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NATURAL HAZARD RESEARCH

Working Paper No.

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PREFACE

This Working Paper initiates a series on research in progress in the field of human adjustments to natural hazards. It is intended that these papers will be used as working documents by the group of scholars directly involved in hazard research as well as inform a larger circle of interested persons. The series is now being supported from funds granted by the U.S. National Science Foundation to the University of Chicago and Clark University. Authorship of papers is not necessarily confined to those working at these institutions.

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THE HUMAN ECOLOGY OF EXTREME GEOPHYSICAL EVENTS

A paradox is presented in man's apparently growing susceptibility to injury from natural hazards during a period of enlarged capacity to manipulate nature. In many countries flood control dams are repaying the capital invested in their construction by preventing flood losses that would otherwise have occurred; arid and semi-arid lands are being made agriculturally productive by the provision of irrigation water from canals and tube wells; snow removal operations are increasingly effective and weather forecasting has improved in reliability and length of range. Nature retreats on every hand and man, armed with a burgeoning technology, is asserting his ecological dominance yet more surely.

Nevertheless, in every month the mass media report in dramatic fashion the occurrence of natural disasters in North America and around the world. Within the recent past a cyclone in East Pakistan, an earthquake in Turkey, and a drought in southern Africa have demonstrated the perils to which man is heir. In fall 1966 floods in Florence were responsible for much human suffering and for damage to paintings, sculpture and books that constitute part of the priceless heritage of western civilization.

An estimate of total losses from selected geophysical hazards in the United States is given in Table 1. These are

Table 1

Estimates of average annual losses from selected geophysical hazards in the United States. Single year estimates are the level of average losses current to year cited. Property damage figures are in millions of dollars unadjusted unless otherwise noted.

HAZARD	Loss of Life			Property Damage		
	No.	Period	Source	Amount	Period	Source
Floods	70	1955-64	(1)	1000	1966	(2)
				350-1000	1964	(3)
				290	1955-64	(1)
Hurricanes	110	1915-64	(1)	250-500*	1966	(4)
				100	1964	(3)
				89	1915-64	(1)
Tornadoes	194	1916-64	(1)	100-200*	1966	(4)
				40	1944-64	(1)
Hail, wind and Thunderstorms				300	1967	(5)
				125-250*	1966	(4)
				53	1944-53	(6)
Lightening Strikes and Fire	160	1953-63	(1)	100	1965	(1)
Earthquakes	3	1945-64	(1, 7)	15	1945-64	(1, 8)
Tsunamis	18	1945-64	(1, 8)	9	1945-64	(1, 9)
Heat and Isolation	238	1955-64	(10)			
Cold	313	1955-64	(10)			
TOTALS	1106			621-2174		

* Insured losses only

the hazard extremes which cause marked human suffering and social dislocation. Annual average damage from all extreme geophysical events is probably between two and three billion dollars a year (11). Social costs seem to be mounting rather than declining.

To understand this paradox it is necessary to examine in ecological perspective the impacts of natural hazards upon human society and the range of response to them. Persistent settlement and use of areas subject to recurrent natural hazards has long excited the curiosity of geographers who have noted that men return to rebuild their devastated settlements in flood plains, on the slopes of volcanoes and in zones of high earthquake activity, and who have recorded the surging waves of success and failure in areas of scanty, uncertain rainfall (12). Awareness of the risk of repeated disasters probably is higher in modern man, but the pattern of reinvasion of hazard areas is no less than in the past, and is very probably stronger.

While the research reported here has revealed many new questions, it also has some significant implications. The most serious of these is that mankind appears to be little nearer the conquest of nature in its more violent and extreme fluctuations. Rather, the magnitude of the impact of rare natural events upon society is increasing in terms of real property damage and loss of life, although there is verbal

reluctance to accept these costs. This phenomenon may be explained in simple terms by the continuing spread of man and his works over greater areas of the earth's surface and his presence in more places in greater numbers than before. In addition to the "real" increase in the impact of natural hazards, the "apparent" increase is due to improved communications which spread the news of the latest disaster to more people more rapidly, and to an increasing expression of intolerance for the vagaries of nature in an age of powerful technology. Natural hazards become greater problems in the minds of men as affluence spreads and as recognition grows of a social responsibility to cushion all members of a society against unexpected hazards.

In a distinctive way the question of man's capacity to shape a livelihood free from disruption by environmental extremes draws together analysis of both physical and social processes. Over the past decade two distinct lines of research have evolved. One approach is exemplified by the NAS-NRC disaster research group (13, 14, 15, 16) and the work of the Disaster Research Center at Ohio State University (17). This work, mainly by behavioral scientists, apparently developed in the search for analogs with nuclear disaster and has been primarily concerned with human behavior during the emergency period and under great stress. This characteristic distinguishes it from the second approach, illustrated by the

research reported here, which has been concerned with the long run persistence of settlement in hazard areas and with associated attempts to regulate the hazards.

