IV. A Framework for Flood Hazards Management

Flood hazards like other natural hazards have their origins in nature. Flood disasters, however, are a consequence of the intrusion of man and his works into an environment that puts them both at risk. The successful application of public policies to the management of flood hazards calls for integrating a number of factors. The three most fundamental of these are: human behavior and the choices people make; natural events and their probabilities; and governmental responsibilities.

Four considerations that have been found useful in addressing an integrated approach to the management of flood hazards are:

- the lifecycle of a flood hazard,
- the time frame needed for planning policy,
- the tools available to Government, and
- an analytical strategy to assist decisionmaking that extends beyond cost-benefit analysis.

THE LIFECYCLE OF A FLOOD HAZARD

An effective management strategy for moderating a flood hazard or any other natural hazard must take into account the hazard's total lifecycle as it evolves from the natural condition in an environment into the risk conditions created by people's intrusion in that environment. The lifecycle shown in figure 5 presents an overall picture from which the relative strengths and weaknesses in current public policy can be identified.

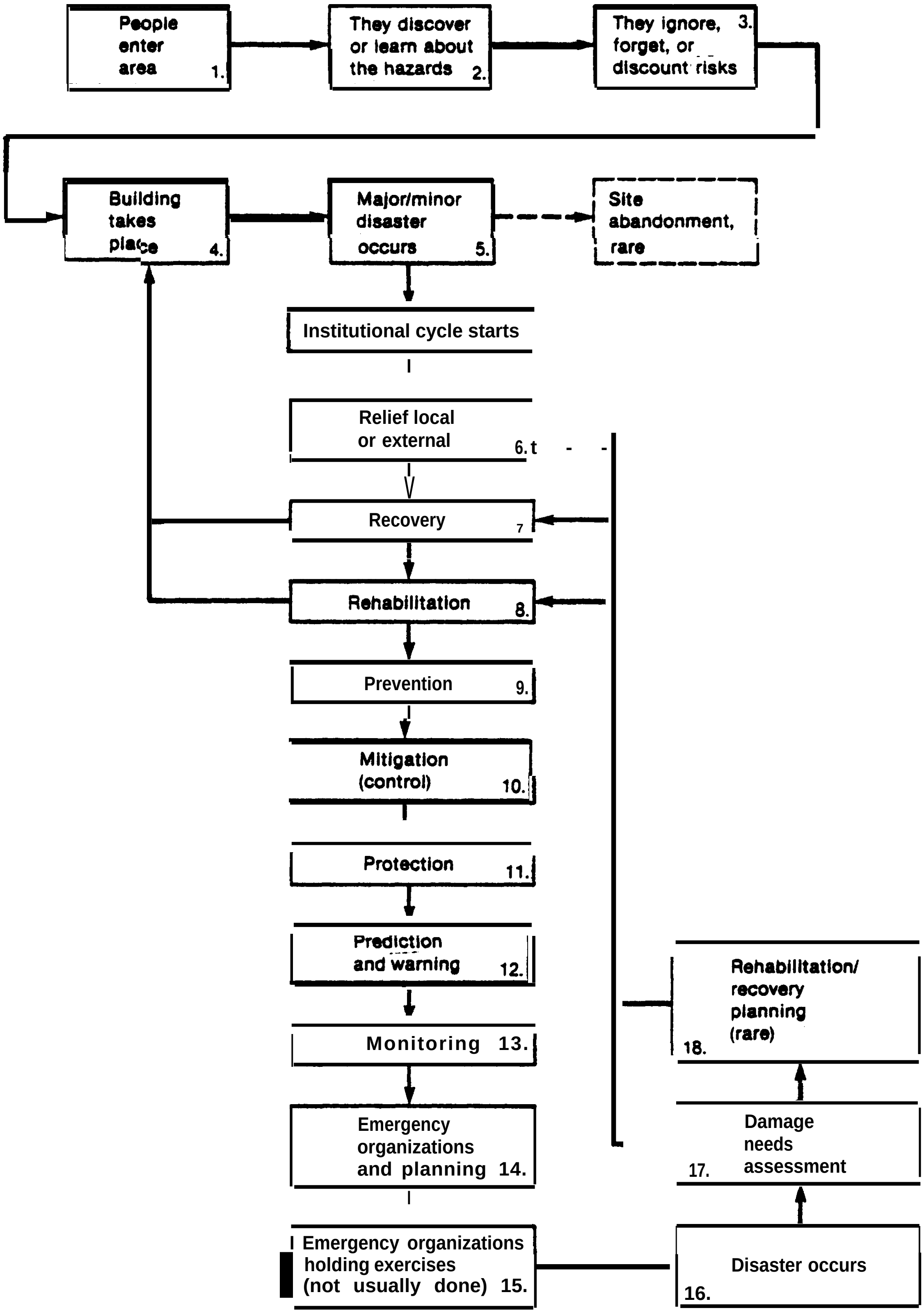
At present, the relatively strong capabilities of flood hazards management are its emergency organization and its planning for dealing with the immediate postdisaster situation (items 6 and 14 in figure 5). The readiness to exercise an emergency response (item 15) is a much weaker capability. Damage assessment (item 17) is relatively well-done after minor floods but much less so after major floods, in most areas. Prediction and warning capabilities (item 12) are being steadily improved, and measures taken for relief, recovery, and rehabilitation (items 6, 7, and 8) are adequate both for sudden disasters and for those that cause less than $1 billion in damage.

