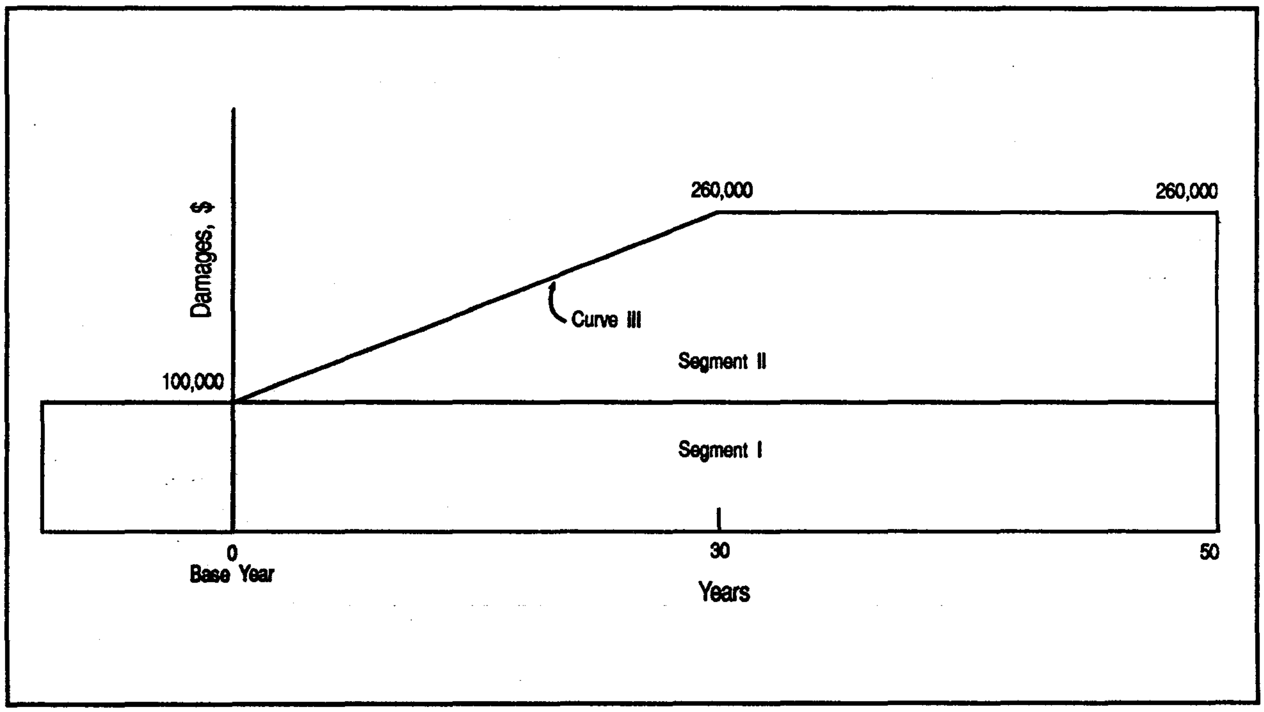

Figure 3-14
Expected Annual Damages

3.3 Non-Physical Costs

3.3.1 Overview of the Process

This section describes the types of costs that are incurred by floodplain occupants beyond the physical flood losses described above. There are two types of non-physical costs: 1) costs that are incurred only in the event of a flood or when flooding looks imminent enough to warrant emergency action; such costs include: income loss, emergency costs, traffic rerouting, and temporary relocation; and 2) costs that are incurred because of the flood potential regardless of any particular flood event.

3.3.2 Problems in Estimating Non-Physical costs

The magnitude of non-physical costs are not well documented. There are few, if any, commonly accepted generalized non-physical cost functions similar to those for structure and content damage. Unless any generalized relationship is available, these costs should be estimated from specific independent data, and not computed as a percentage of physical damage. Accurate estimation of these costs requires compilation of information from a number of public agencies, service organizations, businesses, and individuals. Estimation of non-physical costs also requires the use of "shadow prices" or proxies for the uncompensated time flood victims and volunteers spend in damage prevention and post-flood recovery periods. Because of these problems, non-physical costs often receive limited attention in benefit calculation, and the alleviation of these costs does not generally constitute a large portion of the average annual benefits. The level of detail spent on estimating these costs should depend on whether there is potential of significantly reducing these costs.

The District uses five categories of non-physical costs. These are income losses, emergency costs, floodproofing costs, restoration of land market values, and the modified use of floodplain property. The definition of these categories, the application of these benefits to Maricopa County benefit calculation, and formulas for their calculation are all given below.

3.3.3 Income Loss

Income losses are reductions in income when flooding or the threat of flooding halts production or delivery of goods and services. These losses occur: 1) when the production or delivery of these goods and services are not recuperated by postponing the activity or transferring it to another location, or, 2) when there are additional costs caused by delay or transfer of the activity.

Income losses are incurred by businesses and labor as a result of flood-induced shut-down in the production and delivery of goods and services. These losses can occur at any time during three periods: 1) flood warning, when business operations shut down and effort concentrates on damage prevention and evacuation; 2) flood inundation, when flood fighting and evacuation continue; and, 3) cleanup and restoration, when there may be a phasing in of normal activity. Even the threat of flooding can cause shut down of business operations for extended periods along large river basins. Inundation can vary from several hours to over a week, depending on the sources of flooding.

Income losses may occur directly to the business or institution being flooded or losses may occur indirectly when roads are closed and public utilities are cut off. Business losses can also occur from the spoilage of perishable commodities and when their processing or distribution are interrupted by flooding. Income losses also include any additional transportation or production costs that result from transferring production from one area to another.

There are no general guidelines as to what constitutes non-recoverable income losses. That determination would have to be made by questionnaires and post-flood surveys of the directly affected businesses and other firms that supply identical or easily substitutable goods and services in the same market area. It is likely that non-recoverable business losses mostly follow unique patterns and would therefore require individual attention.

Businesses where losses would be expected to be non-recoverable include:

» Public utilities, including water supply, electricity, natural gas, and telephone;

» Losses where delays in delivery or processing cause spoilage of perishable items, such as meat, dairy products, fruits and vegetables, and baked goods;

» Businesses that produce unique products or businesses whose competitors are at full production;

» Newspapers, radio, and television stations which provide the only sources of local or national information;

The likely production loss that would occur from the use of company resources for repair and clean up of damaged property should not be counted if it has already been used to estimate the physical damage to structure and contents.

The amount of income loss is measured by the value added from the activity at the particular firm in question. "Value added" refers to the increase in value to a final product or service solely from input by the facility in question. Only factors that provide real increases in the value of the output should be considered. For example, the labor and machine processing that goes into an industrial product adds to the real value of a product. The taxes paid by the facility do not directly add to the real value of the product, although they do add to the final price.

The procedure for computing income-loss for any given business is given by the following equation:

$$L = N \times V \times D / H$$

where

L = the income loss for an individual business

N = the number of employees

V = the annual value added by the business per employee

D = the duration in operating hours that a business is closed

H = the number of hours the business operates in one calendar year

Most of the variables in this equation are self-explanatory. The data for most of these variables are readily available. The value added for the business may be estimated by multiplying the number of employees in the business by the average value added per worker for that industry. The formula given above is adapted from *Industrial Flood Losses: Damage Estimation in the Lehigh Valley* (Kates, 1965, p. 56).

Value-added statistics can be obtained from the Regional Analysis Division, Bureau of Economic Analysis (BEA), U.S. Commerce Department. The BEA has compiled value-added statistics for each state by two-digit SIC code equivalents, available on microcomputer diskettes and published by one-digit industries in the BEA publication, *Experimental Estimates of Gross State Product by Industry, Staff Paper #42.* Both the microcomputer data and published information are 1972 data. Annual estimated value-added data are available by the equivalent of 4-digit SIC codes on BEA's National Regional Impact Evaluation System (NRIES) II. These annual data are compiled by somewhat less rigorous means.

3.3.4 Emergency Costs

Emergency costs include:

» Efforts taken to monitor and forecast flood problems.

» Actions taken by police and fire departments, Civil Defense, the Flood Control District, and other agencies to warn and evacuate floodplain occupants, to direct traffic, and to maintain law and order during a flood.

» Flood fighting efforts, such as sandbagging and building closures, taken to reduce flood damages.

» Costs of efforts, such as emergency shelters and provision of money, food, and clothing, offered to relieve the financial situation experienced by flood victims during and after a flood emergency.

» Evacuation costs for floodplain residents.

» The administrative costs for public agencies and private relief agencies in delivering emergency services.

Emergency costs generally include only the variable costs that would be incurred at the time of a flood event.

The fixed costs of emergency programs, such as maintaining the administrative staff and equipment needed in typical daily operation should be considered only if there is a reasonable possibility that these costs could be reduced by a project. For example, the number of people and equipment necessary for a flood warning system might be reduced with a reservoir or a channel project. Less detail might be necessary for maintaining the flood forecast program.

3.3.5 Traffic Rerouting

Flooding can temporarily impede traffic by covering roads and bridges. Even the threat of flooding and concern for public safety may make it necessary to close roads and detour traffic. Bridge and road damage may cause detours for several months until repairs can be made. The costs of traffic disruption include:

- » Additional operating cost for each vehicle, including depreciation, maintenance, and gasoline per mile of detour.
- » Traffic delay costs per passenger.

To determine traffic operating cost, it is first necessary to determine the frequency, elevation, and duration of flooding along major stretches of road that are subject to flooding. In order to concentrate on areas where the most significant benefits might occur, it is necessary to focus on portions of roads where there would be considerable traffic rerouting for long periods of time.

Beyond the inundation mapping, there are eight tasks necessary to determine the operating costs of traffic rerouting:

1) Estimate the amount of time that a particular stretch of road would be impassable.
2) Use local traffic counts to determine the extent of daily and seasonal traffic crossing bridges and major thoroughfares affected by the flooding. Separate counts are obtained for automobiles and trucks.
3) Determine the number of miles in the original route.
4) Determine the number of miles in the best alternative route. Highway departments will often have detour plans that can be used for making these estimates.
5) Determine the additional miles per vehicle.
6) Determine the total amount of additional mileage for all automobile and truck traffic.
7) Estimate the average vehicle operating expense from the closest office of the American Automobile Association. The Private Truck Council of America and Chilton Company publish the *Cost Index Survey for Private Trucks*. Average operating cost statistics are multiplied by the total mileage requirements for automobiles and trucks to obtain the total additional operating cost for each type of vehicle.
8) Add the total additional operating costs for automobiles and trucks together to obtain the operating costs by frequency of event.

An example of these procedures is given in Table 3-4.

The second portion of traffic rerouting is traffic delay costs. This cost accounts for the additional time spent by individuals forced to take the detours due to road closings. Since time is usually more valuable than the average vehicle operating

Table 3-4
Additional Operating Costs Associated with Inundated Roadways
(100-year Event)

Step One:	Flood duration above 1 foot	100 hrs
Step Two:	Average traffic count for flood period	
	Automobiles	70,000
	Trucks	15,000
Step Three:	Number of Miles for the Original Route	25
Step Four:	Alternative Route Mileage	30
Step Five:	Additional Mileage per Vehicle	5
Step Six:	Total Additional Auto Mileage	350,000
	Total Additional Truck Mileage	75,000
Step Seven:	Total Additional Operating Costs	
	Automobiles (350,000 × $0.30/mile)	$105,000
	Trucks (75,000 × $0.50/mile)	$ 37,500
Step Eight:	Total Additional Operating Costs for a 100-year Event	$142,500

costs in the same period, traffic delay costs can be expected to be higher than traffic operating costs.

The procedures for calculating traffic delay costs are as follows:

1) Determine the total number of miles for the original route and for the detour route for automobiles and trucks. This can be obtained from steps 2, 3, and 4 of the traffic operating costs procedures.

2) Determine the amount of time required on the original route for cars and trucks. The average speed under all times and conditions, weighted by the amount of traffic, should be multiplied by the number of detour miles.

3) Determine the amount of time required on the alternative route for automobiles and trucks. The weighted average speed for the alternative route under all times and conditions should be multiplied by the number of detour miles.

4) The additional travel time is computed by subtracting the original travel time from the rerouted travel time for both automobiles and trucks.

5) Determine the approximate average number of passengers per vehicle by contacting the Arizona Department of Transportation or Maricopa County Highway Department.

6) Assess the cost of travel for automobile drivers and passengers, using one-third the average local wage for adults and one-twelfth the average wage for children.

7) We can assume that truck drivers are mostly operating their vehicles in the course of work. Therefore, it is reasonable to use the average local wage for truck drivers to determine the delay costs for trucks.

8) Add automobile and truck delay costs to determine the total cost per event.

An example of traffic delay costs, taken from the Passaic River Study, is given in Table 3-5. Some numbers in this example have been rounded to the nearest tenth.

3.3.6 Floodproofing Costs

The costs of permanent or dry floodproofing measures taken by individuals to protect their property and to meet the National Flood Insurance Program requirements can be eliminated by structural protection measures and permanent relocation.

Table 3-5
Total Travel Cost Associated with Inundated Roadway
(100-year Event)

Step One:	Original mileage for automobiles	
	25 × 70,000 =	1,750,000 miles
	Original mileage for trucks	
	25 × 15,000 =	375,000 miles
	Detour mileage for automobiles	
	30 × 70,000 =	2,100,000 miles
	Detour mileage for trucks	
	30 × 15,000 =	450,000 miles
Step Two:	Original travel time for automobiles	
	1,750,500/45 mph =	39,000 hours
	Original travel time for trucks	
	375,000/45 mph =	8,333 hours
Step Three:	Detour travel time for automobiles	
	2,100,000/10 mph =	210,000 hours
	Detour travel time for trucks	
	450,000/10 mph =	45,000 hours
Step Four:	Additional travel time for automobiles	
	(210,000 – 39,000) =	171,000 hours
	Additional travel time for trucks	
	(45,000 – 8,333) =	36,667 hours
Step Five:	Delay costs	
	Automobiles (171,111 × $2.80/person/ hour × 1.25 adults per vehicle) =	$598,000
	(171,111 × $0.70/person/hour × 0.6 children per vehicle) =	$71,820
	Trucks (36,337 × $12/person hour) =	$440,004
Step Six:	Total delay costs to all vehicles =	$1,109,824

Floodproofing costs are incurred from the adoption of permanent features, known as dry floodproofing, and the adoption of temporary measures during periods of flooding, known as wet floodproofing.

Floodproofing costs should be thought of as applying to individual units, as distinct from emergency preparedness activities that apply mostly to outside property. These costs can be expected to vary a great deal, and they cannot be properly estimated without extensive survey of the study area. The estimated costs should include the expenses for all material and labor, with labor valued at the average area rate for custodial services. The effects of these measures are considered in elevation-damage relationships.

3.3.7 Temporary Relocation and Reoccupation Costs

Temporary relocation includes the additional living expenses incurred by floodplain residents who are forced to find temporary housing during and after a flood. Homes may be made uninhabitable due to:

» Extended periods of inundation.

» Structural damage that is too severe to live with, as when critical parts of the structure, such as plumbing, heating, and electrical systems are ruined or inoperative, or when silt and debris is widespread throughout the structure.

» Large deposits of silt and debris.

» Cutoff of transportation routes and utility services.

Temporary relocation costs include:

» Costs of motel rooms or apartment rentals.

» The extent that costs of restaurant or prepared food exceed ordinary grocery costs.

» Additional costs of commuting to work and school.

» The opportunity costs of the time spent in making household repairs, contracting for repairs, and purchasing new furnishings and personal effects. The net difference in utility expenses should also be considered.

Whether or not individuals are forced to temporarily relocate because of flooding, they will still incur the expenditure of many hours in contracting, supervising and inspecting repairs made on their homes, contracting for repair and replacing household furnishing, and filling out casualty loss forms for flood insurance, income tax deductions, and other disaster assistance. These costs should be determined by interviewing a sample of flood victims who have experienced varying elevations of flooding.

Temporary relocation costs apply primarily to high levels of inundation and when there are flood durations of one day or longer.

3.3.8 Modified Use of Flood-Prone Property

The threat of flooding will often cause occupants not to use areas of their buildings that are subject to the most serious flood threat or cause a less valuable or inefficient use of the property. Arrangements of contents, although it may be considered inconvenient, is not a major economic loss. For benefits to be considered for this category, there should be evidence of a substantial number of rooms or properties otherwise not in full use. This category closely parallels benefits for more intense use of floodplain business property and the affluence factor for residential property described in Chapter 4. The distinction is that intensification benefits and affluence factor include the acquisition and use of new and more valuable contents, while modified use refers strictly to a change (reduction) in the actual use of a portion of the structure.

3.3.9 Restoration of Land Market Values

Restoration of land market values is a seldom used but legitimate benefit category, intended to capture benefits that otherwise might be considered intangible. This might include the psychological trauma and inconvenience of flooding which would be perceived in the real estate market. These are costs faced by the property owner which are over and above the costs of flood insurance premiums, uninsured flood losses, and temporary relocation.

To determine the extent of these costs, it is necessary to compare real estate values in the floodplain with comparable properties outside the floodplain or determine the effects that similar flood protection projects may have had on land values. From that, it is necessary to project the increase in values that flood protection might bring to the project area. A sample calculation of the restoration of land market values benefits is given below in Table 3-6.

Note that the specific concern here should be for long-term land values. The market value of property can be expected to change significantly with the amount of time since the most recent damaging flood. The evaluator should be concerned with long-term land values that would average out the changes of land values for flooding and non-flooding years.

If the land is currently undeveloped, it would be easier to measure the enhanced value as a location benefit. If the land in question is part of developed property, it should be clearly demonstrated that there is no double-counting what may already be claimed under physical inundation reduction benefits.