Recent investigations of floods, drought and earthquake suggest that much technological manipulation of environment produces new hazards while ameliorating old ones, and that effective design of social measures for coping with extreme events calls for a sensitive understanding of natural phenomena as altered by complex social relationships. Such a stance is consistent with one strain of geographic research as outlined by Harlan H. Barrows who saw geography as human ecology or the study of the adjustment of man to his environment (18). From that viewpoint man interferes with the complex systems of air, water, soil and life that surround him, and seeks to isolate himself from many aspects of the natural world, to reconstruct others, and to adjust in varied ways to the rhythms and discontinuities of the resulting environment. In studying these interactions, it may be helpful to combine an anthropocentric notion of ecological human dominance with a normative concern for understanding the implications of human actions and taking responsibility for them. This normative concern is tempered by the hypothesis that man, while capable of powerful actions, possesses severe and shifting limits on both his ability to perceive and understand the world around him and to choose

among appropriate courses of action (19). These limitations, arising from nature, personality, society and culture, provide the bounds within which rational action may take place.

The broad setting of the study of man-environment relationships, the philosophical stance of the bounded rationality of man, and the methodology of behavioral science make it possible to approach the long term human adjustment to natural hazard along five lines. Minimal understanding of conditions upon which social policy might be based would involve research helping to 1) assess the extent of human occupance by hazard zones, 2) identify the full range of possible human adjustments to the hazard, 3) study how man perceives and estimates the occurrence of hazard, 4) describe the process of adoption of damage-reducing adjustments in their social context, and 5) estimate the optimal set of adjustments in terms of anticipated social consequences.

To seek these goals we have sought to identify an inhabitant's view of the hazard. The attitudes of flood-plain residents have been a primary concern and about 2,000 in-depth interviews with residents of riverine and tidal flood plains have been collected (see <u>Table 2</u>). There has been a wide adoption of behavioral science techniques, not new in themselves, but not hitherto employed extensively in geographical research. These include the use of both

Table 2

Personal Interviews with Natural Hazard Zone Occupants

Type of Hazard	Date	No.	Principal Investigator(s)	Location
Flood	1960	103	Roder (20)[1]	Topeka, Kansas
	1960	71	Burton (20)	Hammond, Munster, Ind.
	1960	150	Burton (21)	Rural areas in 12 states
	1961	178	Kates-White (22, 23)	Tenn., Calif., Wisc., N.Y., Ohio
	1963	20	Burton (24)	Belleville, Ontario
	1963	38	Kates (25)	Connecticut
	1963	70	Sewell (26)	Fraser Valley, B.C., Canada
	1966	1022	Czamanske (27)	Ga., Ill., Pa., La., N.J., W. Va., N. Car.
Coastal Storms	1964	361	Burton, Kates Mather, Snead (28)	East Coast of U.S., Maine to N.C.
Drought	1965	100	Saarinen (29)	Great Plains
	1966	70	Kates-Arey[2]	Massachusetts
	1965	249	Rooney (30)	Wy., S. Dak., Ill.
	1966	20	Burton[3]	Ontario snow belt, Canada
Tsunami	1966	211	Havighurst (41)	Oahu, Hawaii

1 Figures in parentheses refer to published accounts in references.

2 In process.

3 Unpublished source.

structured and unstructured interviews (20), thematic aperception tests (29), content analysis of news media (30), models of decision-making (31,22), benefit-cost analysis (23, 24), and new and extended uses of probability theory (23). New uses have been made of traditional geographical methods: land-use mapping, and air-photo techniques (32, 21, 28).

Extent of Human Occupance

Estimates of several kinds have been made primarily with respect to the United States. There are approximately 2,000 cities in flood plains in the United States (32) and 200 communities with populations over 1,000 similarly located in Canada (33, 26). At least five per cent of the area of the United States is subject to flood (2, p. 12). There are about 125,000 structures on the outer shore between Maine and North Carolina less than ten feet above mean sea level (28). A quantity of real property approximately equivalent to the housing stock of Boston is situated in this highly exposed and vulnerable position.

Beyond these estimates little is known. We are aware of only one effort to assess the joint probability of several hazards at one place (34). While many more such estimates of occupance could be made (e.g., of areas subject to a specified

level of risk from hail, tornadoes, tsunamis, etc.), problems of definition and doubt as to their value in relation to the amount of effort required to make the estimate appear likely to inhibit large-scale efforts in this direction. For example, a flood is sometimes said to begin when a river overflows its banks or when rainwater ponds up in poorly drained areas. By another criteria, no flood occurs until damage begins. The delimitation of drought areas well illustrates the illusive character of hazard as defined in human terms. A designation of a drought area by the Russell formula (35) or by the more recent Palmer index (36) assumes that a certain duration and intensity of moisture deficiency will be injurious to agriculture. A change in the genetic characteristics of cultivated plants or in methods of curbing losses in soil moisture would necessarily alter the critical limit.