Planning for rehabilitation and recovery (item 18) is seriously deficient in all areas subject to floods. For maximum effectiveness, comprehensive plans to provide relief, as well as for rehabilitation, must be readied before a disaster strikes. The only long-term strategy that will reduce future losses from floods is to rebuild properly designed structures on suitable sites, avoiding the repetition of past errors. At the present time, however, without properly enforced planning for rehabilitation and recovery after a major flood, it is not likely that the unsound building patterns of the past will be changed.

Prevention has traditionally relied on controlling floods by means of civil engineering works. The increasing inadequacy of civil works that are not closely tied to land use planning is widely recognized. For this reason, how to make long-term land use planning an effective tool for controlling development in flood hazard areas and for guiding postdisaster recovery is a principal public policy question in flood hazards management.

The disorganized, almost haphazard, nature of the Government's efforts and capabilities for addressing a long-term integrated strategy is illustrated by figure 6. This figure shows that there are only a few Federal agencies with responsibility for more than one or two of the key elements in the lifecycle of a flood hazard, and that there isn't one single element which is the responsibility of a majority of the agencies. The President's recent Reorganization Plan for Emergency Preparedness and Response, which established the Federal Emergency Management Agency (FEMA), may help to more effectively organize these multiagencv responsibilities. (The issues confronting FEMA are discussed in a companion report mentioned in the preface.) The problem of integration is discussed in greater detail in chapter VI.