Table 3-6
Restoration of Land Market Values

Value of Restored Land	$20,000,000
Value of Land in Present Condition	$16,000,000
Increase in Value	$ 4,000,000
Reduction in Flood Insurance Premiums, Uninsured Physical Damages, and Temporary Relocation	$ 3,000,000
Total Benefit	$ 1,000,000
Average Annual Benefit	$ 88,770

4

Calculation of Benefits

Various floodplain management options are available to reduce flood damages to existing and future occupants. The options can be divided into two main categories, structural and nonstructural. Structural flood damage reduction measures are defined as those measures that modify the height, amount, duration, frequency or extent of flooding in an area. Similarly, nonstructural measures are defined as measures that modify the response to or susceptibility of floodplain property to flood damage rather than changing the characteristics of the flood itself. Thus, a project to keep river flows within banks would be structural, while removing damageable property from the natural floodplain would be nonstructural. Building a levee around a town would be structural, but building a floodwall around an individual building would be nonstructural.

4.1 Inundation Reduction Benefits for Structural Measures

There are many types of structural measures, including traditional projects like dams, channels, levees, and more recent proposals like movable barriers and diversion tunnels. Each measure can be designed to provide varying degrees of protection and geographic scope. Structural measures may be combined or supplemented with non-structural solutions.

4.1.1 Impoundments: Wet and Dry Reservoirs

The first type of structural measure is an impoundment that holds floodwaters during storm periods and gradually releases the water during periods of lower flow. This serves to reduce the frequency of various flows, reducing flood heights and decreasing flood damage. The storage volume could be part of a multi-purpose reservoir allocated to flood control, or a single purpose flood control reservoir either having a small permanent pool or acting as a dry dam. The magnitude of flood reduction depends on the storage volume available, the amount and timing of the runoff, and the distance to the damage area.

Flood elevations are determined by calculating frequency-discharges for the with- and without-project conditions and converting the discharge to flood elevations using a rating curve or a hydraulic model. The dam would have little effect on the downstream hydraulics, but it would alter the frequency with which certain flood flows would be expected to recur. Benefits may be computed by comparing damages from the elevation-damage relationship, also unchanged, for each condition. Generally, flood control dams produce lower downstream elevations but for a longer duration. This would normally result in less damage for a given frequency flood (a lower frequency-damage curve) and a net beneficial effect. In some agricultural or forestry situations, the duration of flooding is more disruptive than the depth (especially when the depth has been regulated), giving negative benefits (or costs) to the evaluation of the project. These costs should be recognized and could play a significant role in the future operation of the dam. Figure 4-1 shows how various reservoir designs affect damage frequency relationships.

The analyst should note that when evaluating multi-purpose reservoirs, flood control may be only one of many project benefits which must compete for the available storage. Other benefit categories such as water supply, hydropower, water quality releases, recreation, and fish and wildlife enhancement may be adversely impacted by the flood control storage. In some areas at certain times, flood control storage is the only purpose served. The operating system for a reservoir is very important in determining the after-project condition. A single size reservoir at a particular site may have several plan formulations based on the storage allocated to competing uses. The economist or study team must accurately weigh the beneficial and adverse impacts to each category from a particular reservoir operation system.

Most of the impoundments in Maricopa County will be dry dams—as there are limited water sources in this area. A dry dam is a much simpler operating system than a wet dam because it has one primary purpose (flood control, but possibly including some outdoor recreation) whose benefits may be calculated using straight-forward with and without-project conditions. Dry dams are more difficult to justify economically (less benefit categories) and are often less popular with local sponsors. They require large land areas and relocations much like a lake, but would not have the same water quality or evaporation problems. In most urban areas, a multi-purpose project would be much more feasible because of the high demand for additional project outputs, such as water supply and water-based recreation. Since the incremental cost for these features is usually less than the incremental benefits, they improve the economics of the overall project.

An example of an impoundment analysis is a dam site which can be developed to provide 2, 4, or 6 inches of storm runoff storage for all of the basin upstream of the reservoir. Table 4-1 shows the beneficial flood control effects of each option.

Table 4-1
Damage Prevented by Reservoirs for a One Percent Flood

Plan of Development	Acre-ft F.C. Storage	Discharge	One Percent Flood Stage	One Percent Flood Damages	One Percent Flood Benefits
Natural condition	0	50,000	30.0	2,000,000	0
2" Flood condition	6,000	44,000	27.0	1,200,000	800,000
4" Flood condition	12,000	37,000	23.0	600,000	1,400,000
6" Flood condition	18,000	29,000	18.0	200,000	1,800,000

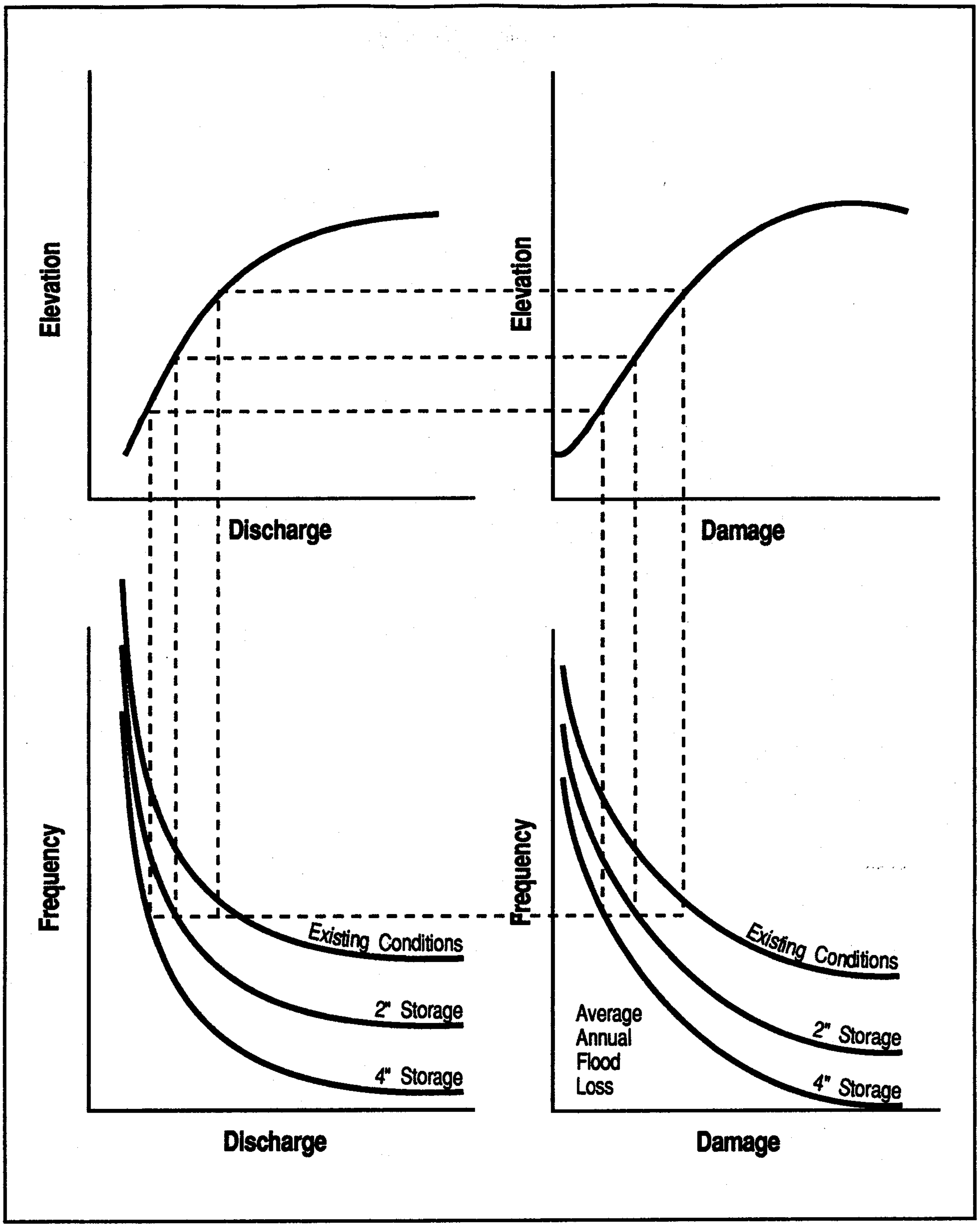

Figure 4-1
Economic and Hydrologic Effects of Reservoirs

4.1.2 Barriers: Levees and Floodwalls

A second type of structural measure is a barrier erected to protect the occupants of the floodplain from inundation. The best known of these are the extensive levee systems along the Mississippi River. Also included would be dikes and floodwalls, floodgates, wind-tide barriers, and coastal berm-and-dune projects. These measures raise the beginning damage level to the top of the structure design height, including a freeboard allowance, and are then subject to complete or near-complete failure. These barriers affect the extent of flooding and may or may not change the flood height or peak discharge volume. Hydrologic and hydraulic (H & H) analyses must be done to determine if lost storage volumes and flow areas are significant enough to change frequency-discharges or flood heights. In the event that a levee is overtopped, damages could be higher than if no levee were built because of a false sense of security, induced development, and longer flooding durations. The local flood warning and evacuation plans are essential with low-level levees and should be planned before such a project is recommended.

Barriers which prevent the entry of water also prevent the exit of water and may require pumps and/or storage areas to reduce damage from interior drainage. In these cases, economic analyses should include residual damages from interior ponding and operation, and maintenance and replacement costs for pumps and flood gates. Benefits for the levee are calculated by modifying the elevation-damage curves to show no damages until the level of protection is exceeded. Dikes are usually designed to include an additional height called freeboard to account for risk, hydrological imprecision, wave action, and uncertainties. A flood reaching the design elevation of the dike would not cause immediate failure because of this freeboard allowance. Present guidance allows for benefits to be claimed in this freeboard area as one-half the total benefits in the area between the design flow and the maximum flow that can be safely passed. In many cases the benefits from this freeboard may be significant, especially when a large freeboard allowance is required. Figure 4-2 shows the effects of various levee designs on the elevation-damage relationship.

An example of a dike plan is an urban levee providing nominal levels of protection and including 3 feet of freeboard allowance. Table 4-2 shows the beneficial effects of various levee heights.

Table 4-2
Average Annual Benefits for Levees

Plan of Protection	Protection Stage	Stage at Top of Levee	Frequency at Top of Levee	Avg Annual Benefits for Design	Avg Annual Benefits for Freeboard	Total Average Annual Benefits
3.33% (30-yr) levee	9.0	12.0	1%	600,000	200,000	800,000
1% (100-yr) levee	12.0	15.0	SPF	1,000,000	500,000	1,500,000
SPF levee	15.0	18.0	>SPF	2,000,000	200,000	2,200,000

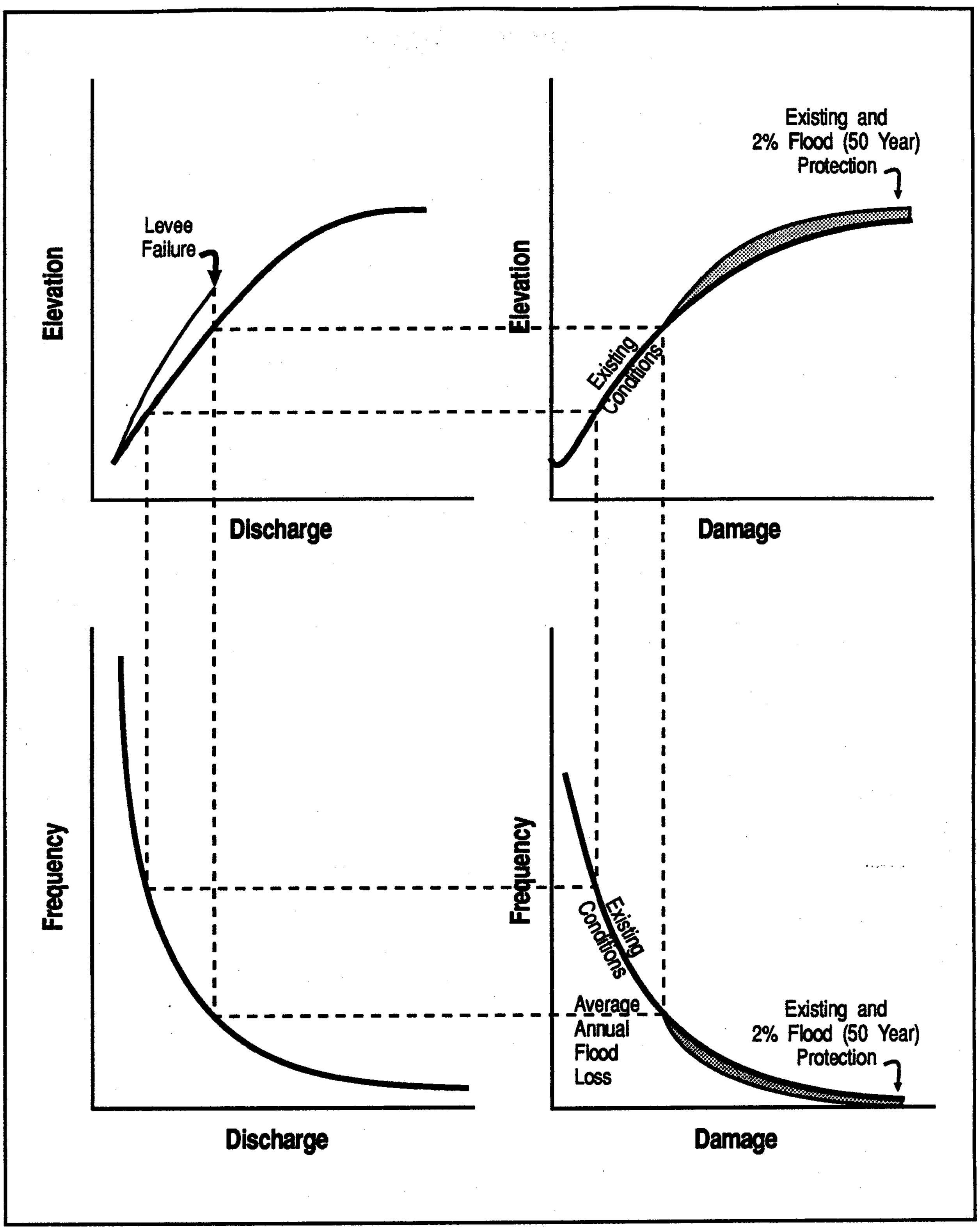

Figure 4-2
Economic and Hydrologic Effects of Levees

4.1.3 Channel Work

A third type of structural measure is an increase in the hydraulic capacity of the stream channel to decrease flood elevations for the same rate of discharge. This increase in flow area may come from widening and/or deepening the channel, cutting a bench channel at a specified height above the stream bottom, or providing a diversion channel or cut-off. In some cases the channel walls may be modified to decrease friction and improve flow, such as paved or concrete channels. Clearing and snagging or removal of vegetation or aquatic weeds may also be done to improve capacity and decrease flood elevations. The new channel capacity is often defined by the frequency-discharge it can contain. Figure 4-3 shows how different channel designs affect the elevation-discharge relationship.

These measures to improve hydraulic capacity may lessen floodplain storage, increase velocity, and decrease peaking times which may result in higher downstream elevations. Benefits may be claimed as the with and without-project elevation-frequency compared to the elevation-damage function. Any area of negative impact should be included. Also, future damage predictions should take into account any decrease in hydraulic efficiency over time, the cost of a preventive operation and maintenance system, and future growth in floodplain occupancy. Regulatory floodways should be established to prevent encroachment into the improved floodplain and maintain hydraulic integrity.

Table 4-3 depicts a channel improvement project with 50, 80 and 120 feet bottom widths and the beneficial effects of each plan.

4.1.4 Impediment Removal

A fourth type of structural measure would be the removal or modification of any impediments to flow, such as dams, restrictive bridges, piles, piers, or rock outcroppings to improve flow and decrease elevations. Evaluation of this measure would be similar to channel improvement and should account for any decrease in water surface elevation for any given frequency of flooding. In bridge replacements, highway betterments may be subtracted from the project cost in the economic analysis. Improvements to navigation should also be considered a benefit.