Every definition of hazard requires assumptions as to human aims and modes of adjustment. Selection of critical physical parameters of flood flows or drought duration is influenced by and, in turn, influences judgement as to what types of adjustment will be desirable.

Further work in the delimitation of hazard areas and measuring the extent of occupance would nevertheless be of value as an aid in understanding the magnitude of the hazard. Just how useful it can be in reducing losses is subject to

question and the answer depends upon perception and choice criteria to be noted . The authors, like many others, believe that in favorable conditions, by informing and educating the public, it is possible to help in the development of improved public policies. Efforts in these directions with respect to floods are being made by the Tennessee Valley Authority which has published flood hazard reports for more than 115 communities since 1950; the U.S. Geological Survey which has issued flood hazard maps in its hydrologic atlas since 1959; and the Army Corps of Engineers which now is embarked upon a national flood plain information program. As an interim measure the Corps is compiling for other Federal agencies a list of all towns having a significant flood hazard. In Ontario, flood hazard estimates have been made for a number of communities by the Conservation Authorities Branch (37).

Beyond problems of definition the question of trends in hazard-zone occupance by degrees of hazard is of special significance. On the outer shores of megalopolis in the period 1940-60 a greater relative increase of structures has occurred below mean high water than in the area above that level (28). An increase in the proportion of flood damage of a catastrophic nature has also been noted and reflects increased occupance of the more hazardous flood plains as well as the failure of engineering structures to contain

extremely large discharges (38). Relative changes in occupance of hazard zones is in part a function of the pattern and range of human adjustment.

Range of Human Adjustment

To any given natural hazard there is a wide range of theoretically possible adjustments. The theoretical range of adjustments to flood, snow and earthquake is given in Table 3. A much more simple graphic device in common use for public information purposes by the Tennessee Valley Authority is reproduced as Figure 1. It might be thought obvious that this full range would be recognized by intelligent occupants of a hazard area as well as by professional observers, but that rarely happens. We find few instances in which all the theoretical possibilities are canvassed.

In examining these adjustments it is useful to make a distinction between those which seek to rearrange or manipulate nature and those which involve a rearrangement or alteration of human behavior. The former may be equated with the technological approach to hazard problems, the latter with the social or behavioral approach. The technological approach emphasizes the construction of dams and levees to control floods; sinking of new and deeper wells in periods of drought; cloud seeding to increase rainfall in

Table 3

Theoretical Range of Adjustments to Geophysical Events

Class of Adjustment	EVENT		
	Earthquakes	Floods	Snow
Affect the cause	No known way of altering the earthquake mechanism	Reduce flood flows by: land-use treatment; cloud seeding	Change geographical distribution by cloud seeding
Modify the hazard	Stable site selection: soil and slope stabilization; sea wave barriers; fire protection	Control flood flows by: reservoir storage; levees; channel improvement; flood fighting	Reduce impact by snow fences; snow removal; salting and sanding of highways
Modify loss potential	Warning systems; emergency evacuation and preparation; building design; land-use change; permanent evacuation	Warning systems; emergency evacuation and preparation; building design; land-use change; permanent evacuation	Forecasting; rescheduling; inventory control; building design; seasonal adjustments (snow tires, chains); seasonal migration; designation of snow emergency routes
Adjust to losses:			
Spread the losses	Public relief; subsidized insurance	Public relief; subsidized insurance	Public relief; subsidized insurance
Plan for losses	Insurance and reserve funds	Insurance and reserve funds	Insurance and reserve funds
Bear the losses	Individual loss bearing	Individual loss bearing	Individual loss bearing