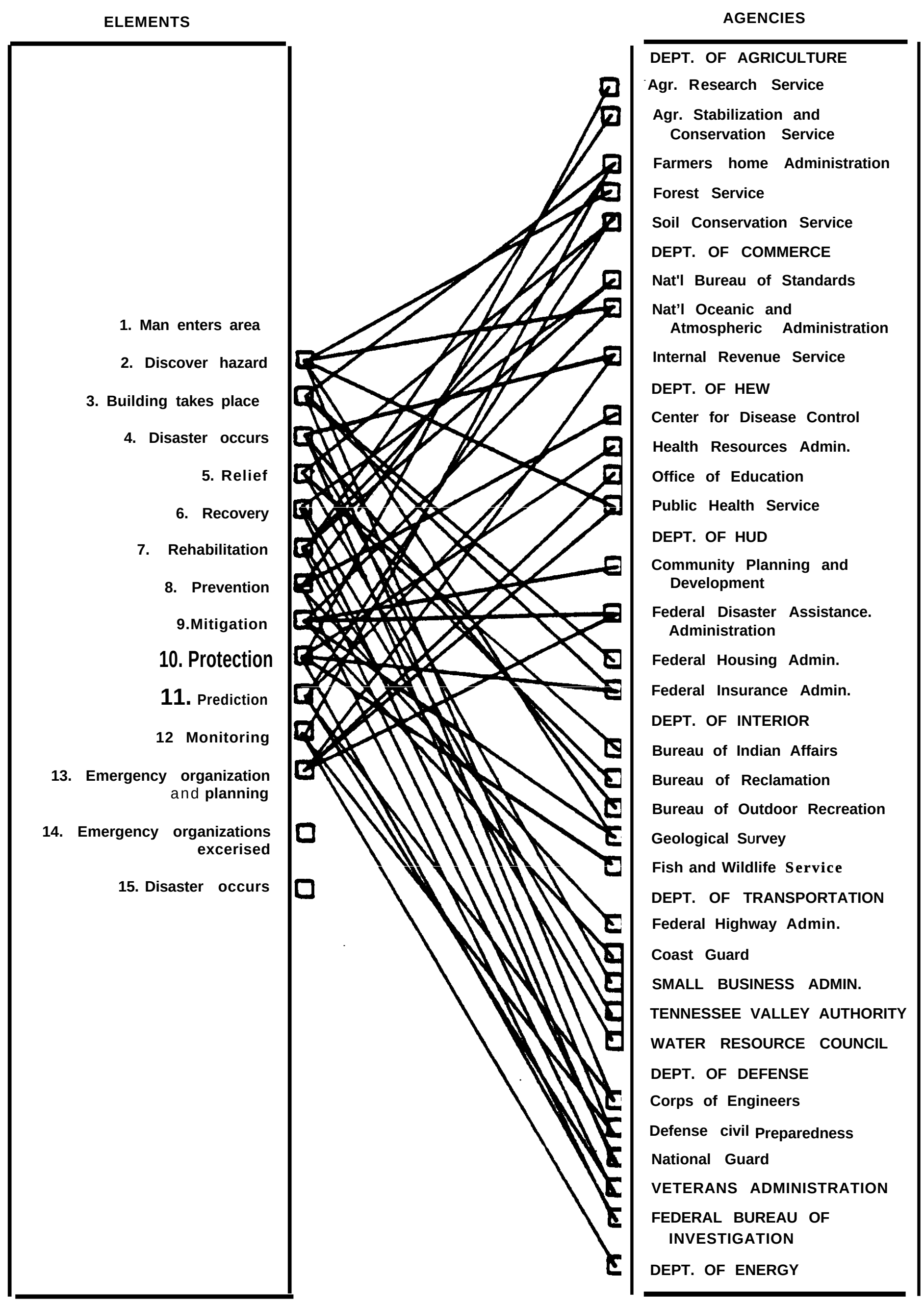
Figure 5.-Lifecycle of a Flood Hazard



SOURCE: Office of Technology Assessment.

Figure 6.-The Complexity and Confusion of Federal Responsibilities

Elements of the lifecycle as related to Federal actors



SOURCE: Compiled by OTA Staff.

WARNING

Whether for flash floods, for severe weather, for storm surges, or for tsunamis, flood warnings can substantially reduce the loss of life and property. Although the best estimates indicate that adequate warning would only reduce losses by about 10 percent, this represents a sizable saving with respect to the property base at risk. Thus, there appears to be a rising demand for warning services.

Flash floods affect over 15,000 communities and recreational areas. Since 1971, about 3,000 localities have been identified as having a high flash flood potential.[1] All of these, along with another 3,000 areas with a somewhat less severe potential for such flooding, would benefit from a local flash flood warning program. To date, however, the National Weather Service only provides site-specific flash flood warning programs to 675 high potential areas.[2] This leaves over 5,300 areas in immediate need of such tailormade warning programs. The small number of new warning programs-75 to 100 annually–which are being put into effect by the National Weather Service, cannot meet the needs of these areas in a reasonable time.[3] Because of its limited staff of 150 hydrologists for the entire United States, the National Weather Service can only handle about 15 percent of the nationwide need for flash flood warnings.

There are approximately 9,000 remaining flood-prone localities where the problem is relatively less serious. These areas can be served by less site-specific, more generalized warnings, which are currently available or soon will be.[4]

Tsunamis, which are large ocean tides induced by earthquakes, have great destructive potential. In 1896, 27,000 Japanese were swept away by tsunamis, and in 1940, tsunamis wiped out every town along 800 km of the Chilean coast. The coastal areas of the contiguous 48 States have thus far been free of these devastating waves (although it is not certain whether earthquakes off the east coast are a significant hazard). Alaska and Hawaii, however, which are close to earthquake epicenters and therefore could be subject to sudden tsunamis, are most directly interested in the National Weather Service's tsunami-warning system. Recent technical developments in understanding these phenomena promise to improve the reliability and usefulness of their forecasting.

[1]Allen F. Flanders, National Weather Service, personal communication, Apr. 5, 1978.
[2]Ibid.
[3]Ibid.
[4]Ibid.

THE TIME FRAME OF PUBLIC POLICY PLANNING AND IMPLEMENTATION

Most of the lives and property at risk from floods are in cities or other heavily developed riverine floodplains and coastal zones. Considering that tens of millions of people and close to a trillion dollars of investments* are located in these flood hazard areas and that the average urban structure has a lifetime of about 40 years, it follows that if land use is changed too rapidly and too radically or there is too forceful an effort to make structural changes in property now at risk, excessive costs would be incurred.

To be effective, a national program for flood hazards management should take into account the 40-year average lifetime of urban structures. Then plans for removing and relocating structures at risk and hence people at risk, would be based on an implementation period of 30 to 40 years. A strategy that takes advantage of this average turnover time for urban structures would be the most acceptable from a socioeconomic point of view. It should not be implied, however, that such a strategy can be left to the normal operation of traditional market forces. Inadequately controlled market forces have been themselves a dominant factor in promoting flood hazard risks.

A major public policy objective framed over a turnover time of 30 to 40 years would not only

*One way to roughly estimate the value of structures at risk in a given flood zone is to multiply the per capita national investment in structures by the resident population. To include all public and private costs, that figure should be increased by roughly one-third co reflect the public service infrastructure (e.g., roads, sewers, bridges, etc.) at risk and increased even more to include the contents of homes and businesses.