4.1.5 Combinations of Measures

The larger flood control studies often analyze combinations of structural measures to produce the desired improvements. Plans are formulated with interrelated measures of various sizes and protection levels to maximize net benefits to Maricopa

Table 4-3
Average Annual Benefits for Channel Work

Plan of Channel	Bankful Capacity, cfs	Beginning Dam Frequency, %	Average Annual Damages	Average Annual Benefits
Natural	5,000	50 (2-yr)	2,000,000	0
50-ft bottom-width	10,000	6.67 (15-yr)	1,200,000	800,000
80-ft bottom-width	20,000	1.25 (80-yr)	500,000	1,500,000
120-ft bottom-width	30,000	0.5 (200-yr)	200,000	1,800,000

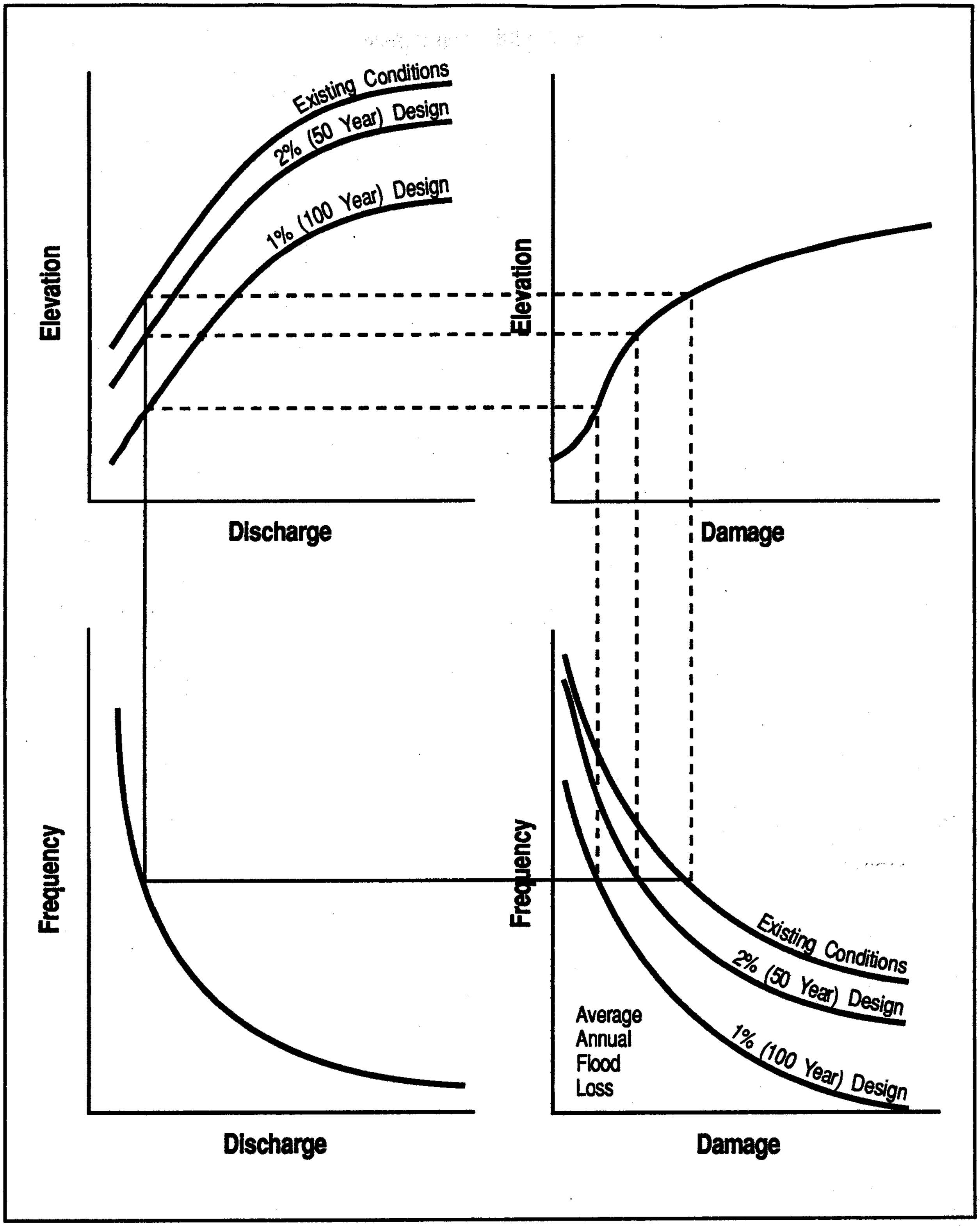

Figure 4-3
Economic and Hydrologic Effects of Channel Projects

County. For example, since land is scarce in urban areas and floodwalls or levees may be unappealing and difficult to locate, floodwalls, levees and channel improvements are often combined to yield higher levels of protection than would be available separately. In some cases, measures to modify the discharge-frequency, elevation-discharge response, and elevation-damage results are all included in one comprehensive plan. The effects of each of the plan's components must be determined individually and collectively during the economic analysis.

Benefits from a combination of measures are not additive, but must be analyzed to determine the combined effect.

4.1.6 Other Concerns

The interaction between the economic and hydrologic aspects of urban flood control planning is crucial to the development of workable plans that will function efficiently. These two study aspects should be matched for level of detail, timing of results, and data compatibility. Elevation-frequency curves should be developed for the existing natural and improved conditions, and at least the base year condition, and 25th and 50th project year conditions.

Many economic flood damage programs are now available which compute damages and benefits directly from hydrologic results, usually HEC-2 flood profiles. They allow accurate computation of flood damages without requiring adjustments to index points. This interaction is placing greater demands on the economist to understand hydrologic engineering and on the hydrologist to become familiar with benefit-cost analysis. Cross-training and developmental assignments can be used to promote this mutual knowledge.

There are some major concerns in analyzing the economic aspects of structural flood control measures. The most important is obtaining accurate, timely and compatible hydrology data. In many cases, the frequency with which flooding can be expected is much more critical to average annual damages and benefits than the dollar damage estimate for a particular flood elevation. With large basin and urban studies being performed almost totally with computer assistance, data which is compatible, both geographically and operationally, between economics and hydrology is a tremendous help. Having hydrology data that have been reviewed and approved before completing the economic analysis can save many weeks of revision and duplication. A good understanding of the effects of with- and without-project hydrology can allow a much better feel for total costs and benefits of a structural measure.

4.2 Inundation Reduction Benefits for Nonstructural Measures

Nonstructural measures generally have a negligible effect on any hydrologic or hydraulic relationships. Nonstructural measures primarily modify the elevation or elevation-damage relationship. The exceptions to this rule are the usually minor and localized effects of floodproofing by use of landfill and relocation of structures from the floodway. The consequences of each type of nonstructural measure on the elevation-damage relationship and the procedure for measuring the subsequent benefits are described below.

4.2.1 Flood Warning and Response

In cooperation with the National Weather Service and Civil Defense, the Flood Control District has devised a flood warning and response system for Maricopa County. The system is designed to improve the community's capability for accurate and timely forecasts of damaging floods by providing the communications network, information, and resources necessary for individuals to evacuate safely and for floodplain occupants to take effective damage reduction actions. The system incorporates six essential elements:

1) District personnel monitor the National Weather Service's radar system to detect weather patterns early, and also monitor rain and stream gauges to determine the magnitude and effect of storms.

2) Forecasts for the location, magnitude, and time of flood crests are calculated after entering the gauge information into flood forecast models.

3) Civil Defense issues flood warnings to floodplain occupants and flood fighting teams so they may take emergency actions.

4) Damage prevention actions are taken, including moving the contents of buildings, moving vehicles, shutting off and disconnecting equipment, rescheduling business operations, sealing entrances, and installing temporary barriers.

5) Evacuation occurs, as necessary. Evacuation is the process of facilitating orderly, safe movement of floodplain occupants from areas where there is the potential risk of physical harm.

6) Finally, there is the continual management of the warning and preparedness system to maintain the physical integrity of the monitoring and warning equipment, to insure the timeliness of the forecasting model, and to maintain the public awareness of the flood threat, warning messages and channels, and what actions to take in the event of an emergency.

The greatest potential lead time is limited, regardless of the forecasting equipment, by the size of basin, topography of the basin, the source of flooding, and the magnitude of flooding. Without the ability to forecast the amount and location of precipitation before it hits the ground, the forecast lead time is limited by the time of concentration, the amount of time between when precipitation hits the ground and when it reaches the area with the potential flood hazard. Figure 4-4 shows how inundation lead time will vary with the frequency of the flood event.

The benefits of a flood warning and preparedness system depend on the extent and quality of the investment made in all of the elements listed above. These benefits are measured by the incremental level of damages and cost prevented by a new system over and above what is already provided by the District's current network.

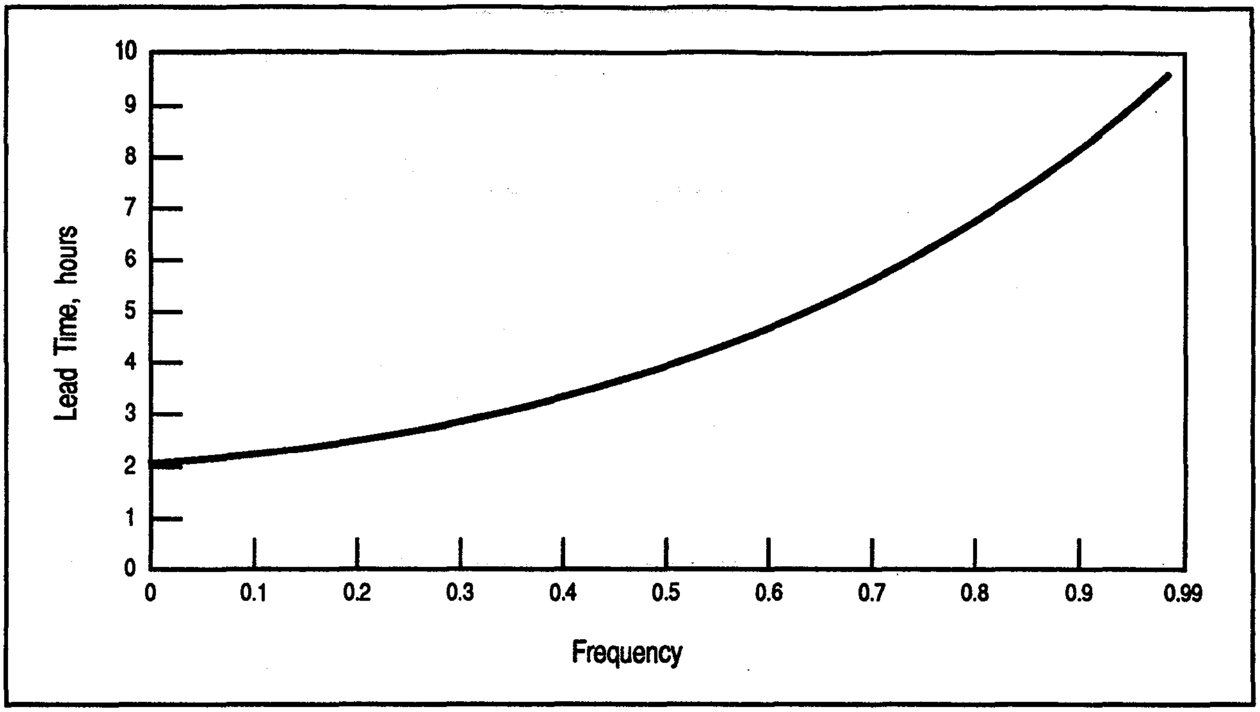

Figure 4-4
Frequency-Lead Time

The benefits of warning systems depend on:

» The accuracy and timeliness of the forecasts.

» Timeliness, informativeness, coverage, and credibility of the warning message.

» The reliability of the forecast system to consistently give accurate site-specific, and timely flood predictions.

» The degree and the effectiveness of the response by individuals, businesses, and local governments.

Since much of the benefit may not be realized without each part of the system operating, and there is a great deal of uncertainty involved in how well each of these components will operate, the benefits of warning are very difficult to evaluate. There is no specific degree of protection below which residual damages are curtailed. Instead, judgments must be made as to how well each of these systems will operate. Other significant problems are the lack of a track record in performing benefit/cost analysis and the even more significant lack of post-flood study to see how well flood warning and preparedness systems have performed.

Benefit calculations for warning and preparedness, when they have been made, generally are limited to physical inundation reduction benefits. This is primarily because of the lack of case studies that would help determine the effect of warning systems on non-physical costs, location, or intensification benefits.

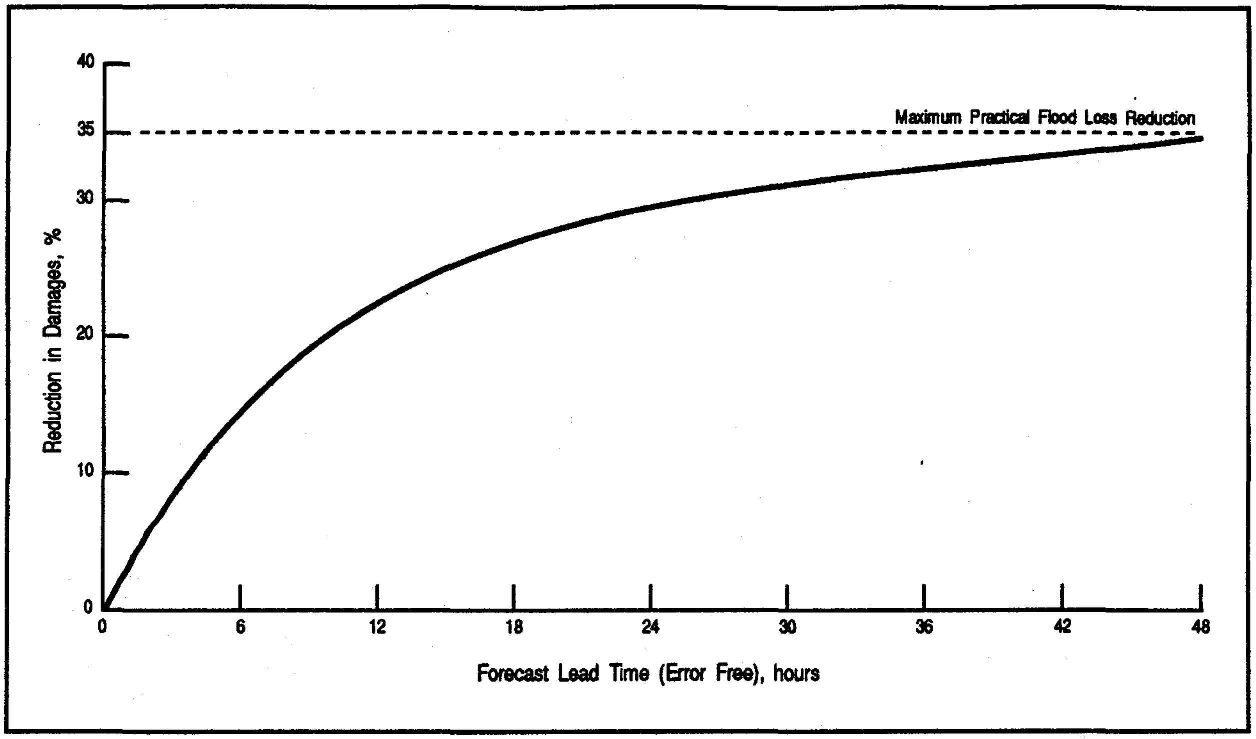

Figure 4-5
Flood Warning Response
Maximum Practical Flood Loss Reduction
(Adapted from Day, 1970)

A basic tool for evaluating benefits of warning and preparedness measures is the "leadtime/damages prevented" function. This function was developed by Harold Day, and has been used by researchers ever since to determine the amount of damage that can physically be prevented within a given amount of time (Day, 1970). The Day leadtime/damages prevented curve is illustrated in Figure 4-5. Day's curve assumed a 100 percent response, which presumes that all of the affected population will receive the message, know what to do and have the inclination and the capability to respond.

The Corps of Engineers' New York District presented a modification of the Day curve with more conservative assumptions on the extent of response in their 1985 feasibility report *Flood Emergency Preparedness System: Passaic River, New Jersey and New York, 1984* (U.S. Army Corps of Engineers, 1985). The degree and the effectiveness of the response were believed to depend on the means by which the message is received, with larger responses expected for a direct warning than a warning broadcast over the media.

The prevention of income losses was another benefit illustrated in *Industrial Flood Losses: Damage Estimation in the Leheigh Valley* (Kates, 1965). Robert Kates presented a business downtime function which showed that flood emergency costs, such as flood fighting, and police and fire custodial safety and traffic direction services, can be expected to increase as part of the costs of warning and preparedness. Efficiencies in delivering emergency service may occur with flood forecasting. The extent of these efficiencies have not been well documented.

Other non-physical costs, such as floodproofing, the administrative costs of flood insurance, temporary relocation, and land market value cannot be expected to change substantially with warning and preparedness.

In areas subject to high velocity floods with limited lead time, public safety considerations may override the need for economic justification.

4.2.2 Permanent (Dry) Floodproofing

Permanent or dry floodproofing includes actions taken in a dry, non-emergency period to reduce potential flood losses. Permanent floodproofing is generally identified with individual properties. Even measures normally thought of as structural, such as levees and floodwalls, are defined as floodproofing.

The measures described above under warning and preparedness are only activated in the case of imminent flooding. The floodproofing measures described here are permanent and usually require no action in the event of an emergency to make them operable. The measures have the obvious advantage of not being subject to a logistical constraint. Because of this advantage, floodplain activities can be assured of a more specific degree of protection and a consistent modification of the elevation-damage function than what is found with warning and preparedness measures.

The degree of protection is, however, site specific. Floodproofing also leaves a high level of residual risk to individuals, because access to and from the structure may be blocked by floodwater and this will present a danger to individuals trying to enter or leave. There is also the threat that floodproofing may fail, causing as much or more damage than would have occurred without the floodproofing.

Permanent floodproofing devices can fall into three distinct categories:

1) Raising, which includes landfill, piers, and high foundations.

2) Closures, which include non-porous construction material and permanent blockages.

3) Barriers, which includes floodwalls and levees.

All of these categories include measures that can be applied to retrofitting existing structures or to new construction. Raising merely involves an adjustment in the building elevation in computing residual flood damage. There is the danger of structural failure to buildings elevated by piers during high velocity events. Benefits for closures can only be considered up to a point where hydrostatic pressure might cause a problem. A particular building might only benefit from closures when flood levels are three feet or less above the first floor.

4.2.3 Permanent Relocation

Permanent relocation is the complete evacuation of existing activities to locations not susceptible to flood damage. Relocation may consist of:

» Physical movement of structures to new locations.

» Demolition of structures at flood-prone locations and construction of new buildings at different locations; or demolition of structures and provision of funds for purchase of new buildings.

In all three cases, the Surface Transportation and Uniform Relocation Assistance Act of 1981 (Public Law 100-17) requires that the agencies implementing the relocation provide funds for moving and resettlement to displaced residents.

Relocation has often been combined with other measures, particularly reservoirs and levees. Traditionally, relocation has served to facilitate other measures by clearing land for construction. Only in recent years has relocation been considered a damage reduction feature in its own right.

Permanent relocation consists of:

» Purchase of all buildings and associated land within designated reaches and flood zones.

» Relocation assistance in the form of direct grants to individuals for their resettlement costs.

» Regulation of new uses for flood-prone property.

Relocation projects, like other nonstructural measures, generally have a negligible effect on the elevation-discharge relationship. However, there can be a significant drop in elevation on small streams for high levels of discharge when structures are removed from the floodway and the flow is unrestricted.