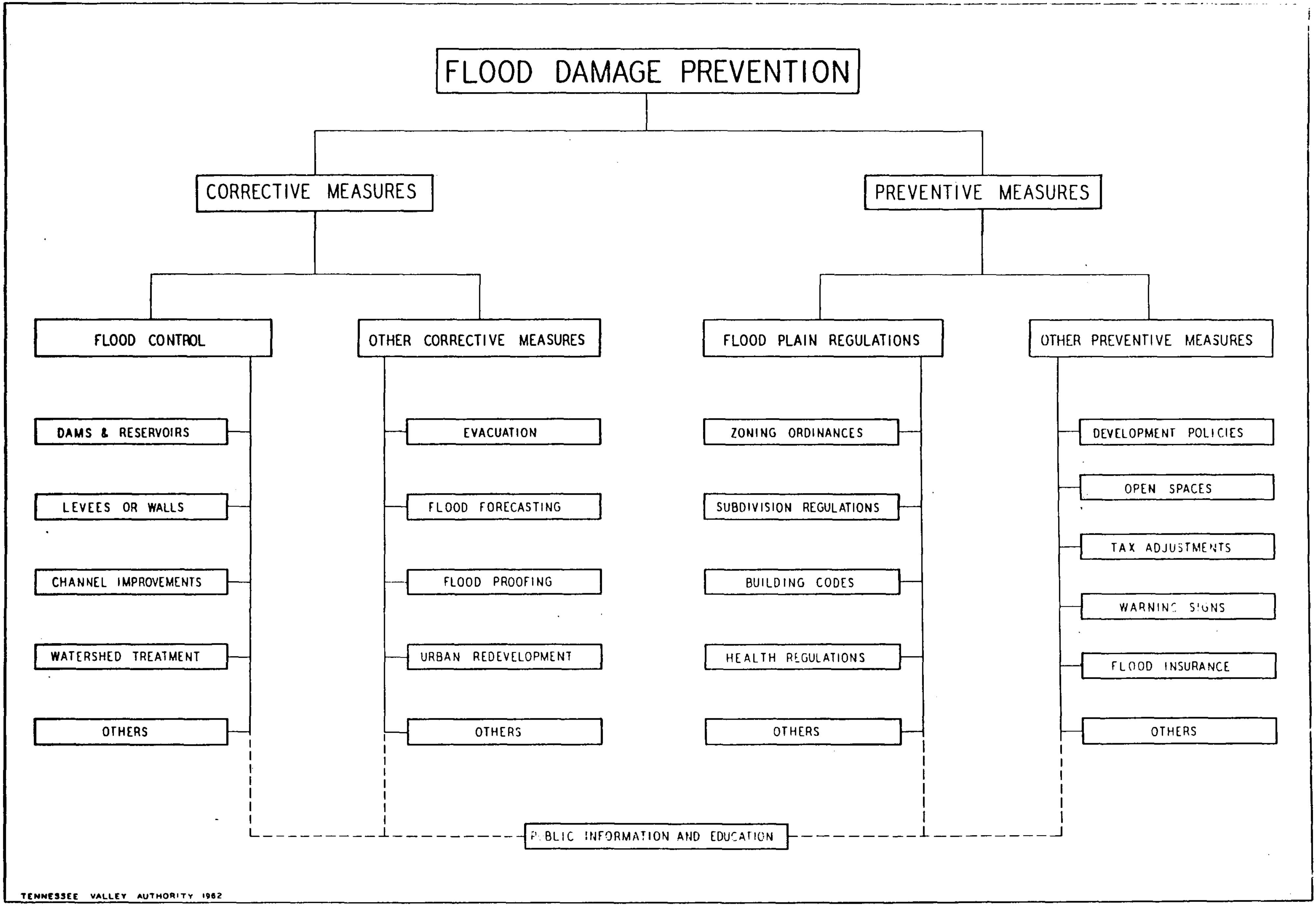

Figure 1. Diagram of alternative measures for preventing flood losses. This was prepared by the Local Flood Relations Division of the Tennessee Valley Authority for use with local planning agencies.

sub-humid areas; and the buttressing of potential slide areas in earthquake zones. All these actions are directed to affecting the cause of the problem or to a modification of the hazard itself.

The social or behavioral approach emphasizes the careful planning of flood-plain land use; more cautious use of water and/or curtailed water use in times of drought, and use of legislative guides to encourage better building design for earthquake resistant structures (39). The prevailing public approach has been to offer immediate relief and then to turn to the technological approach. Dams follow floods, irrigation projects follow droughts.

The dichotomy between technological and social adjustments is useful, but can also be misleading. It is not intended to imply that technological adjustments are not required, but that they should be used cautiously and in conjunction with a knowledge of their likely effects. This knowledge can then be used to call into play the appropriate social adjustments as well. The dichotomy is further complicated because it coincides, to a large degree, with different allocations of costs. Technological solutions are commonly carried out largely at public expense. Social adjustments are often left to private citizens, or their cost is borne largely by a few people. There is often strong pressure, therefore, for technological solutions because they involve a shift of the

costs away from vociferously objecting individuals to the society at large. The fact that overall costs may thereby be increased does not appear to act as a deterrent. An obvious conclusion is the need to place the burden of costs for technological solutions more desirably on the shoulders of those who benefit and/or to find ways of carrying out social adjustments partly at public expense through the use of subsidies, incentive payments and the like.

From the standpoint of human ecology, a recent bias has been to encourage recognition of the possible social and behavioral adjustments and to study the impact of technological adjustments on human behavior and society. We find that when carried out in isolation without adequate reference to social considerations, the technological adjustments may lead to an aggravation of the problem rather than an amelioration, as when upstream reservoir construction encourages increased invasion of a Tennessee valley flood plain at Chattanooga. Commonly, the benefits received are short run, and involve the elimination of numerous "small" losses at the cost of greater long-term losses often of a catastrophic nature.

Control of floods seems to induce more rapid development of flood plains, plus a relaxation of emergency preparations. Thus a consequence of adopting the technological fix is the relaxation of preparations for other, more extreme, action.