Number of housing units	74 million
Average size	1,100 sq. ft.
Replacement cost/sq. ft.	$30
Population	220 million
Total residential investment	$ 11,350 per capita
Nonresidential sq. ft.	29 billion sq. ft.
Replacement cost/sq. ft.	$50
Population	220 million
Total nonresidential investment	$6,W@ per capita
Total national investment in structures	$17,940 per capita

SOURCE: Prepared by OTA with the assistance of John P. Eberhard.

minimize costs but would also make it possible to closely examine change as it takes place. This monitoring of change would provide Congress and the executive branch with feedback useful for ascertaining the progress of flood hazards management programs in meeting long-term national policy objectives.

TOOLS AVAILABLE FOR FLOOD HAZARDS MANAGEMENT

Numerous Governmental mechanisms are available for managing flood hazards. These can be conveniently organized in terms of three general strategies:

- Modifying the hazard by using structural control to alter the course or flow of the water.
- Moderating the impacts of flooding on individuals and communities through insurance, disaster relief, and tax adjustments.
- Reducing the risks of flood damage.

Modifying the Hazard

The traditional approach to flood hazards at the Federal, State, and local levels has primarily been to modify the course or flow of water by the application of physical methods. The volume of runoff during the peak stage of a flood; the time of occurrence and the duration; the extent of area flooded; and the velocity and depth of the water, thus the amount of pollutants and debris carried by the flood, can all be modified by physical means such as: dams, dikes, levees, flood walls, channel alterations, spillways, land treatment, and other civil works.

The adequacy of such physical methods as the predominant approach to controlling flood hazards is increasingly being questioned. Reliance solely on civil works, which cannot possibly be constructed to protect against every potential flood, encourages "apparently" protected flood zones to be developed. This, in turn, may lay the groundwork for larger, rather than smaller, future disasters.

Moderating the Impacts

Flood emergency measures, which range from emergency flood-proofing and disaster contingency preparedness to the warning of impending danger, are other traditional approaches to flood hazards. These measures by themselves, however, are recognized as inadequate for effectively dealing with the consequences of floods. Warning schemes, for example, may save a few lives but at most reduce property loss only by about 10 percent, as brought out in the flood workshop.

Once a flood occurs, postdisaster recovery measures such as insurance and tax adjustments are needed to moderate its impacts. A public policy dilemma associated with postrecovery measures is the extent to which they encourage risk-taking. If a community knows that should a disaster strike it will receive assistance and relief in the form of low-cost and subsidized insurance, this expectation could act to discourage the use of more effective preventive measures.

Reducing the Risks

The approach to the management of flood hazards is shifting towards measures that reduce the susceptibility to flood damage by integrating land management techniques, such as restricted occupancy, with traditional strategies and tools, such as civil works. The emphasis is increasingly being placed on such risk reduction measures as zoning codes, regulations, the implementation of development and redevelopment plans, and policies to improve the design and location of structures.

These measures are not equally suitable for every situation. Some, e.g., zoning restrictions, are more applicable to the development of untouched floodplains, others, e.g., flood-proofing, to urban rather than rural areas. The chief difficulty in implementing these approaches is that they reverse the traditional time sequence in which benefits are dispensed. Consequently, the political advantages to National, State, and local leaders would be considerably altered. Risk reduction measures also shift the burden of integrating and applying knowledge from the Federal Government to State and local levels. This places great demands on their skilled, but relatively small, professional staffs. A further complication is that State and local jurisdictions tend to be subject to pressure from narrow and short-term special interests. The principal policy tools for managing flood hazards are shown in table 8.

The limitations of the strategies for each of the three methods of flood hazards management: modifying the hazard, moderating the impacts, and reducing the risks are shown in table 9. Four

Table 8.-Governmental Strategies and Tools for Flood Hazards Management

Modify the hazard

Dams and reservoirs
Dikes, levees, floodwalls
Channel alterations
High-flow diversions and spillways
storm drainage
Land treatment measures
- reduction of erosion
- vegetation
- terraces
- runoff division

Onsite detection measures
Watershed treatment

Moderate the impacts

Flood insurance
Tax adjustments
- amortization for nonconforming uses
- reinforcement of regulatory policies

Forecasting and warning evaluation
Flood emergency measures
- emergency flood-proofing
- exercise of emergency response groups

Coordination of response and rescue
- communication links
- preflood planning
- damage assessment

Disaster assistance
- loans
- temporary housing, etc.
- direct compensation

Postdisaster recovery: rehabilitation coordination with other renewal objectives
Remote sensing

Reduce the risks

Regulations
- zoning
- subdivision regulations; standard setting
- building codes
- housing codes
- sanitary and well codes; health codes
- realtor disclosure of risk
- land acquisition

Development and redevelopment policies
- design and location of sensitive public services
- open space acquisition; public ownership
- easements
- redevelopment and renewal
- permanent evacuation
- tax incentives/disincentives subsidies, grants, loans

Preparedness and response planning
- training
- postaudits
- research; futures research
- coordination and support of planning
- impact analysis

Flood-proofing buildings and structures
- public awareness programs
- training local hazard personnel; training residents

Program and project evaluation
Priority setting and policy definition

SOURCE: Office of Technology Assessment.