In a 1985 review, the Corps of Engineers found permanent relocation has had limited use as the primary project component. It has been most successful when combined with other mitigation measures, and for areas with severe and repeated flood damage, within the 25-year floodplain (Moser, 1985).

Relocation is the only measure where the residual damages for the affected activity can be assumed to be zero for all levels of flooding.

Benefits from permanent relocation can be classified into five categories:

1) Value for the new use of the vacated land.

2) Reduction in damage to public property, such as roads and utilities.

3) Reduction in emergency costs.

4) Reduction in the administrative costs of disaster relief.

5) Reduction in the flood insurance subsidy.

The first category represents the location benefit. The other four categories represent benefits from the reduction in the publicly-borne costs of flooding.

There is no benefit taken for reduction in private flood damage because it is assumed that expected flood losses are, for the most part, reflected in lower property values. Because the reduced property values lower the costs of relocation, it would be double-counting to also consider the costs of the physical damages.

The location benefit is critical to the economic justification of a relocation project. It is unlikely that a relocation project can be justified if the evacuated property does not have considerable value in its new use. The location benefit is measured by the value of the floodplain in its new use. Unlike location benefits for structural projects, the value of the property in its old use is not subtracted because that value has already been considered in the purchase price of the relocated property.

The location benefits for agricultural or other income-producing activities can be determined by estimating the net income of the projected activity. An example of the net income approach to location benefits is given in the section on location benefit later in this chapter. Location benefits can also be determined by the hedonic price and contingent value approaches illustrated below.

The hedonic price procedure measures the internalized value of nonmarketable attributes. An example of this approach would be determining the value of open space land by comparing the market value of adjacent property to comparable property without the open space land nearby. The difficulty with this approach is finding "comparable" property with buildings and lots of similar size, condition, accessibility, character, and availability of community services.

The public damage reduction considered in the calculation of permanent relocation benefits includes reduction in damages to streets, sewers, water supply lines, lighting, electrical transmission lines, gas lines, and public vehicles. Care should be taken to consider any residual costs to transportation facilities and utilities that would remain to service areas outside the floodplain or any new activity that moves in as a result of the relocation.

Emergency flood costs, including the administrative costs of disaster relief, can be measured by the procedures described in Chapter 3. Permanent relocation would have the following implications to the emergency costs listed in Chapter 3: it can be assumed that flood forecasting costs could not be substantially reduced, because they are generally applied to a much larger area than would be affected by a relocation. Warning, temporary evacuation, flood fighting, reoccupation costs, and administrative costs of disaster relief could be virtually eliminated, depending on the new use of the evacuated floodplain. The magnitude of emergency costs should be estimated for various land uses and frequencies of flooding. The benefit will be the difference in expected costs with and without the relocation project.

Unlike structural projects, permanent relocation is concerned with the reduction in the flood insurance subsidy, rather than just the elimination of the administrative costs of flood insurance. This subsidy, like the emergency costs mentioned above, will cause distortions in the market value of land. The market value is distorted upward because the subsidies reduce the out-of-pocket costs to the landowners and renters.

The flood insurance subsidy is determined by deducting the average annual insurance premium from the average annual expected insured loss and the administrative costs of flood insurance. The insured loss assumes coverage of all physical costs including damage to the building structure, damage to contents, and cleanup of the structure and contents. It excludes damages to certain contents, such as paintings or antiques, damage to outside property, and requires a $500 deductible per loss for structure and contents. Table 4-4 is an example of the flood insurance subsidy benefit for a single residence.

An additional subsidy which can distort the value of floodplain property is the tax savings from casualty claims on Federal and state income tax forms for individual taxpayers. The magnitude of the casualty deduction is limited to uninsured and otherwise uncompensated losses. Only the portion of uncompensated loss that exceeds 10 percent of the taxpayer's adjusted gross income is deductible. Even insured properties will still have uninsured losses on deductibles and types of losses excluded from coverage.

Table 4-4
Flood Insurance Subsidy Calculation

Item	Amount ($)
House Value	$15,000
Contents Value	8,000
Agency Cost	
Average Annual Damages	1,450
Agent Fee (15% of the premium)	15
Other Administrative Costs	20
Total	$ 1,485
Policy Holder's Cost	
Annual Insurance Premium ($0.40/$100 of structure value and $0.50/$100 of contents)	100
Annual Uninsured Damage	150
Annual Expected Deductible	300
Total	$ 550
Average Annual Flood Insurance Subsidy	$ 935

4.3 Other Benefits

While inundation reduction benefits have constituted the great majority of economic justifications for flood projects, they do not measure the total economic gain for flood loss reduction. Location and intensification benefits represent increases in economic welfare because reduction in flood risk allows for higher economic use of the property. These benefit categories are described below. Also described are benefits for advanced bridge replacements that extend the life and improve conditions of stream and river crossings. Finally, this chapter describes negative benefits, which result from damages induced by flood control structures to neighboring properties.

4.3.1 Location Benefits

Location benefits occur when a reduction in the level of flood risk makes it profitable for new activities to locate in the floodplain. Location benefits are determined by the increase in net income or property values brought on by the new use.

4.3.1.1 Criteria for Location Benefits: There are four criteria that must be met before location benefits can occur. These include:

1) The land must become relatively flood-free. At a minimum, there must be less than a one percent chance of a flood occurring in any year.

2) The land must go to higher economic use than it would without the project.

3) The land must have a location advantage over alternative sites. Physical, aesthetic, infrastructural attributes of the floodplain sight must be significant enough to allow considerable location advantages over alternative flood-free locations. This location advantage must be significant enough to allow an increase in net profit over and above alternative sites and beyond any expected residual flood damage. This criterion can be put to a test, which is illustrated by the example given in Table 4-5.

Table 4-5
Test for Applicability of Location Benefits

Present Value at Year 0	Floodplain Site	Non-Floodplain Site
Economic rent*	$10,000	$6,000
Expected loss, w/o flood protection	$5,000	0
Expected loss, with protection	$ 1,000	0
Location decision without flood protection		
	($10,000 - $5,000) < $6,000 The activity will select the flood-free site.	
Location decision with flood protection		
	($10,000 - $1,000) > $6,000 The activity will select the floodplain site.	

*Economic rent is defined here as the net income of the activity occupying the land.

Since economic rent minus expected flood loss is less than the economic rent for the non-floodplain site without project, but greater with protection than the economic rent of the non-floodplain site, the project can be assumed to meet the location advantage criterion for location benefits.

4) Finally, there must be a sufficient demand within the affected area to support the development of the new activity. This can be determined by the economic base study and land use allocation process described in Chapter 3.

Location benefits build on the procedures described previously for the calculation of future conditions without-project. Before location benefits can be calculated, it is necessary to determine the spatial requirements for various land uses, based on demographic and economic projections. For many studies, it is assumed that land use requirements will be the same with and without the project. However, the distribution of activities may change, depending on the extent and location of flood protection. For example, portions of projected requirements for 1,000 additional acres of industrial land use can be allocated to newly protected floodplains, if that area has a location advantage over alternative flood-free sites.

The following three sections outline three primary measures for location benefits: net income differences, threshold levels, and changes in market values. These three methods do not necessarily lead to the same results. At least two of the procedures can be applied to help determine which procedure is the most appropriate. Justification should be made in each case as to why a particular method was selected.

4.3.1.2 Net Income Difference

The net income difference approach is the most direct procedure for measuring the location advantage of any site. It is the approach that most explicitly follows the prescribed definition of location benefits. It is crucial that advantages of the floodplain versus alternative sites be quantifiable. It is also necessary to be able to identify the change in net income for the displaced activity. Calculation of net income differences consists of the following six steps:

1) Calculate the net income of the new activity for the floodplain site and subtract the net income at the alternative location. The costs of land and residual flood damage are excluded in calculation of net income for the floodplain site at this point.

2) Calculate the net income for the displaced activity (where costs exclude economic rent and residual flood damage) and subtract the net income at the alternative site.

3) Subtract the loss in net income of the displaced activity (Step 2) from the net income of the new activity (Step 1).

4) Subtract the expected annual damages to the new activity without project from the increase in net income determined in Step 3.

5) The without-project damages to the displaced activity should be added to the total benefit.

6) Any external flood damage caused by the new activity should be deducted from any increase in net income (See induced flood damages, later in this chapter).

Table 4-6 is an example of the net income method.

4.3.1.3 Threshold Method

The threshold level is defined by the amount of flood protection that would be required for a change in activity to exist between the floodplain location and the alternative flood-free location. When the threshold level has been identified, the benefit can be determined by estimating what damage reduction there would be for the new activity over and above the threshold level. Any benefits from reduction in damages to the displaced activity must be subtracted if it has already been considered under inundation reduction benefits.

Assume that there are two industries that would find a location advantage to a floodplain site if expected flood damages were reduced below a threshold. Table 4-7 shows the firm's net income at the floodplain and alternative site, the expected flood damage without flood protection, and threshold level of protection necessary to induce a floodplain location. Figure 4-6 shows how Industry 1 is indifferent to the floodplain location at T_1 at the 2 percent or 50-year flood level, and likely to choose the floodplain location for anything above that level of protection. Industry 2 is indifferent at point T_2, the 20-year or 0.05 percent flood level.

The benefit under threshold level is equal to what the expected damage for the new activity would be if it was located in the floodplain without the project, minus the expected residual damages with the project. To avoid double counting, the expected annual damage for the displaced activity should not be counted as a benefit.

Table 4-6
Example: Net Income Method

Present Value of Average Annual Income	New Activity, $	Displaced Activity, $
Net Income Floodplain Site	550,000	400,000
Net Income at Alternative Site	390,000	370,000
Expected damages w/o project	150,000	40,000
Expected damages with project	10,000	7,000
Step One:	550,000 − 390,000 = $160,000	
Step Two:	400,000 − 370,000 = $ 30,000	
Step Three:	160,000 − 30,000 = $130,000	
Step Four:	130,000 − 10,000 = $120,000	
Step Five:	120,000 + 40,000 = $160,000	
Step Six:	No significant induced damages.	
Total Location Benefits	$160,000	

Table 4-7
Threshold for Location Decisions

	Industry 1		Industry 2	
	Floodplain Site	Flood-free Site	Floodplain Site	Flood-free Site
Net Income Minus Expected Flood Loss	$47,500	$50,000	$49,200	$50,000
Threshold Level for Residual Flood Loss	$2,500		$800	
Expected Annual Flood Loss Reduction	$6,000	0	$5,000	0
Threshold Level of Protection	0.02 or 50-year flood		0.002 or 500-year flood	
Expected Annual Location Benefits	$3,500		$4,200	

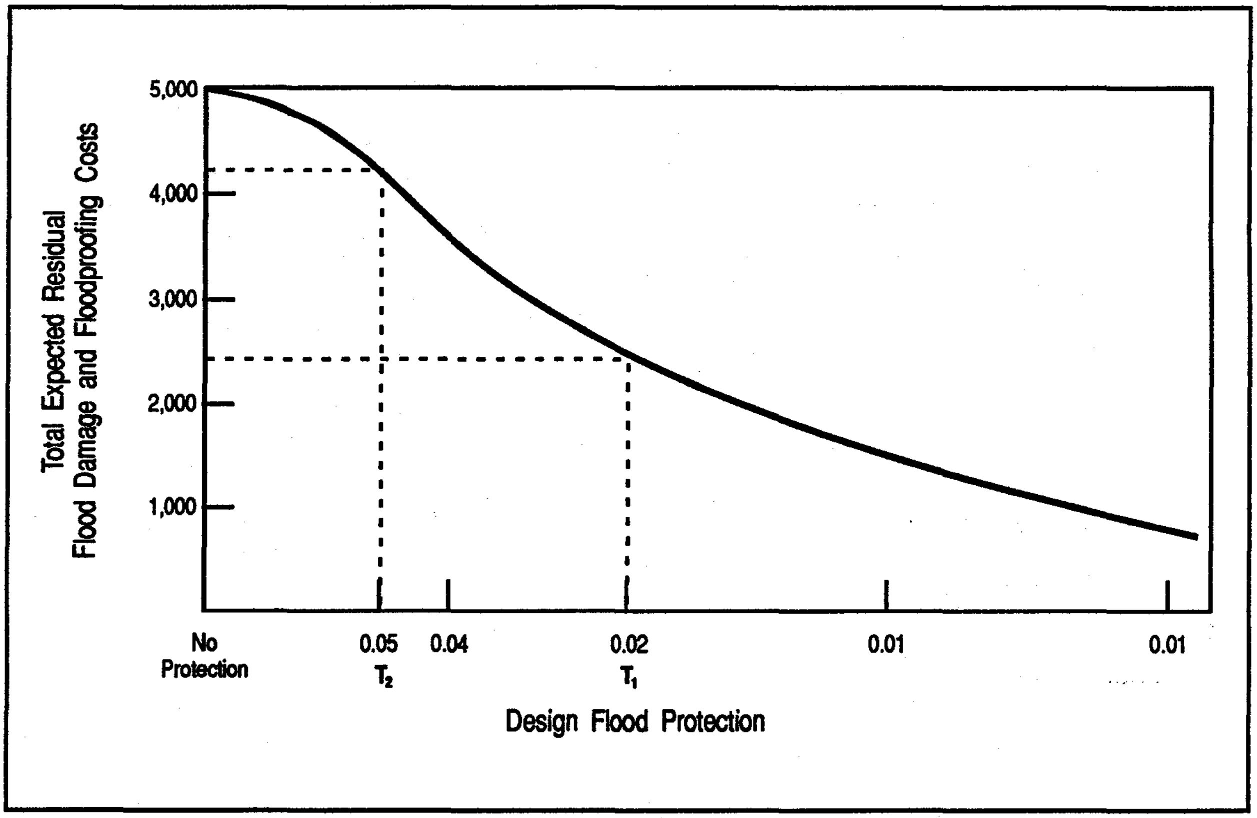

Figure 4-6
Threshold Method for Computing Location Benefits

4.3.1.4 Market Value of Land

The market value of land is the simplest of the three methods in theory and the most difficult to practice. The market value method assumes that the value of the property will increase by an amount equivalent to the increased net income. There are many factors that can influence changes in property value, including perceptions of the level of residual flood risk. The change in market value is difficult, at best, to project but it is also necessary to segregate the individual factors that contribute to changes in property values. It is therefore recommended that the market value approach be limited to a verification of the other techniques.

4.3.1.5 Limitation on Location Benefits

The limit on the amount of location benefits is the expected damages that the new activity would have for without-project conditions. This limitation is a corollary to the second criteria listed in Section 4.3.1.1—that the land must go to higher economic use than it would without the project. The rationale is that the flood protection will not account for a change in land use productivity beyond the reduction in expected flood losses.

4.3.2 Intensification Benefits

Intensification benefits are increases in net income where land use or type of economic activity does not change under with-project conditions.

These benefits have most often been applied to agricultural areas, realized through increased net income from crop production. This benefit category has had limited application to urban land uses.

Intensification benefits can be substantiated when there is evidence that business or agricultural operations have been considerably scaled back from what they would be with flood protection. They apply to business activities where there is an increase in net income due to a change in the method of operation. Intensification benefits will occur when a reduction in flood threat is significant enough to allow additional investment in labor or capital.

Intensification benefits can theoretically apply to residential property. However, increases in net income or market value over the cost of intensification would generally be small and difficult to verify. The benefit is equal to the increased net income from the intensification of the operation at the floodplain site, minus any increases in residual flood damages over what there would be if the intensification did not occur.

The same three methodologies used in evaluating location benefits—the net income, threshold, and market value approaches—are applicable to calculating intensification benefits. The specific procedures are somewhat simplified because there is no need to consider displaced activities.

The intensification benefit for each enterprise under the net income approach is given by the following formula:

$$B = (I - C_i) - (F_i - F_p)$$

where

B = the intensification benefit

I = the gross income of the intensified operation

C_i = the annualized cost of the intensification

F_i = the annual expected costs of flooding to the intensified operation,

F_p = the annual expected costs of flooding under pre-intensification conditions

Under the threshold method, it is necessary to know the extent of flood protection needed to induce the intensification. As with location benefits, the benefit is simply the average annual expected flood damage avoided to the intensified activity over and above the threshold level of damage reduction necessary to induce intensification.

Intensification benefits under the market value method would be the increase in market value for the intensified operation, minus the annualized cost of the intensification.

4.3.3 Advanced Bridge Replacement Benefits

If a railroad, highway, street, or pedestrian bridge is replaced as a result of a flood control project, a benefit can be claimed to at least partially offset the cost of the bridge replacement. Advanced bridge replacement benefits are taken for the period that the useful life of the bridge is extended by the project.

4.3.4 Affluence Benefits

Affluence benefits are an inundation reduction benefit based on an increase in residential content value that coincides with an increase in residential income. The basis for the affluence factor was described earlier in this procedure. Table 4.8 gives sample calculations for Affluence Benefits.

Table 4-8
Example Calculation of Affluence Benefits

Average Home in Floodplain	
Structure Value	$40,000
Contents Value	$20,000
Average Annual Benefits, Existing Conditions	
Structure	$500 per house
Contents	$200 per house
Number of homes protected by project	1,000
Per capita income growth rate	2 percent
Current year (existing conditions)	1980
Base year	1990
Interest	$8^1/8$ %
Project Life	100 years

Calculate benefits for protecting projected increase in content value:

Contents now are valued at 50 percent of structural value. They can increase to 75 percent, a 50 percent increase. Benefits can increase at the same rate: $200 to $300. The annual increase in benefits/house = 2 percent x $200 to $300. There is $100 increase at $4 per year = 25 years to reach the 75 percent limit. There is no discounting to the base year, which is 10 years off. Until then, there is a $4 per year increase, for a total of $40. The total benefit will be the $40 + the present value of the benefits realized after the base year. This is computed by multiplying the remaining $60 by a present worth factor of (0.61215), which = $37. The average benefit per house is $40 + $37 = $77, multiplied by 1,000 houses = $77,000.