This has been observed in both urban and rural areas (21, 32). In some agricultural areas on large flood plains, the severing of farm units by the construction of levees has permitted the cultivation of more valuable crops on unprotected land by giving farmers a more secure base for their operations on the protected farmland. In providing the partial protection of levees for part of a farming operation the technological approach also encourages a more speculative utilization of more hazardous land. This "levee effect" has been observed on the flood plains of the Mississippi and Rio Grande Rivers (21, 40).

Hazard Perception

One principal reason that public information as to hazard has not led to rapid and solid adjustments is that there is great difference among individuals in perception of hazards. It has been found useful to distinguish between professionals (those for whom dealing with one or more natural hazards is a professional occupation that commands their continued attention) and non-professionals (for whom hazards are incidental to their main pursuits). The perceptions of the two groups rarely correspond, but this is not necessarily because non-professionals are simply ignorant or stupid. Professionals often express their ideas

in a way which non-professionals find confusing. For example, non-professionals often assume that the hydrologist's 100-year flood occurs once every hundred years. While such a mistaken view may affect the choices made and the actions taken or neglected, it also conforms to a non-professional penchant for making events knowable and cyclical.

We find that non-professionals have a higher degree of awareness of hazard than is commonly assumed by professionals and that total ignorance is very rare, although the frequency and probability of a hazardous event is often distorted from the scientific description. This is frequently done by making phenomena determinate in the form of an assumed cycle of periodicity. On the other hand, while the professional view incorporates stochastic probabilities comfortably, the estimates of frequency and magnitude are not as good as they are often assumed to be by the non-professional. The unreliability of professional hazard estimates can reasonably be explained by the fact that the events themselves are often infrequent and the period of record is short by comparison. This results in a lack of adequate knowledge of the underlying distribution of extreme events, and no one theory yet commands widespread acceptance. In this regard, professionals often mislead non-professionals in much the same way and for the same reasons that medical doctors do in their legitimate efforts to preserve a doctor-patient relationship.

Professionals are required to make difficult judgements but they must maintain their client's confidence if they are to continue to be useful. Thus the engineer's client or the doctor's patient usually receives a final judgement or diagnosis that fails to convey the full range of uncertainty that was involved.

A fundamental difference between the two groups therefore appears to be in their tolerance of uncertainty. We have categorized common attitudes to the uncertainty of natural hazards among non-professionals in Table 4. Readers may see parallels to their own attitudes to hazards. Non-professional views are shared by all who are involved with hazards in an incidental fashion. From this rule, we would by no means exclude ourselves.

Adoption of Adjustments

A model of decision-making has been developed (31) which helps to explain the adoption process. Under this the choice made by individuals in the face of hazard is seen as affected not only by their perception of the hazard itself, and the range of choice open to them, but also by their perception of the technology which they command, the economic efficiency of the alternatives, and their linkages with other people. Social constraints and incentives can shape the decision.

Table 4

Common Responses to the Uncertainty of Natural Hazards

Eliminate the Hazard		Eliminate the Uncertainty	
Deny or Denigrate Its Existence	Deny or Denigrate Its Recurrence	Making it Determinate and Knowable	Transfer Uncertainty to a Higher Power
"We have no floods here, only high water."	"Lightning never strikes twice in the same place."	"Seven years of great plenty . . . After them seven years of famine."	"It's in the hands of God."
"It can't happen here."	"It's a freak of nature."	"Floods come every five years."	"The government is taking care of it."

Empirical evidence from personal interviews suggests that adoption of damage-reducing adjustments bears little or no relation to age or education. There is a weak relationship with previous experience that becomes most evident in areas where very heavy damage has been sustained. Adoptions do not appear to be related to socio-economic status except where the cost is high (28, p. 584, 22, p. 78). There is a strong relationship, however, between adoptions and frequency of hazard and especially the perceived frequency of hazard. A large number of adoptions are made by a high proportion of the population where the probability of a hazard occurrence is high, and where the perceived frequency is equated with positive certainty (i.e., it will happen). There are very few adoptions by a small proportion of the population where probability of a hazard occurrence is low and where the perceived frequency is equated with negative certainty (i.e., it will not happen). The most interesting situation lies between these extremes, where the frequency of the hazard is intermediate and high variability of perceived frequency is observed in the population. Here wide variations are found in the adoption of adjustments by people in similar circumstances, and wide variations are also to be expected in the proportion of population from place to place making any particular adjustment. These findings are graphically presented in Figure 2. The figure is not intended to imply

a continuous distribution of responses to changing flood frequency. Both in urban areas and on agricultural flood plains there appear to be discrete points of frequency at which the human response shifts. These occur at recurrence intervals of 1-2 years and 4-5 years (21, 22, 25).