Table 9.-Relevance of Nonstructural Measures to Floodplain Management Objectives

Nonstructural measure	Reduce existing losses	Prevent increased losses	Redis. tribute losses
Flood insurance	no	no	yes
Flood warning and emergency evacuation	yes	yes	no
Acquisition in fee	no	yes	no
Clearance/relocation	yes	no	no
Acquisition of rights less than fee	no	yes	no
Floodplain zoning	no	yes	no
Tidal wetland regulations	no	yes	no
Building codes	no	yes	no
Subdivision regulations	no	yes	no
Flood proofing	yes	yes	no
Control of utility location	no	yes	no
Encroachment regulations	no	yes	no
Emergency relief	no	no	yes
Education and information	yes	yes	no

SOURCE: Philip B. Cheney and H. Crane Miller. "The Application of Nonstructural Measures to Coastal Flooding," for *The New England River Basin's Commission,* June 1975, p. 12.

of the fourteen nonstructural measures listed would reduce existing losses, eleven would prevent increased losses, and two would redistribute losses. None would accomplish all three. It follows, therefore, that there is a need to integrate nonstructural with structural approaches.

Historically, the preferred measure has been to use civil engineering to modify the hazard by constructing dams, dikes, levees, etc., which reduce the risks for the typical more frequent but relatively minor floods. This approach, however, has several disadvantages. It is the only method that can actually increase the risk of life and property losses in many areas. This could happen if there were a major event that exceeded the planning specifications of the protective physical construction in a flood hazard area. Furthermore, by encouraging development in areas that are not holly protected against all possible events, the reliance on civil works can place additional lives and property at risk. There is no economically practical way to modify a flood hazard that can protect against a rare or catastrophic event.

The strategies that moderate the impacts of floods do so in three ways: 1) by spreading the loss, e.g.) through insurance; 2) by relieving the short-term stresses, e.g., through low-cost loans; and 3) by cutting the losses by some small percentage, e.g., through emergency flood-proofing or early warning.

Regulations, development and redevelopment policies, flood-proofin buildings and structures, education, and information are some of the strategies that can be used to reduce the risk of floods. It is socially desirable to redistribute flood losses through such means as insurance and relief. By themselves, risk-reducing strategies tend to incur excessive opportunity costs, since to reach a high level of risk reduction could be so costly as to drain public resources away from other meritorious public projects. These strategies also fail to deal effectively with the short-run and transitional problems of existing communities that are at risk during the changeover period from one set of strategies to another.

Ten approaches or policy options available to Government for implementing nonstructural measures are displayed in table 10. The desired outcomes are qualified by the limitations of such means. On the basis of surveys of the willingness of individuals to employ particular loss reduction or hazards management strategies, conducted by L. Douglas James of the Georgia Institute of Technology, he arrived at eight "individual factors affecting response to implementation means."[5] These are:

- time and inclination to execute individual measures,
- faith in availablilty to act,
- seclusion versus access as a reason for floodplain occupancy,
- sympathy for program goals and objectives,
- willingness to conform to regulation,
- philosophy of individual on public versus private responsibility,
- perceived personal benefits, and
- perceived personal losses.

The individual response data coupled with the policy options listed in table 10 suggest three determinants of successful policies for floodplain management:

- the establishment of a coherent Federal policy,

*Opportunity costs are the benefits forgone in making one choice over another. Every economic decision involves opportunity costs.

[5]L. Douglas James, "Formulation of Nonstructural Flood Control Programs," Water Resources Bulletin, August 1975, p. 693.

Table 10.-Means or Policy Options in the Implementation of Nonstructural Measures

Means or policy options	Desired response	Limitations
1) Disseminate information warning of an impending flood emergency	Immediate employment of short-term measures and a later inducement to consider individual long-term measures	Some don't receive the warning, some don't take it seriously, some don't know what to do, some unable to respond
2) Disseminate information detailing hazards on the floodplain	Induce greater use of individual long-term measures	Same as above, plus some pursue personal, not public, goals
3) Disseminate information on ecological effects of floodplain occupancy	Induce personal long-term measures by appealing to community welfare rather than personal hazard	Same as 2 -
4) Penalize, tax, or charge those failing to employ specified measures	Add a financial incentive to induce still greater use of individual measures	Difficult to set fair rates, burden on low-income groups
5) Provide trained experts to analyze and advise property managers	Add expertise to induce greater/ efficient use of individual measures	Poor communication, cost, different values
6) Deny group measures or financial relief to areas not requiring individual measures	Induce communities to require individual nonstructural measures; social pressure on mavericks	Communities object of intervention leading to nonenforcement
7) Legislate and enforce statutes requiring individual measures	complete compliance with statutes	Puts financial burden for a public policy on a few owners
8) Financially aid those who implement individual measure —insurance, subsidies	Add financial means to respond to expert advice	Puts financial burden on public, subsidizes floodplain occupants
9) Purchase hazard areas and leave in natural use	Ensure no development, improve recreation and natural areas	Expensive to buy and maintain
10) Purchase hazard area for redevelopment in optimum use	Ensure optimum development and compliance	Planners unable to figure precise optimums, puts Government in competition with private sector