4.3.5 Negative Benefits: Induced Flood Damages

Induced flood damages can occur as the result of a levee or floodwall constricting a river channel and causing an increase in river or stream elevations for various frequencies of flooding. Channel enlargement projects can also induce flood damages to downstream locales by raising flood levels and increasing flood velocity. It should be noted that only large levee, floodwall, and channel projects have any appreciable influence on surrounding locations. However, when hydraulic engineers are able to determine a significant increase in flood elevation, induced damages should be calculated and treated as negative benefits.

5

Discounting Procedures

The following text is incorporated from the Corps of Engineers' discounting procedures for economic analysis of flood control projects (*National Economic Development Procedures Manual—Urban Flood Damage,* COE, Chapter XI, 1988).

This chapter describes the procedure in a general way, giving users a sense of the concepts required for discounting, and gives specific instructions for performing each step. The interest and discount rates for economic evaluation may vary by project, by year, and by the other agencies that may be involved in the project. The rate established for use on District projects is 3 percent. The Project Manager may not change the rate to be used without input from the economist nor without the approval of the Chief Engineer and General Manager.

5.1 Introduction

Corps of Engineer water resource development projects typically involve many alternatives; require several years to plan and install; and provide benefits and incur operation, maintenance and replacement (OM&R) and sometimes deferred installation costs for many years after implementation. They typically incur the greater proportion of their costs early, during the construction (or installation) phase. Benefits then accrue over an extended project life, often increasing over time.

Recognizing that a dollar in hand is not worth the same as a dollar 1, 10, or 25 years hence, the problem confronting the water resource development analyst is to convert unevenly distributed cost and benefit streams to comparable measures. The concept of "equivalence," that is, that payments that differ in total magnitude but that are made at different dates may be equivalent to one another, enables such comparisons to be made. (Throughout the following discussion, the word payment is used in a generic sense and could be replaced by either "benefit" or "cost." Discounting and compound interest procedures provide the analyst with the tools needed to make these comparisons. The purpose of this chapter is to describe and illustrate, with examples, some of the important concepts and procedures needed to compare costs and benefits over time.

A typical "evaluation setting" for a Corps water resources development project is depicted in Figure 5-1. Some of the important principles and terms associated with this setting are described below.

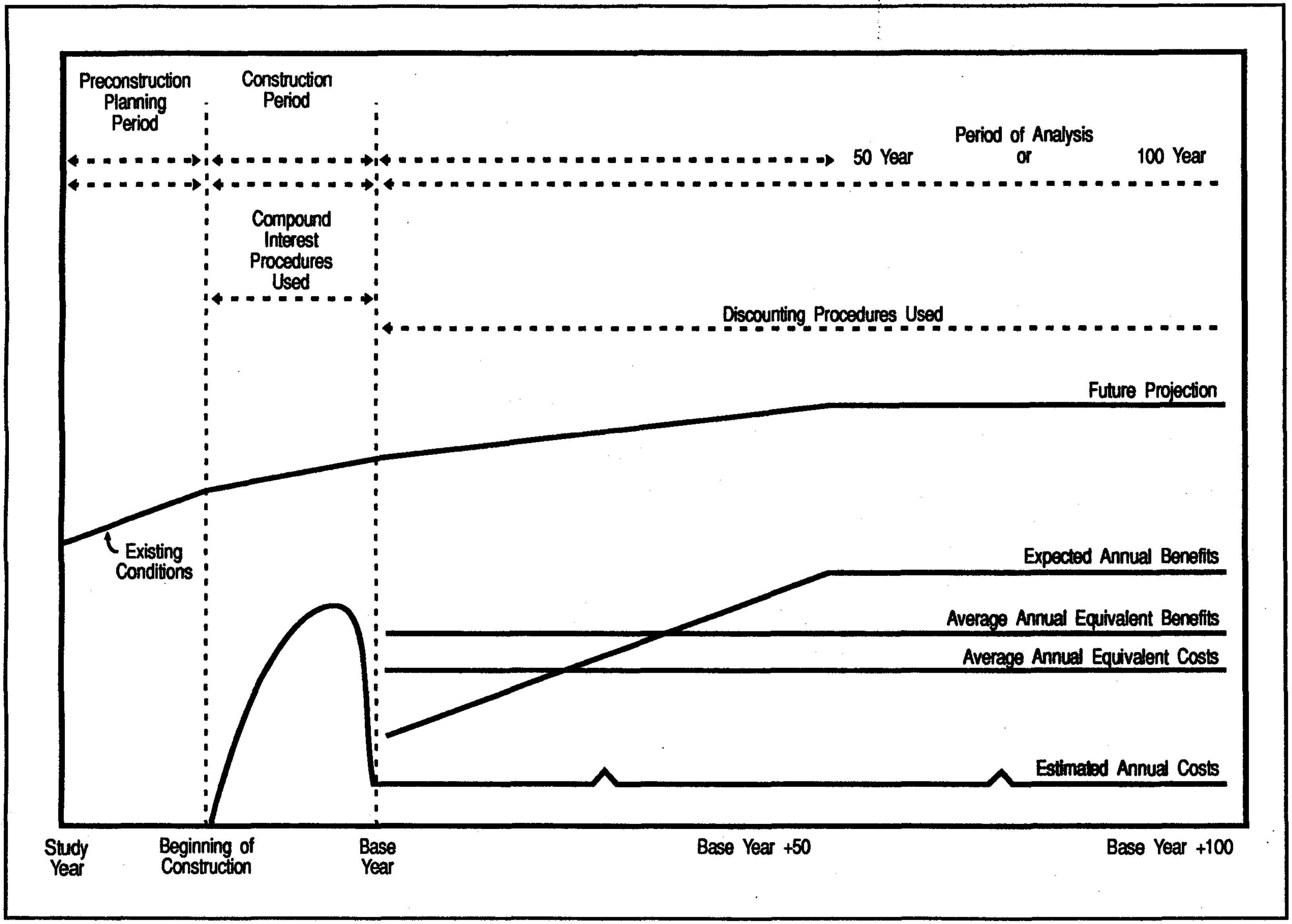

Figure 5-1
Evaluation Setting

The *study year* is the year the current study (evaluation) will be completed. As a study proceeds through the planning process, the study year will move to the right on the time line depicted in Figure 5-1. *Existing conditions* are the measures of economic factors and water and related land resources, existing at the time of the study (normally referenced to the end of the study year). These conditions serve as the bases for *future projections* under both with- and without-project conditions. Since benefits and costs must be expressed in constant dollars, the conditions at the time of the study also determine the *price level* to be used in the analysis.

The *beginning of construction* is the year in which construction begins, while the *base year* is the first year in which the project is expected to become operational. For the purposes of this discussion, the *period of analysis* is defined as the time horizon, beginning with the base year, for which project benefits and deferred installation and OM&R costs are considered. For most Corps' studies, the period of analysis is either 50 or 100 years. When comparing alternatives, the same base year and period of analysis should be used for all plans being evaluated.

The *expected annual benefits and costs*, often referred to as *benefit and cost streams* in a benefit-cost analysis, are the estimates of the annual benefits and costs that are expected to occur during the construction period and project life. Generally, benefits are only anticipated after plan implementation, but for some projects benefits can also occur during the construction period. The analytical problem is to convert the varying benefit and cost streams to their equivalent and comparable average annual measures over a common time period, that is the period of analysis.

An intermediate step is required to convert the benefit and cost streams to equivalent average annual measures; the present worth of the streams must first be determined. The *present worth* for each stream is the single value, in the base year, that is equivalent to the many payments that would accrue from that stream. *Discounting* is the procedure used to reduce future values, those occurring during the project life, to their present worth in the base year. *Compound interest procedures* are used to determine the present worth of benefits accrued and interest on construction incurred during the construction period, prior to the base year.* As will be illustrated in the examples that follow, the present worth value of the entire benefit or cost stream is dependent on the magnitude, number, and timing of individual payments as well as the appropriate discount and interest rate used in the analysis.

The *average annual equivalent benefit*, generally termed the *average annual benefit*, is then defined as the *amortized value* over the period of analysis of the present worth (in the base year) of the benefit stream. The average annual or amortized value, therefore, is a constant amount of benefit, occurring each year during the period of analysis. This constant stream of benefits is *equivalent* to the present worth in the base year of the entire benefit stream. Obviously, the constant stream of average annual values is also *equivalent* to the benefit stream itself. *Average annual equivalent costs* are similarly defined.

* In some texts, present worth refers only to discounted future payments, while present value refers to the equivalent value—in the base year—of payments received prior to the base year. For the purposes of this manual, present worth and present value will be used interchangeably.

5.2 Interest and Discount Rates

As noted above, the interest and discount rate used is important for determining the magnitude of the present worth and average annual value of a particular benefit or cost stream. In business, *interest* is usually defined as the charge for the use of money. In more general terms, it is considered the return obtainable from the investment of capital. The *interest rate* is the ratio of gain received to amount invested, or the amount paid to amount borrowed. Somewhat similarly, the *discount rate* is the ratio between the value of a future payment and its present worth at some specified time (the base year in water resource development studies). Since interest and discount rates are critical to the analysis, a decision must be made as to the appropriate rates to be used.

Starting in 1969, the discount rate for water resource development studies has been based on the average yield, during the preceding fiscal year, of marketable United States securities, which, at the time of computation, have 15 years or more to maturity. A policy decision was made by the Water Resources Council (WRC) that the discount rate for Fiscal Year (FY) 1969 would be 4 ⅝ percent, and that the rate should neither be raised nor lowered more than ¼ of 1 percent in any year. This WRC rule was enacted into law in 1974. The Federal discount rate to be used in Corps' studies is distributed annually by the Office, Chief of Engineers in the *Fiscal Year Reference Handbook*. In FY 1987, the discount rate was 8⅞ percent. The Federal discount rate is also to be used for calculating interest during the construction period.

5.3 Interest Rate Formulas

Some examples will be presented later to illustrate the discounting concepts described above. The basic interest rate formulas most frequently used in benefit-cost analysis are first presented. The derivation of these formulas is described in most engineering economy and business finance textbooks, such as *Principles of Engineering Economy* (Grant, Ireson, and Leavenworth, 1982).

5.3.1 Symbols

The symbols used in these formulas are:

i = interest or discount rate for a given interest period, usually a year.

n = number of interest periods.

P = present worth of a sum of money.

F = a sum of money at the end of n periods from the present-worth date that is equivalent to P with interest i.

A = the end-of-period payment or receipt in a uniform series continuing for the coming n periods, the entire series equivalent to P at interest rate i.

5.3.2 Formulas

The compound interest formulas most commonly used in benefit-cost analysis are:

Given P, to find F: $$F = P\,(1+i)^n \tag{1}$$

Given F, to find P: $$P = F\,\frac{1}{(1+i)^n} \tag{2}$$

Given P, to find A: $$A = P\,\frac{i(1+i)^n}{(1+i)^n - 1} \tag{3}$$

Given A, to find P: $$P = A\,\frac{(1+i)^n - 1}{i(1+i)^n} \tag{4}$$

The interest portions of the above formulas, e.g., $(1 + i)^n$ in Equation 1, are often called interest factors. Values for these factors for various interest rates and time periods are provided in Interest Factor Tables in most engineering economy and business finance textbooks. In addition, the Corps annually computes and publishes the values for these factors, based on the current Federal discount rate, in its *Fiscal Year Reference Handbook.* With the advent of micro-computers, and especially the accompanying spreadsheet software, these formulas can also be readily incorporated into analytical packages, minimizing the re-analysis effort required when interest rates change. In fact, most of the larger, computerized flood damage programs used on mainframe computers have had these formulas incorporated into their analytical package for some time. Following is a brief description of the formulas and associated factors. Subsequent examples will illustrate their application in benefit-cost analysis.

5.3.2.1 Single Payment, Compound Amount Factor (Equation 1): This is the amount that will accumulate when $1.00 is invested at compound interest for a given period of time and the interest is not withdrawn. The single payment, compound amount, interest factor at 8 percent is $(1 + 0.08)^1$, or 1.08, for one year; $(1 + 0.08)^2$, or 1.17, for two years; and so forth. Similarly, the compound amount of $1 in one year at 8 percent interest is $1.08, in two years $1.17, and so forth.

5.3.2.2 Single Payment, Present Worth Factor (Equation 2): This is the amount that must be invested at the beginning of the period of analysis to have a value of 1 in a given length of time and at a given interest rate. For example, the interest on $92,593 at 8 percent for one year is $7,407, and the interest and principal one year hence is $100,000. The present value of $100,000 received 1 year hence at 8 percent is, therefore, $92,593 and the single payment present worth factor is 0.92593.

5.3.2.3 Capital Recovery Factor (Equation 3): The pay back of a financial obligation (both principal and interest) in equal installments is called amortization. The amortization factor is also referred to as the partial payment, the annualizing, and, most frequently, the capital recovery factor. It is the amount of the installment required to retire a debt of $1 in a given length of time. The product of the capital recovery factor and the present worth of a benefit (or cost) stream is the average annual (equivalent) value of that stream.

5.3.2.4 Present Worth of Annuity (Equation 4): The present value of an annuity factor is the reciprocal of the capital recovery factor. It is a measure of the present worth of annual payments of $1 over a specified period of time. Since the present worth of the annuity is the reciprocal of the capital recovery factor, their product must always equal one.

5.3.3 End-of-Accounting Interval Convention

Before presenting specific examples, one additional concept needs to be discussed. The end-of-accounting interval convention is typically used in discounting studies. That is, all payments that occur throughout an accounting interval (most typically a year, but other intervals such as months or quarters can also be used) are treated as if they occur at the end of that accounting interval. This convention greatly simplifies the application of discounting conversions and, usually, does not introduce significant error.

5.4 Examples

5.4.1 Single Values

The simplest of cases is where there is a single payment for which the average annual value is to be determined. Remember, for Corps benefit-cost studies, the objective is to compute the average annual value, over the period of analysis, for all payments. To do this, it is necessary to first convert all prior (during the construction period) and future (during the project life) payments to their present worth values at the beginning of the base year, and then convert the sum of present worth values to average annual values.

If, in the single value example, the payment occurred at the end of the year immediately preceding the base year, the value of the payment would be the same as its present worth. [The base year, the first year following implementation of a plan, is year one in the period of analysis. With the end-of-year convention, payments occurring during the base year would have to be discounted one year to determine their present worth value. Payments at the end of the year immediately preceding the base year are present worth values.] It would then only be necessary to convert the present worth, P, to an average annual value, A, for a specified interest rate, i, and number of years (period of analysis), n. Equation 3, above, is used for this conversion. The compound interest factor that results from solving the interest

Example 1		
Amount of payment at base year (present worth)	=	$1,000
Interest rate	=	8 percent
Number of years in period of analysis	=	50
Compound interest formula used (equation #)	=	3
Average annual value = 1,000 x 0.08174*	=	$82

*The value 0.08174 is derived either by solving the appropriate portion of Equation 3 with the applicable interest rate and time period (8 percent and 50 years in this example) or by referring to Compound Interest Factor tables as noted above.

portion of this equation for a particular interest rate and time period is commonly referred to as the capital recovery factor. It indicates the amount of annual return required (for the particular interest rate and time period) to "recover" the value of the investment made. See Example 1.

Next, consider the situation where the single payment occurs prior to the base year, (i.e., during the construction period). The present worth of this payment first needs to be computed, before the capital recovery factor can be used to determine the average annual value. Equation 1 can be used for this conversion, although a slight change in the terminology is required. In this situation, the future value (F) being solved for is actually the present worth value, since the timing of the payment occurs before the base year. Likewise, the value of the payment is used as the value of *P* when solving the equation. This situation is illustrated in Example 2.

Example 2			
Amount of payment		=	$1,000
Interest rate		=	8 percent
Number of years between prior payment and base year		=	3
Compound interest formula		=	1
Present worth	= 1,000 x 1.2597	=	$1,260
Number of years in period of analysis		=	50
Compound interest formula		=	3
Average annual value	= 1,260 x 0.08174	=	$103

Example 3			
Amount of payment		=	$1,000
Interest rate		=	8 percent
Number of years between base year and payment		=	25
Compound interest formula		=	2
Present worth value	= 1,000 x 0.1460	=	$146
Number of years in period of analysis		=	50
Compound interest formula		=	3
Average annual value	= 146 x 0.08174	=	$12

In the final single value case, consider the situation where the single payment occurs after the base year, during the period of analysis. The first step is to discount *F* to *P* in the base year. Equation 2 is used for this first step, and then, once again, Equation 3 is used to derive the average annual value from the present worth (Example 3).

5.4.2 Effect of Timing of Payment and Interest Rate Used

The above three examples not only illustrate the basic discounting principles under the simplest of scenarios, but also the effect of one of the important variables, that is the timing of the payment. In all three examples the number (1) and amount ($1,000) of the payment are the same, as well as the interest rate (8 percent) and length of the period of analysis (50 years). The only variable changed is the timing of the payment relative to the base year, yet the results are three substantially different average annual values. Thus, in the scenario presented above, the average annual *equivalent* value of a $1,000 payment three years prior to, at the beginning of, and 25 years after the base year is $103, $82, and $12, respectively.

Similarly, the effect of the discount rate used can also significantly affect the results. For example, the following tabulation shows the results of the first three examples when using discount rates of 4, 8, and 12 percent, and a 50 year period of analysis. That is, the present worth and average annual values for a single $1,000 payment received 3 years prior to, at the beginning, and 25 years after the base year are shown for each of the three discount rates. As can be seen from this tabulation, the higher the discount rate, the lower the discounted value (present worth) of *future* payments.