The full range of adjustments seems more likely to be considered by non-professionals under conditions of positive certainty than otherwise. The dominant approach of many professionals, under any level of hazard frequency is to exhibit a strong preference for the technological fix. This appears to stem from a strong belief on their part in the efficacy of technology and a distrust of "social engineering" or adjustments in social and behavioral responses. Technology as exemplified in the flood control dam is seen as more dependable than social engineering with its plan to evacuate persons and property upon receipt of a flood warning, where the unpredictable behavior of many people is involved. On the other hand, there is a large school of professionals who eschew exclusive reliance upon technology and emphasize the subtle human adjustments to an unmodified nature. This was the strong theme of successive geographic analyses of Great Plains drought ranging from Powell's recommendations as to integrated land and water use patterns (42), to the Great Plains Drought Committee's proposals for readjustment in farm management plans (43).

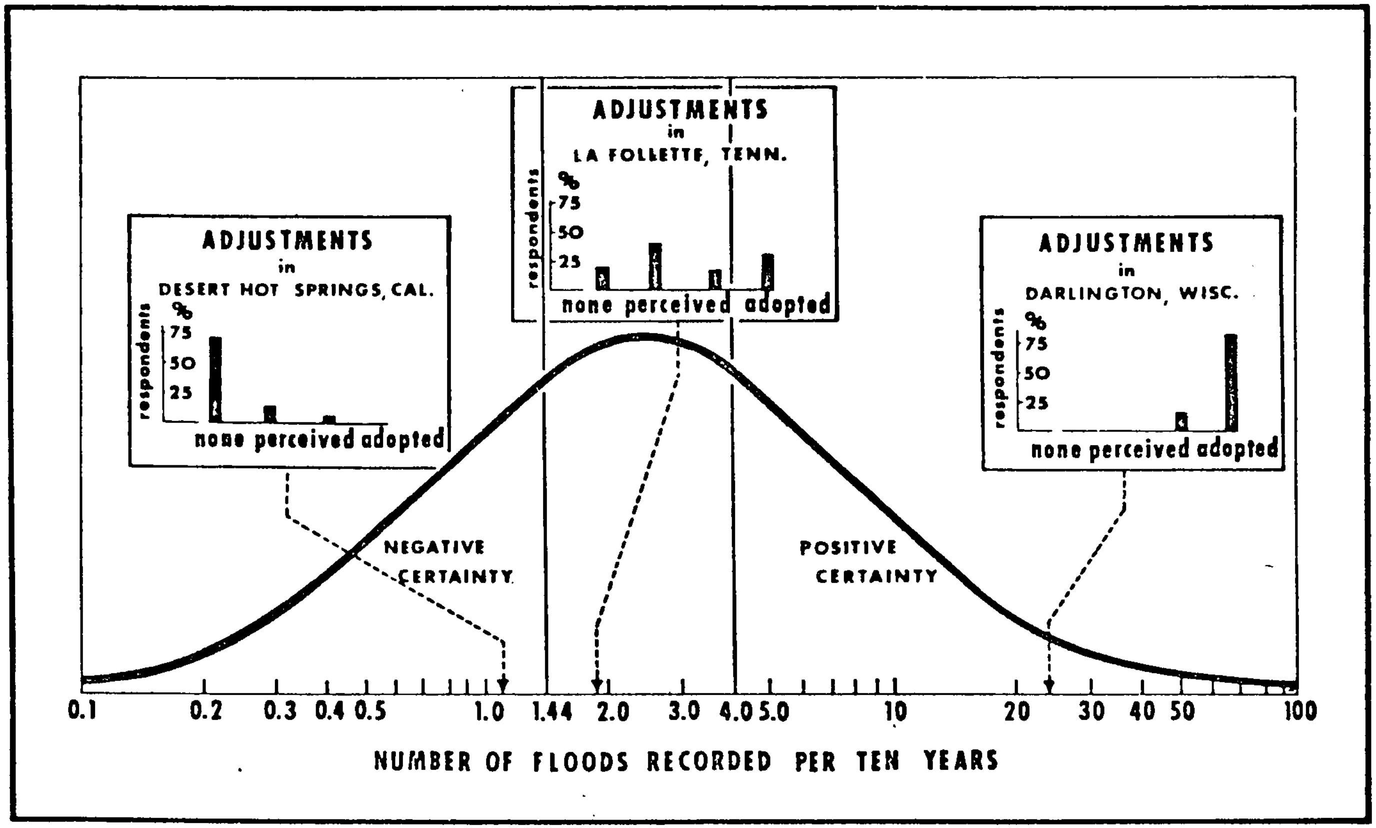

Figure 2. Superimposed on a log-normal distribution of 496 urban places for which flood frequency data were available are a series of insets showing perception and adjustment at three sites. Adjustment is scaled from total ignorance (none), through two levels of perception (perceived), to adoption (adopted). We suggest that the variation in perception and adoption is related to flood frequency, and even more so to perceived frequency shown hypothetically as negative and positive certainty.