SOURCE: L. Douglas James, "Formulation of Nonstructural Flood Control Programs," Water *Resources Bulletin,* August 1975, p. 690.

- the cooperation of community leaders and institutions in adopting and enforcing standards, and
- the predictability of individual response to specific policies.

As a rule, it should be recognized that in managing social problems and establishing a coherent Federal policy, institutions rarely have effective control over all or most of the fundamental variables affecting or likely to affect their interests. Thus, the institutions most directly responsible for the management of flood hazards have the least control over those variables that affect flood hazards in the long term. For example, money-lenders, the mortgage industry, banks, and Federal agencies such as the Federal Home Loan Bank Board are the predominant institutions that influence and control building construction and land use management. Often, the organizations that have the capability and power to reduce the potential of flood risk are inattentive or insensitive to this opportunity.

The limitations of the traditional approach to analyzing natural hazards have been examined in this chapter and three elements have been suggested as crucial to effective flood hazards management: 1) the lifecycle of a flood hazard, 2) the 30- to 40-year time frame of planning, and 3) the need to systematically integrate the three major methods of dealing with flood hazards; modifying the hazard, moderating the impacts, and reducing the risks.

The formal calculation of costs and benefits is a well-established, if not a paramount, element in flood control planning. The following section highlights the practical limitations of this technique. A framework is presented for a larger range of considerations that could usefully enter into those aspects of policy planning concerned with selecting and organizing the techniques and strategies for dealing with flood hazards.

BEYOND CALCULATING COSTS AND BENEFITS

The Flood Control Act of 1936 established the basic national flood management policy that prevailed for the next three decades. This policy emphasized reliance on massive flood control projects that would be built largely at Federal expense. (As a consequence of earlier "308 studies"* carried out by the Corps of Engineers, several hundred flood control projects were under consideration in 1936.

The Act specified that no project would be authorized by Congress unless its total benefits exceeded its total costs "to whomsoever they may accrue. " This rule established a requirement for cost-benefit analysis in planning water resource projects. It was supplemented by the National Environment Policy Act of 1969 (Public Law 91-190), which requires that environmental impact statements be prepared for major Federal projects affecting the environment. An inherent shortcoming of applying cost-benefit analysis to water resource projects is that it has only served to justify individual projects, and even in these cases it has involved somewhat questionable assumptions about future costs and benefits. On the whole, cost-benefit analysis has been used to address basinwide or regional planning.

Alternative nonstructural measures have often been ignored as possible means of managing flood losses. For example, floodplain zoning to define land use could be used to limit the encroachment of development on downstream floodplains below a flood control dam. In the absence of a comprehensive analysis of the costs and benefits of alternative or complementary measures, flood losses have increased steadily since the 1936 Act as a consequence of the continued encroachment on downstream floodplains that are believed to be totally protected by flood control structures. If there is a flood that exceeds the capacity for which the protective structure was designed, great damage occurs.

During the 4 years, 1974-78, there were 127 floods, which the President declared were disasters, that exceeded the 100-year flood level.[6] There are, in fact, several thousand civil works that were designed to protect against the 100-year flood level. (This is the flood level that is used as the most common basis for designing protective civil works.) It would appear, therefore, from the above statistics that every year a number of these will be exceeded.

*"308 Studies" are provided for by the Rivers and Harbors Act of 1927, Public Law 560. These studies were among the earliest involving integrated planning.

[6]Richard Krimm, Federal Insurance Administration, OTA Workshop, Mar. 21, 1978.