	Present Worth Value, $			Average Annual Value, $		
Timing of Payment	4%	8%	12%	4%	8%	12%
3 years before base	1,125	1,260	1,405	52	103	169
Base year	1,000	1,000	1,000	47	82	120
25 years after base	375	146	59	17	12	7

5.4.3 Straight Line Growth

Before addressing straight line growth, it is important to first discuss constant, annual, and future values. (It is also important to remember that, in Corps of Engineers economic analysis, benefit-cost ratios are determined form average annual rather than present worth, values.) It is widely understood that if there is a constant stream of annual value of, say, $20,000 for 50 years, the average annual value is $20,000. There is nothing magical about this, since this result is consistent with discounting and analyzing procedures, as demonstrated in Example 4.

Example 4		
Uniform annual value	=	$20,000
Interest rate	=	8 percent
Period of analysis	=	50 years
Compound interest formula	=	4
Present worth = 20,000 x 12.233	=	$244,700
Compound interest formula	=	3
Average annual value = 244,700 x 0.08174	=	$20,000

Thus, the average annual value of a uniform stream of values of $20,000, is $20,000. Although somewhat obvious, the above finding also illustrates an important consideration in discounting. That is, when the discount rate is the same as the interest rate, (as for Federal water project analysis), the present worth (or discount) factor for a series of uniform payments is the reciprocal of the capital recovery (or analyzing or amortization) factor. Regardless of the interest rate, the product of these factors is, therefore, one, and the uniform and average annual values are the same. With this in mind, discounting of a future stream, including a straight-line growth segment, will now be examined.

The payment stream outlined in Example 5 is also depicted in Figure 5-2. A payment of $20,000 occurs in the base year (year 1). Payments increase by $2,000 per year through the 25th year, when the annual payment equals $68,000. Payments then remain constant at $68,000 per year for the remaining 25 years of the period of analysis. This linear growth period conforms to a gradient series, typically used in engineering economy

Example 5		
Period of analysis	=	50 years
Growth period	=	25 years
Discount rate	=	8 percent
Base year payment	=	$20,000
Incremental increase in payments per year	=	$2,000

studies (Grant, et al, 1982). That is, the series changes at the end of each accounting interval by successively increasing multiples of a fixed sum. The gradient series does not begin until the end of the second accounting interval. If the gradient is g, the *amount of yearly increase* is then: zero for the first year, g for the second, 2g for the third, and (n-1)g for the nth.

One way to estimate the average annual value of this stream is to repeat the process described for a single payment in Example 3 for all 50 payments. That is, the present worth of each payment would first be determined by multiplying the payment by the appropriate single payment present worth factor derived from Equation 2. The sum of the present worth values for all 50 payments, multiplied by the capital recovery factor derived from Equation 3, would then yield the average annual value. This procedure can be readily accommodated by most microcomputer spreadsheet programs and is incorporated into most computerized flood damage programs with a discounting capability. It is, however, quite tedious and time-consuming when automated programs are not available. Several short-cut methods are available, one of which relies on the gradient series present worth factor, given g to find P (Equation 5).

$$P = g\left[\frac{1}{i} - \frac{n}{i}\left(\frac{i}{(1+i)^n - 1}\right)\right] \left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \qquad (5)$$

When using the gradient series factor, the payment stream depicted in Figure 5-2 is analyzed in two segments. Segment I represents the constant portion of the payment

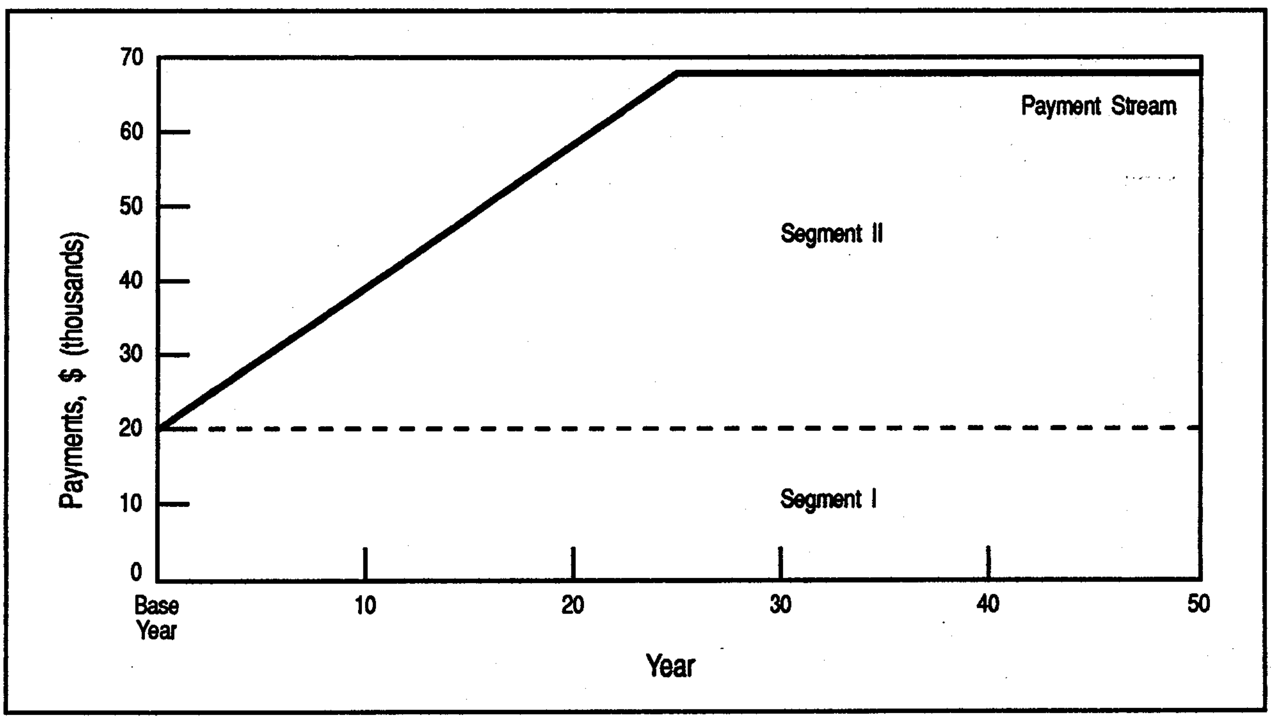

Figure 5-2
Straight Line Payment Stream

stream. As illustrated in Example 4 above, the average annual value of a constant payment stream is the annual amount of that stream, or $20,000 in this example.

The second segment contains two parts: a gradient series increase (Segment IIA), and a constant payment stream (Segment IIB). To find the present worth (in the base year) of Segment IIA, the gradient amount ($2,000), is multiplied by the present worth of a gradient series factor for 25 years at 8 percent (87.50 derived form Equation 5), or $2,000 x 87.50 = $175,600. It requires two steps to determine the present worth (in the base year) of Segment IIB. The amount of the payment stream ($68,000 – $20,000, or $48,000) is first multiplied by the present worth factor of an annuity for 25 years at 8 percent (10.675 from Equation 4). This yields the present worth of the payment stream ($512,400 in this example) at the beginning of year 26 (or the end of year 25). This value is then multiplied by the single payment present worth factor for 25 years, (0.1460 from Equation 2), to determine the present worth value in the base year ($74,810). The sum of the present worth values of Segment IIA and Segment IIB ($175,600 + $74,810), is then multiplied by the capital recovery factor (0.08174 from Equation 3), to determine the average annual value—or $20,470 (rounded) for the 50-year period of analysis.

The sum of the average annual values from Segments I ($20,000) and IIA & B ($20,470) is the average annual value for the entire payment stream, or $40,470.

5.4.4 Straight Line Growth with Multiple Rates

In the above example, there was only one growth rate throughout the entire growth period, that is the constant annual increase of $2,000 over the first 25 years. More often than not, in an actual planning study, the rate of growth may change, often between decades, during the growth period. The above procedure can still be used; however, some additional analysis is necessary. For example, consider the situation depicted in Figure 5-3 and described in Example 6.

Example 6		
Period of analysis	=	50 years
Discount rate	=	8 percent
Incremental increases in payments per year		
Years 2 - 10	=	$2,000
Years 11 - 25	=	$1,000

Using the gradient series approach, the average annual value for each of the three segments of the payment stream depicted in Figure 5-3 are computed and then summed, to estimate the average annual value for the entire stream. The computational process is as follows.

5.4.4.1 Segment I: The derivation of the average annual value for Segment I is identical to that used in Example 5. That is, the average annual value of a constant payment stream of $20,000 per year throughout the period of analysis is $20,000.

5.4.4.2 Segment IIA & B: The present worth (in the base year) for Segment IIA is $51,960, determined by multiplying the gradient ($2,000) by the present worth gradient series factor for 8 percent and 10 years (25.98 from Equation 5). Segment IIB represents a constant payment stream of 40 years (years 11 through 50). Remembering the end-of-accounting interval convention, the amount of this payment

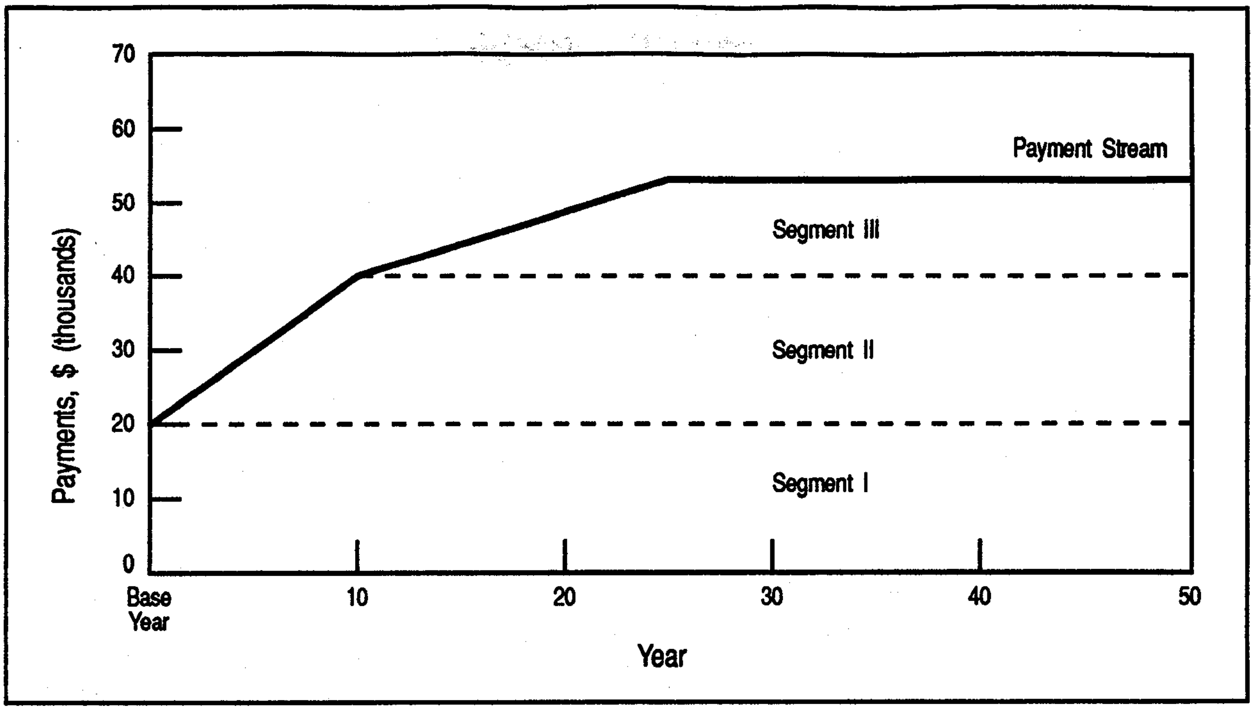

Figure 5-3
Straight Line Payment Stream with Multiple Growth Periods

stream is $19,000; that is, the end-of-year 11 payment less the constant payment of Segment I ($39,000 – $20,000). The present worth (in the base year) of Segment IIB is then the constant payment, multiplied by the present worth of an annuity for 40 years from Equation 4, multiplied by the single payment present worth factor for 10 years from Equation 2, or $19,000 x 11.925 x 0.4632 = $104,950. The sum of present values of Segment IIA ($51,960) and Segment IIB ($104,950) or $156,910, multiplied by the capital recovery factor (0.08174 from Equation 3) yields the average annual value of $12,826 for the combined Segment IIA & B.

5.4.4.3 Segment IIIA & B: The average annual value for Segment IIIA & B is determined somewhat as for Segment II A & B. The present worth (in the base year) of Segment IIIA is the amount of the gradient (now $1,000), multiplied by the present worth of a gradient series factor for 15 years from Equation 5, multiplied by the single payment present worth factor for 10 years from Equation 2, or $1,000 x 47.89 x 0.4632 = $22,183. The amount of the constant payment of Segment IIIB is $14,000, that is, the maximum annual payment ($53,000) less the sum of the constant payments from Segment I ($20,000) and Segment IIB ($19,000). The present worth (again, in the base year) of Segment IIIB is then the constant payment, multiplied by the present worth of an annuity for 25 year (from Equation 4), multiplied by the single present worth factor for 25 years (from Equation 2), or $14,000 x 10.675 x 0.1460 = $21,820.

The sum of the present values of Segment IIIA and Segment IIIB ($22,183 + $21,820 = $44,003), multiplied by the capital recovery factor for 50 years (0.08174 from

Equation 3) yields the average annual value of $3,597 for the combined Segment IIIA & B.

The average annual value for the entire payment stream is then the sum of the average annual values from Segments I, IIA & B, and IIIA & B, or, approximately, $20,000 + $12,826 + 3,597 = $36,400.

5.4.5 Exponential Growth Rates

For many projects, future benefit and cost streams are projected to grow at exponential, rather than linear growth rates. As with linear growth projections, one method for determining the average annual value of a payment stream with an exponential growth component is to determine the present worth of each annual payment, sum the present worth of all payments, and amortize the total. An alternative procedure is available when the growth rate and period of growth are known. Consider the payment stream depicted in Figure 5-4 and summarized in Example 7.

Example 7		
Period of analysis	=	50 years
Discount rate	=	8 percent
Initial (base year) payment	=	$20,000
Growth rate per year	=	2 percent
Number of years in growth period	=	25

The total payment stream is divided into segments for estimating the average annual value, somewhat similar to the linear growth examples described above. A cumulative present worth (CPW) factor is used for estimating the average annual value for the growth period (Segment I), while the basic compound interest for-

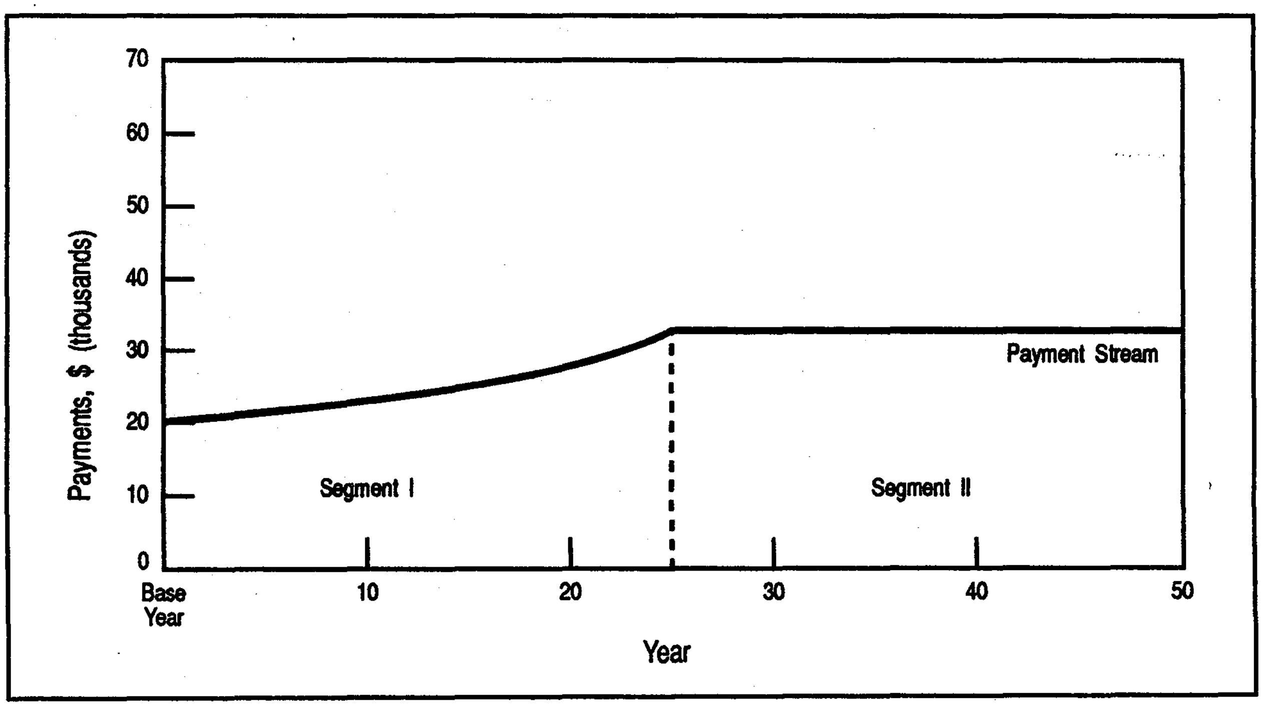

Figure 5-4
Exponential Payment Stream

mulas, described at the beginning of this chapter, are used for the period where the payment is constant (Segment II).