Optimal Adjustment

Although little research effort of the type reported has focussed on the optimizing procedures developed by economists, occasional use has been made of such methods and they are always present as a criterion of evaluation in theoretical terms (23). Rational economizing approaches such as cost-benefit analysis, program budgeting and systems analysis appear to be most useful where the problems are well defined in terms of risk probability and in terms of streams of benefits and costs. Such techniques seem less appropriate and less useful under the conditions of uncertainty and the complex benefit streams commonly associated with rare and extreme events. Complacent optimism about the future role of these analytical techniques is not warranted in a society where uncertainty is of increasing significance. Much interest has centered, for example, on the selection of an appropriate discount rate for reducing expected future benefits to present value. It appears, however, that the results in terms of economic analysis from adopting the range of discount rates now used and proposed is less than the consequences of uncertainty in how to interpret the hydrologic record (23).

Had the latent power of the Arno River been fully recognized in 1956, would any different set of adjustments have been adopted by the citizens of Florence before the

great flood hit them ten years later? How would they have computed their social costs and gains, given the uncertainty of an event that might not come for another 1000 years?

An abridged schema for human adjustment to flood is given in Figure 3. This is designed to show the major choices and their outcomes available to a manager of an industrial plant in the Lehigh Valley, Pennsylvania. The schema also illustrates the opportunity for individual and collective choice and for social engineering (change land use) or for technological adjustments (protection). The optimal choice may normally be assumed to involve some combination (23, 44).

When the economically optimal combination of adjustments mixes measures that commonly are taken by individuals, as in the case of flood proofing, with public measures, such as levee construction or land acquisition, it is extremely difficult to state it as a practicable alternative. Yet such combinations are feasible and they do exist, as on the Golden Triangle in Pittsburgh (45). The unified national program for flood loss management indicates how a variety of national policies (highway planning, urban renewal, mortgage financing and the like), might be articulated so as to foster intelligent conscious choice at the local level (2). This was the first concerted effort by public agencies to deal with all aspects of public action bearing on a