Unfortunately, encroachments on downstream floodplains have frequently been anticipated and counted as benefits in the cost-benefit analysis for a given project. Initially, the benefits of flood control works were determined by the projected reduction of damage to existing buildings and associated activities in the floodplain. However, the method and tone of justification have been modified to include the reduction of property losses to future structures. Krutilla explains that "of 59 Corps of Engineers projects authorized by the 1965 Act that were 'justified' wholly or in part by flood control benefits, from 3 percent to 85 percent of the total flood control benefits were accounted for by expected future development in the floodplain. For half of all the projects, the proportion of benefits represented by anticipated future development in the floodplain amounted to over 40 percent. Approximately half of the single-purpose flood control projects would not have been 'justified', save for the anticipated more intensive use of the floodplain stimulated by the flood control projects "7

As civil works attract more people and property into flood hazard areas, the groundwork is laid for catastrophic floods because relatively unregulated growth is permitted. The situation is exacerbated by the possibility that poorly designed protective civil works may fail structurally. White elaborates:

> . . . Each stream reach protected by levees or dams is candidate for a flood exceeding the design capacity of the planned control works. The design rarely attempts to cope with a theoreticall y maximum possible event.[8]

The total cost of floods and flood hazards should include the losses directly associated with the floods themselves, and the construction and related infrastructure costs for flood control and flood hazards management. It is also useful to consider the costs that are not directly reflected in the Government outlays, such as changing land values and lost time and labor. The calculation of costs is complicated by the related matter of benefits. It turns out to be surprisingly difficult to ferret out and make sharp distinctions between costs and benefits.

As pointed out above, it is a frequent practice to include in the benefits the development of a floodplain that results from the security provided by flood control measures. But, viewing floodplain development as favorable puts new resources at risk that become potential costs when the flood control measures fail, as they ultimately must. The costs and benefits of natural hazards management should be treated in terms of a total lifecycle of development, from initial occupancy of the floodplain or coastal zone, through the flood disaster itself and the recovery period. Cost should also include the new risks generated by hazards management, operating costs, and private, personal, and business costs. A number of the factors that enter into a comprehensive cost-benefit calculation are shown in tables 11 and 12.

The complexity of a broad framework for flood hazards management cannot be overestimated. It is reflected in the following conditions that must be taken into consideration by any strategy for reducing flood damage.

- Impacts are marginal, not drastic or extreme.
- Impacts are chiefly economic or can be readily translated into economic or quasi-economic values.
- Impacts are chiefl y direct.

However, even when cost-benefit analysis meets the above conditions, it may have, in practice, a number of serious limitations.

- It only provides a narrow range in which to search for possible impacts, and as normally practiced, does not actively search for all the impacts on society and the environment.
- It cannot deal satisfactoril y with questions of equity involving the distribution of costs and benefits.
- It tends to distort or ignore impacts that cannot be directly measured in dollars.
- It tends to exclude externalities, indirect, and long-term effects.
- It does not alert decisionmakers to previously unsuspected risks or unidentified uncertainties.
- All of the above tend *to* become magnified when dealing with unprecedented technologies or projects ..?

[7] John V. Krutilla, "An Economic Approach to Coping With Flood Damage," Water Resources *Research*, **1966, p.** 185.

[8] Gilbert F. White, F/. *Hazard in the United States: A Research Assessment*, Monograph #NSF-RA-E-7 5-006 (Boulder, Colo.: Institute of Behavioral Science, University of Colorado), **p.** 32.

[9] V. T, Coates, *A Handbook of Technology Assessment* (The George Washington Universitv, March 1979).

Table 11.-Identification of Costs by Sector

Category	Agricultural	Business	Organizational	Personal	Public
Direct . .	—Structural/building —Croplosses —Land and soil —Damage -Machinery/equip. -Cleanup –Other	–Inventory —Structural/building —Furnishings —Machinery/equip. —Avoidance —Cleanup –Other	-inventory -Structural/building —Furnishings -Machinery/equip. —Cleanup -Relief effort -Other	–Structural/building –Contents —Avoidance -Cleanup –Other	—Structural/buiiding —inventory —Furnishings -Machinery/equip. —Avoidance —Cleanup —Other
indirect.	-Lost productivity —Lost man-days —Land value	-Lost man-days —Lost business profit —Transportation problems —Property values	—Lost "man-days	—Transportation problems –Man day of effort to combat flood —Loss of wages —Property values	-Lost man-days —Redirection of effort to the flood —To estimate damage —Transportation problems —Opportunity cost/benefit of funds used to compensate victims —Cost of disruption of Government activity
Intangible . .		-Elasticity of new investment	—Loss of recreation enjoyment	-Exhaustion —Family separation –Loss of life —inconvenience	

SOURCE: Environment Canada, Technical Bulletin No. 81, P. 78, Halifax, Nova Scotia. 1974.

Table 12.-Identification of Benefits by Sector

category	Agricultural	Business	Organizational	Personal	Public
Direct . .	-Silt deposits	—Sale of damaged goods			
Indirect.	-Difference in price	-Flood recovery business prosper		—Relative decrease in property taxes	—Multipler effects of block infusions of Federal cash into the provincial economy —Multiplier effects of transferring public funds into private hands
Intangible . .	—Flood experience	— Flood experience	—Emergency training	—Flood experience –Unaffected got curiosity fulfilled —Unexpected public holiday —Other intangible benefits	—Emergency training —Sense of pride and accomplishment

SOURCE: Environment Canada. Technical Bulletin No. 81, P. 79, Halifax, Nova Scotia. 1974.