5.4.5.1 Segment I: The cumulative present worth factor is:

$$CPW = \frac{\left((1-(1+k)^{-(n-1)})/k\right)+1}{1+i} \qquad (6)$$

where:

CPW	=	cumulative present worth, or the summation of all future discounted values in the growth period
k	=	((1 + i) / (1 + j)) – 1
i	=	discount rate (8 percent in this example)
j	=	growth rate (2 percent in this example)
n	=	number of years in the growth period (25 in this example) **Note:** The gradient series concept is used again. The year 1 payment is $20,000. Payments then increase by 2 percent a year, beginning with the year 2 payment. The payment in year 25 is $\$20,000 \times (1.02)^{24}$.

Solving Equation 6 for the example conditions yields a CPW factor of 12.6741. Multiplying this factor by the initial payment in the growth period yields the total cumulative present worth (at the beginning of the period) of all payments for that period. In this example, 12.6741 x $20,000, or $253,482 is the cumulative present worth in the base year of all payments for the years 1 through 25. The capital recovery factor, Equation 3, is then used to convert the cumulative present worth in the base year to an average annual value for the period of analysis: $253,482 x 0.08174 = $20,720.

5.4.5.2 Segment II: Segment II represents a constant annual payment over the remainder of the period of analysis, i.e., period of analysis less length of growth period(s). In this analysis, the constant payment is $32,200 and the remainder of the period of analysis is 25 years. The average annual value for this segment is computed similarly to Segment III in Example 6, except that the first step is not required. Multiplying the constant payment ($32,200) by the present worth of an annuity factor for 25 years (10.676 from Equation 4) yields the present worth of the segment at the end of year 25 ($343,767). Multiplying this value by the single payment present worth factor for 25 years (0.1460 from Equation 2), yields the present worth in the base year ($50,190). Finally, multiplying the present worth value by the capital recovery factor for 50 years (0.08174 from Equation 3) yields the average annual value ($4,102) for the period of analysis.

The sum of the average annual values from Segments I and II ($20,720 + $4,102) then yields the average annual value for the entire payment stream, (approximately $24,800 for this example).

Note: For this, as well as previous examples, it is not necessary to separately annualize the present value for each segment. The same result is obtained if the separate present values for each segment are first summed, and then the sum multiplied by the capital recovery factor.

5.4.6 Negative Growth

The three previous examples were all based on increasing future trends. There can, of course, be declining trends. This topic will be addressed in less detail, however, since these cases are the exception, and since much of the previous discussion on growth curves still applies.

5.4.6.1 Negative Straight Line Growth: Example 8 is, basically the reverse of the situation depicted in Example 5. That is, an initial payment of $68,000 is received in the base year. Payments then decline by $2,000 per year until year 25 when they equal $20,000, and remain constant for the remainder of the period of analysis. This payment stream is depicted in Figure 5-5 and Example 8.

Example 8		
Period of analysis	=	50 years
Growth period	=	25 years
Discount rate	=	8 percent
Base year payment	=	$20,000
Incremental decrease in payments per year	=	$2,000

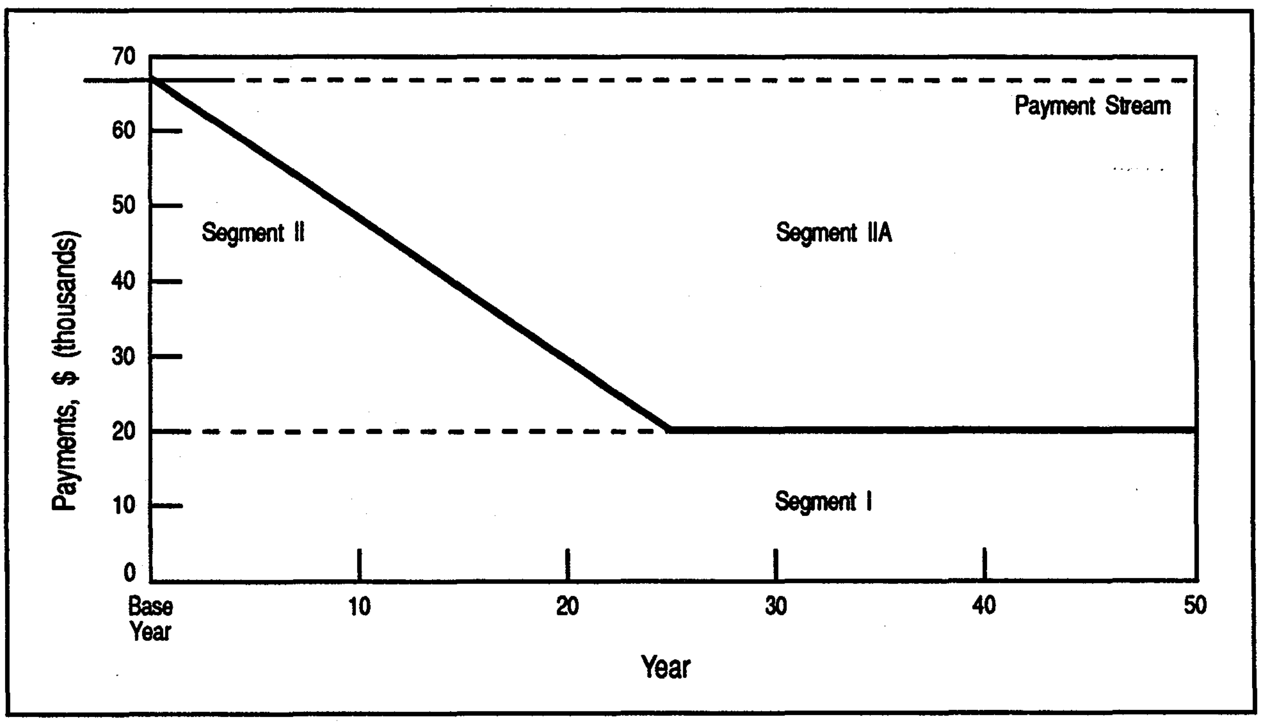

Figure 5-5
Straight Line Negative Growth Payment Stream

To compute the average annual value for the entire stream, estimates of the two segments, I and II, are needed. As in Example 5, the estimate of Segment I is straightforward, the average annual value of a constant stream of payments of $20,000 is $20,000.

The approach to Segment II is less obvious, however, since this represents a declining, rather than an increasing, payment stream. It can be seen, however, that the sum of Segments II and III equal a constant payment stream ($68,000 – $20,000 = $48,000, in this example) throughout the period of analysis. In addition, Segment III can be treated as an increasing growth segment, increasing by $2,000 per year, from a payment of $0 in year 1 to $48,000 in year 25, and then remaining constant for the remainder of the period of analysis. Although graphically Segment III is an upside down version of Segment IIA & B in Figure 5-2 (Example 4), its average annual value is calculated exactly the same, and is also equal to $20,470. The average annual value of Segment II in Example 8 is then $48,000 – $20,470 = $27,530, and the total value of the payment stream is $47,530 ($20,000 from Segment I plus $27,530 from Segment II).

5.4.6.2 Negative Exponential Growth: To properly discount a trend that declines exponentially, it is first necessary to have an understanding of the derivation of a negative growth rate. The equation used for this computation is:

$$(1-j)^{n-1} = T/B \tag{7}$$

where

T	=	terminal value of nth year value
B	=	base (year 1) value
j	=	growth rate
n	=	growth period in years (**Note:** Again the gradient series concept is used; i.e., if there are n years in the growth period, (n – 1) increments of growth will occur.)

With a growth period of 10 years and base and terminal values of 3,000 and 4,000, respectively, the computation of j is as follows:

$$(1-j)^9 = 3{,}000/4{,}000 = 0.75$$

$$(1-j) = (0.75)^{1/9} = 0.9685$$

$$j = 0.9865 - 1 = 0.0315$$

The annual rate of decline is 3.15 percent, or $j = 0.0315$, in this example. The formula for estimating the average annual value for an exponential growth period presented in Equation 6, can still be used when addressing negative exponential growth; the negative growth rate is merely substituted for j, instead of a positive value.

5.4.7 Some Special Cases

The planner will find it necessary to do discounting in certain situations that can be considered unique. These include benefits (or credits) for advanced bridge replacement, major replacement costs, periodic maintenance, and operation and maintenance (O&M) costs. Again, techniques developed previously are applicable to some of these cases, as discussed below.

5.4.7.1 Advanced Bridge Replacement: For many projects, relocations will result in the replacement of existing bridge facilities. Often the expected life of the replacement bridge will be greater than that of the existing structure, thereby extending the life of the bridge service being provided. Since the total cost of the new bridge is included in the first cost of the project, a credit for this extension is needed on the benefit side. A credit is also needed if any reduction in O&M costs will occur during the remaining life of the existing facility. Sample computations required to compute these benefits are presented in the following example and described below. All the interest factors used have been previously presented.

The first seven lines of Example 9 describe the basic conditions and values needed for the analysis. The basis for the credit for the extension of the useful life is that the replacement cost for the existing bridge will be deferred for 30 years. The annual credit for years 21 through 50 is assumed to be equal to the average annual value (cost) of the new bridge for each of those years. This annual value (line 9) is estimated by multiplying the cost of the new bridge (line 1) by the capital recovery factor (line 8). The credit is a constant annuity in years 21 through 50. Its present worth in year 20 (line 11) is the amount of the annual annuity (line 9) multiplied by the present

Example 9
Sample Computation of Bridge Replacement Benefits

1.	Cost of new bridge			=	$500,000
2.	Life of new bridge			=	50 years
3.	Remaining useful life of existing bridge			=	20 years
4.	Extension of bridge life (21st through 50th year)			=	30 years
5.	Annual O&M of existing bridge			=	$5,000
6.	Annual O&M of new bridge			=	$2,000
7.	Interest Rate			=	8 percent
8.	Capital recovery factor (for 50 years)			=	0.08174
9.	Annual cost of new bridge	=	$500,000 x 0.08174	=	$40,900
10.	Present worth of annuity factor for 30 years			=	11.258
11.	Benefits in year 20, credited to bridge life extension	=	$40,900 x 11.258	=	$460,500
12.	Single payment present worth factor for 20 years			=	0.2145
13.	Present worth in year 1 of bridge extension	=	$460,500 x 0.2145	=	$98,800
14.	Annual O&M savings (years 1-20)	=	$5,000 – $2,000	=	$3,000
15.	Present worth of annuity factor for 20 years			=	9.818
16.	Present worth in year 1 of O&M savings	=	$3,000 x 9.818	=	$29,500
17.	Present worth of total credit	=	$98,800 + $29,500	=	$128,300
18.	Average annual credit (benefit)	=	$128,300 x 0.08174	=	$10,500

worth of an annuity for 30 years (line 10). The present worth in the base year (line 13), is then this value multiplied by the single payment present worth factor for 20 years (line 12).

The estimated annual savings in O&M costs expected during the remaining useful life of the existing bridge are $3,000 (line 14). These annual savings would accrue during the first 20 years, and their present worth (line 16) is the product of the annual value and the present worth of an annuity for 20 years (line 15). The present worth of the total credit (line 17) is the sum of the present worth of the bridge extension credit (line 13) and annual O&M cost savings (line 16). The average annual value of the credit (line 18), is the present worth value multiplied by the capital recovery factor for 50 years (line 8).

5.4.7.2 Periodic Maintenance: Often project maintenance expenditures will occur at periodic intervals, rather than uniformly every year. In the following example, the project life is assumed to be 50 years with periodic maintenance expenditures of $75,000 required every 10 years. Note that no expenditures are included beyond the 40th year since any additional expenditures would cover a period beyond the project's life.

5.4.7.3 Major Replacement and Operation and Maintenance: If future replacement is a single event, the procedure for discounting is the same as that described in Example 3 for a single future payment. If the future replacement is recurring, the procedure for discounting is the same as described for periodic expenditures (Example 10). Where operation and maintenance occurs annually and the value is constant, as is usually the case, the average annual value is equal to the constant O&M expense, as presented in Example 4.

Example 10
Sample Computation for Periodic Expenditures

1.	Life of project		=	50 years
2.	Expenditure cycle		=	10 years
3.	Discount rate		=	8 percent
4.	Periodic expenditure		=	$75,000
5.	Present worth of 10th year value - single payment, present worth for 10 years	0.4632 x $75,000	=	34,700
6.	Present worth of 20th year value - single payment, present worth for 20 years	0.2145 x $75,000	=	$16,100
7.	Present worth of 30th year value - single payment, present worth for 30 years	0.0994 x $75,000	=	$7,500
8.	Present worth of 40th year value - single payment, present worth for 40 years	0.0460 x $75,000	=	$3,500
9.	Total present worth: (5) + (6) + (7) + (8)		=	$61,800
10.	Average annual value - capital recovery factor for 50 years	0.08174 x $61,800	=	$5,100

5.4.7.4 Interest During Construction: According to the Corps' *Economic Considerations* (EP 1105-2-45, January 1982), interest during construction (IDC) accounts for the cost of capital incurred during the construction period. The cost of a project to be amortized is the investment incurred up to the time that the project begins to produce benefits, or the time when it is placed in operation. The investment cost at that time is the sum of construction and other initial costs plus interest during construction.

Costs incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are incurred to the beginning of the period of analysis (base year). Interest on any additional expenditures incurred after the in-service date will be an operating expense. Example 11 is a sample calculation of IDC assuming uniform, end-of-month payments. The process is similar when using more typical, irregular monthly payments (costs varying with the construction season or cycle), when using different accounting periods (years rather than months), or when assuming a different timing of payments (costs being incurred at the middle, rather than the end of the month).

The first four lines in Example 11 describe the basic conditions and values needed for the computations. In line 5, the monthly interest rate to be used in the computations is derived. Normally in financial analysis, the monthly rate is found by simply dividing the annual rate by twelve. For example, if the annual rate is 12 percent, the monthly rate is 12/12, or 1 percent. However, because of the cumulative nature of compounding, interest earned on 12 percent compounded monthly will be greater than on 12 percent compounded annually. The difference can be derived from Equation 1, presented at the beginning of this chapter. The single payment compound amount factor for an interest rate of 1 percent, compounded over 12 periods is 1.1268, whereas the factor for an interest rate of 12 percent, compounded over one

Example 11
Sample Computation for Interest During Construction

A. Input Data

1.	Construction period		=	2 years
2.	Total construction cost		=	$24,000,000
3.	Middle of month uniform payments	= $24,000,000/24	=	$1,000,000
4.	Annual interest rate		=	8 3/8 percent

B. Determination of Monthly Interest Rate

5. $(1+i)^{12} = 1.08375$

$1 + i = (1.08375)^{1/12}$

$i = 0.00672$

C. IDC Computation

6.
$$\text{IDC} - \sum P_m \left[(1+i)^{\overset{n}{n-1}}_{m-1} - 1 \right]$$

where

n = number of periods, in months

P_m = the mth monthly payment

i = monthly interest rate

7. IDC (from Table 5-1) = $1,949,000

Table 5-1
IDC Computation Example

Month	Payment		Interest Factor		Interest
1	1,000,000	x	$[(1.00672)^{23} - 1]$	=	$166,500
2	1,000,000	x	$[(1.00672)^{22} - 1]$	=	158,800
3	1,000,000	x	$[(1.00672)^{21} - 1]$	=	151,000
4	1,000,000	x	$[(1.00672)^{20} - 1]$	=	143,300
5	1,000,000	x	$[(1.00672)^{19} - 1]$	=	135,700
6	1,000,000	x	$[(1.00672)^{18} - 1]$	=	128,100
7	1,000,000	x	$[(1.00672)^{17} - 1]$	=	120,600
8	1,000,000	x	$[(1.00672)^{16} - 1]$	=	113,100
9	1,000,000	x	$[(1.00672)^{15} - 1]$	=	105,700
10	1,000,000	x	$[(1.00672)^{14} - 1]$	=	98,300
11	1,000,000	x	$[(1.00672)^{13} - 1]$	=	91,000
12	1,000,000	x	$[(1.00672)^{12} - 1]$	=	83,700
13	1,000,000	x	$[(1.00672)^{11} - 1]$	=	76,500
14	1,000,000	x	$[(1.00672)^{10} - 1]$	=	69,300
15	1,000,000	x	$[(1.00672)^{9} - 1]$	=	62,100
16	1,000,000	x	$[(1.00672)^{8} - 1]$	=	55,000
17	1,000,000	x	$[(1.00672)^{7} - 1]$	=	48,000
18	1,000,000	x	$[(1.00672)^{6} - 1]$	=	41,000
19	1,000,000	x	$[(1.00672)^{5} - 1]$	=	34,100
20	1,000,000	x	$[(1.00672)^{4} - 1]$	=	27,200
21	1,000,000	x	$[(1.00672)^{3} - 1]$	=	20,300
22	1,000,000	x	$[(1.00672)^{2} - 1]$	=	13,500
23	1,000,000	x	$[(1.00672)^{1} - 1]$	=	6,700
24	1,000,000	x	$[(1.00672)^{0} - 1]$	=	0
Total	$24,000,000		—		$1,949,000

period is 1.1200. This stated annual rate of 12 percent is usually called the *nominal rate*, whereas the compounded rate of 12.68 percent is usually referred to as the *effective rate*.

Since the objective of benefit cost analysis is to compare all benefit and cost streams at the same annual discount rate, it is necessary for the IDC computations to find the interest rate that, compounded monthly, will yield an annual effective rate equal to the discount rate being used. This can be done by solving the equation provided in line 5 of Example 11.

Once the monthly rate to be used has been determined, the IDC can be computed. The equation at line 6 is for computing the total interest earned for n monthly installments at a rate of i. Solving this equation (Table 5-1) at an interest rate of 8⅜ percent for 24 monthly payments of $1,000,000, will yield the total interest earned ($1,949,000 in this example) *at the time of the final payment*. If the payments are assumed to be incurred at the end of the month, then the final payment will usually occur concurrently with the beginning of the base year. The interest calculated with the equation at line 6 is then the total IDC. However, if some other timing of payments is assumed (e.g., *Economic Considerations*, January 1982, suggests interest be computed from the middle of the month in which expenditures are incurred), then the additional interest that would be incurred between the timing of the final payment and the beginning of the base year may also (if significant) need to be calculated and included in the final estimate of IDC.

5.5 Summary

The above examples have been presented to illustrate some of the basic discounting concepts and procedures that are often used in water resource development benefit-cost analysis. In order to clearly illustrate the concepts involved, lengthy hand calculations were sometimes used, especially in Example 11. Some short-cut techniques were presented that can reduce the computations required and, as indicated, closely approximate the estimates derived from more detailed, analytical approaches. These latter approaches, however, are readily adaptable to micro-computer spreadsheet and other software programs. Analysts are encouraged to use such programs. The programs are relatively easy to use, can minimize set-up and computational errors, and can easily incorporate changes in such factors as interest and growth rates and price levels.

6

Minimum Study Requirements

At the outset of a study, its scope is determined. The preceding pages attempt to cover the broadest scope of possible categories for economic analysis. The more of these factors the report takes into account, the more accurate its results will be. However, there are times when a report's scope must be very limited. In this event, the following information provides guidelines on the minimum amount of information and work an economic analysis should include.

6.1 Minimum Information to be Included in Final Report

The report's results should include the following:

1) Definition of the study area.

2) Summary of alternatives examined by the study, including the level of protection and costs of each alternative.

3) Other studies or considerations important to the study's results.

4) Summary of benefit categories and calculations.

5) Summary of implications of the data, including benefits, levels of protection, costs, cost-benefit ratio, and any other important considerations revealed in the course of the study.

6.2 Minimum Amount of Information to Gather for the Study

In performing an economic analysis, the following data must be gathered:

1) Elevation-damage relationships for without-project conditions (both present and future) and with-project conditions. Establishing these relationships requires the following data:

   a) Floodplain evaluation:

      » Structure count.

      » Survey of 1st floor pads of all structures.

- » Assessment of average or cumulative value for structures (including contents, and outside property).
- » Assessment of other damage areas, such as public utilities, roads, and traffic.
- » Estimates of future developments of population and land use.

b) Hydrology:

- » Establish the following relationships for four or five frequencies: elevation-discharge curve, discharge-frequency curve, and elevation-frequency curve.
- » Determine minimum damaging flood and velocities of floodwaters.

2) Compile and analyze damages/benefits.

- » Estimate damages for all structures and other categories for selected frequencies.
- » Calculate average annual flood damages with and without project.
- » Calculate present value of project benefits and discounted present value of damage prevention at selected project life and discount rate.

The Flood Damage Inventory Forms in Appendix A should guide the analyst in collecting the minimum study requirements outlined above.

References

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Moser, David A., *Assessment of the Economic Benefits from Flood Damage Mitigation by Relocation and Evacuation*, 1985, U.S. Army Corps of Engineers Institute for Water Resources Research Report 85-R-1.

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Appendix A

Flood Damage Inventory Forms

JUNE 1972
FILE CODE WS-14

FORM APPROVED
OMB NO. 40-R3806
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FLOOD DAMAGE -- TRANSPORTATION -- UTILITIES

Watershed ______ Reach ______ State ______ Interviewer ______ Date ______

Respondent ______ Institution Represented ______

Location of Damage ______ Item Damaged ______

Date of Flood ______

(1) Depth of Water Related to Item Damaged (feet)	(2) Type of Damage	(3) Cost of Repair 1/ (dollars)	(4) Other Damages (dollars)	(5) Total Damages (dollars)	(6) Estimated Damages if Floods were: Higher			Lower		
					1′	2′	3′	1′	2′	3′

1/ Indicate the year repair made if other than year damaged ______

Bridge Information

(7) Location	(8) Size and Kind of Bridge	(9) Estimated Remaining Life of Bridge (years)	(10) Estimated Cost of Replacement (dollars)	(11) Estimated Life of Replacement (years)

Remarks

SCS-WS-3
JUNE 1972
FILE CODE WS-14

FORM APPROVED
OMB NO. 40-R3808
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FLOOD DAMAGE--COMMERCIAL--INDUSTRIAL

Watershed ____________ State ____________ Reach ____________

Interviewer ____________ Date ____________

Type of Business ____________ Address ____________ Owner ____________

Structure:

Construction: Frame ☐ Brick ☐ Metal ☐ Other (specify) ____________

Market Value (do not include land) $____________

Size: Basement ________ sq. ft. 1st Floor ________ sq. ft. No. of Floors ________

Value of Contents: (estimated) Basement $________ 1st Floor $________ 2nd Floor $________
Other $________

1st Floor Storage (per cent stored in relation to elevation):

0.0 - 1.0 ft. ______ % 1.1 - 3.0 ft. ______ % 3.1 - 5.0 ft. ______ % 5.1 ft. and over ______ %

Number of Employees ________ How Often Do Damaging Floods Occur? ________

Date of Flood ________ Type of Flood: Backwater ☐ Flowing ☐

Depth of Flood: Grounds ______ ft. Basement ______ ft. 1st floor ______ ft. 2nd Floor ______ ft.

	Estimated Damages (Dollars)			Remarks
Grounds – Parking lots, walks, signs	XXX	XXX	$	(Loss prevented by evacuation, emergency preparations, etc.)
Lawns, shrubs	XXX	XXX		
Structure – Foundation	XXX	XXX		
Walls	XXX	XXX		
Other	XXX	XXX		
	Basement	1st Floor	Other	
Contents – (Stock) Merchandise	$	$	$	
Equipment				
Records				
Misc. (specify) ________				
Other – Loss of Business	XXX	XXX	$	
Evacuation-Reoccupation	XXX	XXX		
Flood proofing	XXX	XXX		
Employee Wages Lost	XXX	XXX		
Misc.	XXX	XXX		
Totals	$	$	$	

TOTAL LOSS FOR FLOOD $________

Estimated Damages at Higher or Lower Stages Than This Flood

Higher 1' $________ 2' $________ 3' $________ 4' $________ 5' $________

Lower 1' $________ 2' $________ 3' $________ 4' $________ 5' $________

SCS-WS-2
JUNE 1972
FILE CODE WS-14

FORM APPROVED
OMB NO. 40-R3805
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FLOOD DAMAGE – RESIDENTIAL PROPERTIES

Watershed ______________________________ State ________________

Reach ____________________ Interviewer ____________________ Date __________

Occupant ____

Address ______________________________________ Years lived here __________

Times residence flooded: No. ________________ Dates ____________________

Date of specific flood event ________________ Hrs. of advance warning received __________

Depth of water in basement ______________________________________

Describe source of floodwater (through windows, walls, basement drains, etc.)

Depth of water on or above first floor ______________________________

Depth of water on grounds or lawn ______________________________

Depth of water in garage ______________________________

Depth of water in other buildings ______________________________

Depth of water in automobiles ______________________________

Location of automobiles when flooded

Depth below the above flood at which damages begin ______________________________

Times residence flooded - No. - Number of times this house has been flooded since you have lived in it.

Dates - Month, day, and year of all damaging floods mentioned in the previous

FLOOD DAMAGE - RESIDENTIAL PROPERTIES - APPRAISAL

Item	Specific Flood Event and Dates of Stages Above and Below							
	Specific Flood Event							
	Extent of Damage (Dollars)(Specify price base if different from flood year)							
Structure - House								
Outbuildings								
Driveways and walks								
Contents - Basement: Furniture								
Appliances								
Personal belongings								
First Floor: Furniture								
Appliances								
Personal belongings								
Lawn								
Vehicles								
Other (specify)								
Cleanup (Lawns, driveways, basement, floors, etc.)								
Subtotal - Direct Damages								
Emergency measures of evacuation, etc.								
Loss of income								
Other (specify)								
Subtotal - Indirect Damages								
Total Damages								

Size of residence ________________ sq. ft.

Market value of residence (do not include lot) $ ________________

Replacement value of contents $ ________________

Remarks:

All information in the body of this table should be in terms of dollar damage estimates. Physical effects should be described in the "remarks" section of the table.

Appraisal of Flood Damages:

Specific flood event and stages above or below - The specific flood event is the historical flood for which detailed damage estimates are to be recorded in one column of this table. Stages above and below the specific flood event refer to floodwater depths in or at this higher (above) or lower (below) than that experienced from the specific flood event. Stages above and below the specific flood event should, as a minimum, include large, medium, and small flood events. The large flood event should at least equal the 100-year flood. These damage data may be related to the first floor elevation of the house or may be obtained on a frequency-depth of inundation type basis. Use these columns to fit your method of obtaining flood damage for a range of flood frequency events.

Extent of Damage - Dollars - Give a detailed dollar listing of damage for each identifiable item changed. When damage estimates are obtained from the person being interviewed, it is important to know what year his estimates are related to if other than year of flood.

Indirect Damages:

Emergency measures for evacuation - Dollar value of labor, equipment, utilities, and time expended in attempting to prevent flood damages from the specific flood event.

Loss of income - Income lost by occupant and family either to prevent flood damages or for clean-up activities, that has not been accounted for in the direct flood damage estimate above.

Other (specify) - Name other types of indirect damage which fit under the indirect damage category for this watershed flood plain occupant, such as loss of refrigerated foods due to power failure, added medical costs due to flooding, added travel expenses caused by increased travel route, added living expenses because of flood damage to residence, etc.

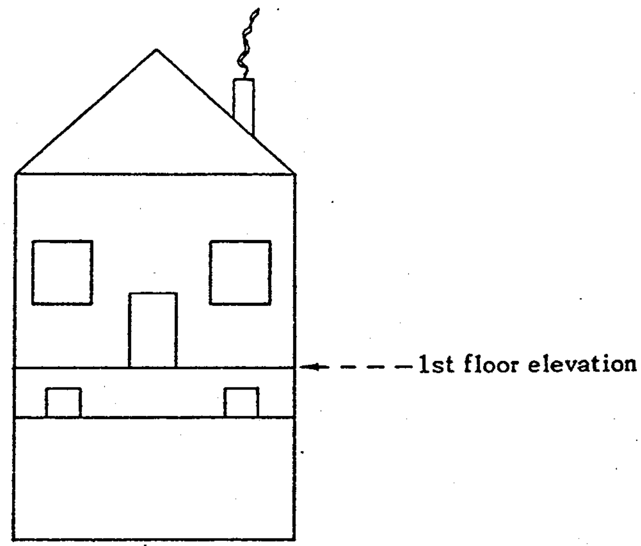
Size of residence - Give approximate living area of home in terms of square feet; e.g., 30' x 60' = 1800 sq. ft.

Market value of residence (not including lot) - Approximate value of house and outbuildings exclusive of the value of the land area (lot) on which they are located.

Replacement value of contents - Give the approximate cost to the dweller of replacing, with equivalent facilities, the furniture, appliances, and personal belongings normally contained in this home.

FLOOD DAMAGE – RESIDENTIAL PROPERTIES

Show height of experienced flood stage (depth) on the residence. Denote basement windows and depressed basement entranceways as related to first floor elevation and depth of inundation by specific flood event.



Class of Structure (check one)	Type		
	Frame	Masonry	Other (specify)
Single story, no basement			
Single story, with basement			
Two story, no basement			
Two story, with basement			
Split level			
Mobile home			
Other (specify)			

This standard drawing is intended to be used in numerous ways. Any use that can be made of this drawing that serves the enumerator's purpose should be shown. Any penciled modifications, as necessary, should be made.

Class and type of structure (check one)	-	Check the one block which most accurately describes this residence. If the "other" block under "Type" is checked, specify, by footnote, what this "other" refers to.

Flood Damage Schedule Work Sheet
(Sample)

Name ____________ Years on Farm ____________ Subwatershed ____________

Flood of ____________ Acres Flooded ____________ How frequently do floods of this size occur ____________

Acres Flooded by Largest Flood ______

NOTES

Damage to Crops and Pasture From Flood of Above Date

Crop	Depth	Acres Flooded	Present Acres This Crop	Expected Yield If No Flood	Yield After Flood	Extra Cost		Expenses Saved	
						Kind	Amount	Kind	Amount
Cotton	0'-2'	10	5	200 lb.	150	Replant Extra	10	Picking	50 lbs/ac
Corn	0'-2'	10	5	30 bu.	15	Cultivation	10	Harvest	15 bu/ac
Wheat	2.1'-4'	10	10	15 bu.	10	Combines	10% longer to harvest	None	
Johnsongrass Meadow	2.1'-4'	5	15	1 ton	1	None	-	None	
Pasture	4.1'-6'	10	10		No damage				

Other Damage From this Flood

Type	Damage	
______	Quantity	Value
Fence	4 rods	
Poultry	12 hens	
Livestock	1 heifer	

Equipment: None
Levees: None
*Scour: 5A/20%
*Bank Cutting: ____________
*Sediment: 5A/25%

Value of Cropland: $100 acre Value of Pasture: $30 acre

Q. What changes in land use have been made due to floods? A. 10 acres of row crops to Johnsongrass meadow.

Q. What changes would be made if the frequency of flooding were reduced by half? A. All of meadow to crops and 5 acres of pasture to crops.

Q. How often do large floods occur? (If the flood described above is a large flood, change this question to small floods.) A. Once in 8 years.

Q. During what seasons are floods most common? A. Large floods: Spring - 1/2; Fall - 1/2. Small floods: Spring - 3/4; Fall - 1/4;

Q. In addition to the loss in yield described above, was there any damage to quality of crops? A. Wheat-weeds because wheat down. (Estimated percent. Docked price of wheat 25%.

Q. What damage did this flood do to roads and bridges nearby? A. Washed out approaches, about 10 loads needed.

*These items may be total damage since he has been on the farm.

Figure 3.7

FLOOD DAMAGE - RESIDENTIAL
(Sample)

Watershed ______________________ Reach ________

Location of property: Stream mile ____________ No. __________

Occupant ______________________________ Years Occupancy __________

Damaging floods: No. _______ Dates ______________________

APPRAISAL OF DAMAGE

Property damaged	Experienced or Potential Floods 1/		
	Extent of damage		
Residence and contents			
(Depth of water in basement)			
(Depth of water on first floor)			
Foundation			
Basement and contents			
Floors and walls			
Furniture			
Personal belongings			
Lawn			
Garage (depth of water)			
Other buildings (depth of water)			
Automobiles (depth of water)			
Other losses			
Clean-up			

Relevant Data:
Type of residence: Frame _____ Masonry _____. Size of residence _____ square feet. Market value of residence $________. Replacement value of furniture $______. For experienced flood describe any emergency activity for prevention of losses or evacuation __________

1/ Indicate the date of experienced floods. Show height of other flood stages in terms of plus or minus depth increments referenced to the experienced flood.

Figure 3.8

Explanatory Notes

1. Location of damage -- This may be by reach or other meaningful terms to identify where the damage occurs.

2. Respondent -- This would be the individual providing the information.

3. Institution Represented -- This may be the County Highway Department, railroad, utility company, etc.

4. Item Damaged -- Specify item and kind of item such as gravel road, steel bridge, main railroad line, electric generating plant, etc.

5. Column (1) -- This is to reflect the depth of water either over or below item damaged such as road surface, bridge deck, etc.

6. Column (2) -- This is to show whether damage consisted of washing out a bridge, eroding of abutments, gravel washed off road surface, flooding pumps, breaking utility poles, etc.

7. Column (4) -- This includes loss of business, wage loss, rerouting costs, emergency measures, cost of preventing damage, etc. Explain under remarks.

8. Column (6) -- This is not for a specific flood but is related to estimated damages if flood stages were either higher or lower. This estimate may be by respondent or technicians or both.

9. Bridge Information -- This data is to reflect without project conditions. This data may be useful if the replacement period and cost of replacement is affected by project conditions. It is most applicaple to bridges in close proximity of structures.

10. Column (8) -- This is to show size of bridge opening and whether steel, timber, etc.

11. Remarks -- Use to clarify any data obtained or additional information not specifically covered.

Appendix B

FEMA Depth-Damage Relationships

The table that follows has been produced by FEMA and contains the data used by the U.S. Army Corps of Engineers to estimate structure and content damages by percentage relative to the inundation depth. Depth is measured in feet; structure and content data are percentages of the estimated value. Hence, if a residential structure is inundated to the one-foot level, the estimated damage would be:

13.35 x $ Value of Structure = $ Damage to Structure

17.00 x $ Value of Contents = $ Damage to Contents

Note that the Inundation Depth is measured from the first level (including homes with basements) and that –1.0 Inundation Depth means flooding occurs to one foot below the first floor.

1989 FEMA Depth Damage

Inundation Depth	Residential		Commercial		Mobile Home	
	Structure	Content	Structure	Content	Structure	Content
-1.0	0.00	0.00	0.00	0.00	0.00	0.00
-0.5	3.85	5.66	3.85	3.59	4.14	1.63
0.0	7.78	11.31	7.78	7.18	8.26	3.25
0.5	10.56	14.16	10.56	8.46	26.28	14.92
1.0	13.35	17.00	13.35	9.74	44.33	26.58
1.5	16.79	24.52	16.79	13.73	53.79	37.85
2.0	20.23	32.04	20.23	17.71	63.25	49.11
2.5	23.36	33.35	23.36	20.13	68.28	56.60
3.0	26.49	34.66	26.49	22.54	73.30	64.09
3.5	27.57	35.77	27.57	25.42	75.88	67.23
4.0	28.65	36.88	28.65	28.31	78.47	70.37
4.5	29.25	38.75	29.25	30.73	79.11	72.98
5.0	29.85	40.61	29.85	33.15	79.74	75.59
5.5	35.25	42.76	35.25	36.19	80.30	76.64
6.0	40.66	44.91	40.66	39.23	80.86	77.68
6.5	41.74	47.38	41.74	41.64	81.38	78.24
7.0	42.83	49.86	42.83	44.05	81.89	78.80
7.5	43.41	52.32	43.41	47.04		
8.0	44.00	54.77	44.00	50.03		