Further problems with cost-benefit analysis arise when faced with decisions and choices about:

- discount rates,
- the scope of benefits and costs entering into the analysis,
- the selection of alternative projects for comparison,
- double counting, and
- when an effect is a cost or a benefit.

Considering the limitations of cost-benefit analysis, a broader analytical framework appears to be required to develop the policy approaches and strategies needed to reduce flood damage. It is suggested here that the concept of technology assessment would provide such a framework.

Technology assessment (TA) is a type of policy study that attempts to provide decisionmakers with a base of information about the possible societal consequences of developing a new technology or of significant changes in an existing technology. It is an open-ended search, using various techniques both qualitative and quantitative, for the potential impacts of a technological development on the economy, on the environment, on the polity, on social behavior, and on social institutions. TA examines what the need, the desirability, and the justification are for Government to intervene in order to stimulate or control the development of a new technology. It attempts to delineate the uncertainties involved in such an intervention as well as the societal costs and benefits; and it presents decisionmakers with a set of alternative or complementary policy options along with their long-range implications.

Recently, the application of TA throughout the Federal Government was reviewed.[10] There was little indication that TA under that or any other name was being used by the Corps of Engineers at the district or operating level as a policy tool for flood management. The Institute of Water Resources (IWR), however, does carry out a substantial amount of TA related studies.

IWR was created by Congress in 1969 to assist the Corps of Engineers in meeting new planning requirements arising from the public's concern over the environment and the quality of life. The principles and standards (P&S) published by the Water Resources Council in 1972, required planners to take into account regional development, economic development, environmental quality, and social well-being. In response, in 1975 the Corps promulgated a series of regulations (the 200 series) that provide guidelines to Corps planners for multiobjective planning. Many of the concepts of TA can be found in these regulations.

TA related activities are going on to some extent at the Waterways Experiment Station (Vicksburg, Miss.). The Station's report on water resources assessment methodology contains impact assessment and alternative evaluation intended to assist planners in meeting the social impact requirements of Corps regulations. The Construction Engineering Research Laboratory (Champaign-Urbana, Ill.) is also conducting research related to social impact assessment and the North Central Division of the Corps is in the initial phases of a study of the impacts of winter navigation in the Great Lakes.

In working towards a more comprehensive and effective decision-oriented planning process that uses TA concepts, the following 12 preliminary questions should be addressed before implementing any strategy to reduce flood damage.[11]

- What **systems** are affected by floods? (i.e., what entities are susceptible to flood damage? What are the kinds and causes of flood damage? What is the relative importance of the various kinds of damage? What priorities should these be given?)
- What are all the **alternative strategies** for preventing or significantly reducing the various kinds of flood damage?
- What **elements** of flood damage does each strategy significantly address? What degree of impact does it have?
- Is each particular strategy based on, or can it be supported by, **adequate data?**
- How does each strategy **compare** with others in its degree and scope of effectiveness, in its costs, and in its feasibility.
- What other strategies and measures must each be **linked to** in order to be maximally effective?
- Would the strategy work at **cross-purposes** to, or be neutralized by, any other measures to reduce flood damage? Might the strategy undermine another more effective strategy?
- Might the strategy have the effect of actually **increasing** certain kinds of potential flood damage?
- Is the strategy appropriate to or equally adaptable for **all types of flood-prone areas?**
- **Is** the implementation of the strategy **compatible with all the other requirements of the system** it affects? (For example, are specifications for elevated foundations compatible with the specifications for earthquake-proof foundations in areas—such as the west coast—where flood and earthquake zones overlap?
- What, if any, are the specific benefits of flooding? Of locating within a floodplain? How do these benefits compare with damage costs for each vulnerable area?
- Outside the issues of flood damage, what are the positive and negative **side-effects** that this strategy might have? What other policy areas intersect with flood policies? (e.g., a national land use policy, environmental impact policies, etc.)

[10] Program of Policy Studies in Science and Technology, *Technology Assessment in the Federal Agencies* (The George Washington University, March 1979).

[11] American Institute of Architects, An *Evaluative Approach to Alternative Strategies for Flood-Damage Intervention*, June 1974, p. 2.

Four elements useful in promoting an integrated approach to flood hazards management have been considered in this chapter.

- the concept of a flood hazard lifecycle,
- the time frame in which to plan flood-reducing policies,
- the array of tools available to Government for managing flood hazards, and
- technology assessment as an analytic strategy to expand the decisionmaking value of cost-benefit analysis.

In the next chapter, trends in flood hazards management as they relate to the concept of a flood hazard lifecycle will be discussed in order to elucidate current issues and future options.