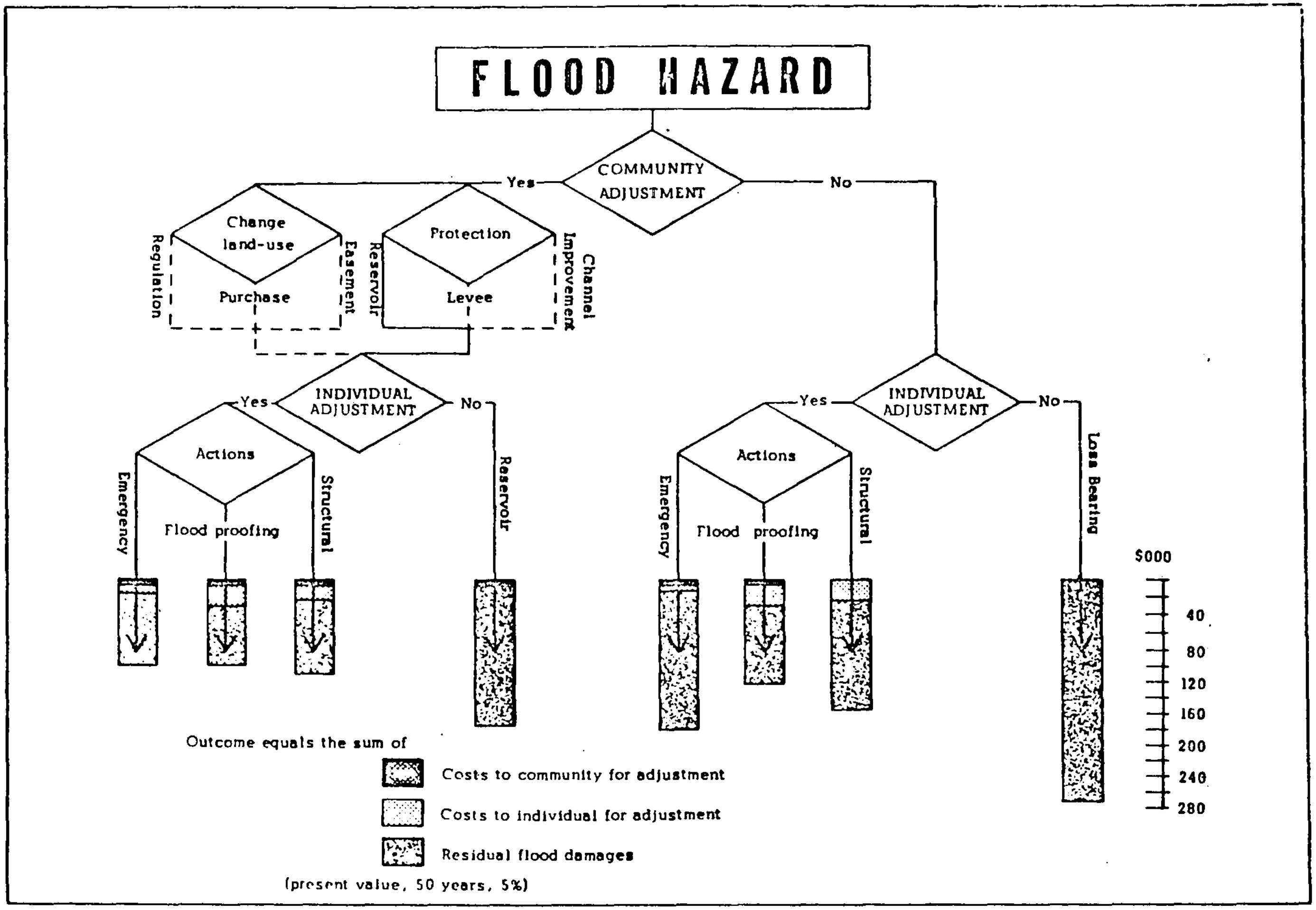

Figure 3. An abridged schema of human adjustment to flood hazard. Major choices available to a manager of an industrial plant in the Lehigh Valley, Pa. are shown along with monetary consequences of each choice. The outcome with the smallest sum of costs, $97,100 (here shown as the reservoir and emergency action combination), is most socially desirable but may not be chosen either through ignorance of alternatives or inadequate institutional encouragement to make the choice. Note also the opportunity for individual and collective choice and for social-engineering (Change land-use) versus the technological fix (Protection). The optimum choice is usually some combination.

single hazard. But the means for making the necessary comparisons still are clumsy at best.

On the question of why men persist in hazard areas and continue to occupy them at an increasing rate in spite of the sure knowledge that disasters will certainly follow, the research offers some grounds for a preliminary approximation. A not entirely obvious explanation is that men often have good reason to be there. Hazard areas may present economic opportunities superior to those available elsewhere, at least from an individual point of view, or to a non-professional perceiver. In some cases, people located in hazard areas would find it extremely difficult to move out without help from some outside sources, or to do so may require sustaining a loss, the abandoning of an investment or a livelihood. Even when the reasons for being in a hazard area are not absolutely compelling (as in the use of seacoasts for vacation homes and recreational amenities), many people do not feel strongly threatened. In such cases they may eliminate the hazard from their perceptions, or reduce them to some managable and comfortable status.

Even if people have no good reason to be in hazard zones and do feel threatened, institutional arrangements in society often operate to keep people in the same place and to protect existing interests by reinforcing the status quo. Thus,

relief payments are commonly given to victims of disaster to permit them to rebuild and rehabilitate only on the same site. Help is rarely offered to permit or induce people to move to a less hazardous location. Even after years of experience in widespread relocation projects (dams, highways, urban renewal), total evacuation never seems to run smoothly and rarely accomplishes its ends. Despite the removal of the town of Valdez from its perilous deltaic position (the town waterfront slipped into the ocean in the March 27, 1964 Alaska earthquake), new barge facilities have just been built at the former location.

Continuing damages may be viewed as a natural rent imposed upon mankind for the use of the earth. Why then should it not be recognized as a continuing charge and budgeted for? That would imply spreading the cost over time and distributing it among those who decide to take the risk. Now, costs are heavily concentrated at moments in time and are often imposed on those least able to bear them. One possible strategy is the development of an all-hazard insurance program that would be an extension of that now being developed for floods (46). The paradoxical danger is that in spreading the costs, changes in society and human behavior may be induced which would have the long-term effect of increasing the rent payable to nature. The task of spreading the rent over time and over people is therefore

not a simple one.

The Limits of Adjustment

The foregoing findings suggest that the United States will continue to bear a heavy burden of the effects of natural hazards for the indefinite future and that new strategies can be devised to change the character of losses and to reduce this burden within definite limits. It is clear, for example, that loss of life can be substantially reduced. This has been achieved to a large extent in North America. It results in part from more effective forecasts and warning devices; from a more highly mobile population, and from more substantial structures having greater resistance to natural forces. If some elements, at least, of advanced Western society can be transferred to the rest of the world, there are strong grounds for optimism in the curbing of future loss of life.

There appear to be, however, severe limits on the reduction of property losses from natural hazards that can be achieved. By a policy of the deliberate biassing of institutional arrangements to permit flexible responses to disasters, including specifically the possibility of removal, by applying available and new technology, and by formulating and executing plans of action to utilize

effectively the full range of adjustments, there are grounds for hope that future damages may be reduced by up to 30-50% on a national scale over the next few decades and much less, in the foreseeable future, on a global scale. Even if this could be done, and it will not be a simple task, the residual damages of over 50% of potential will probably remain. The problem will be with us for a long time.

Critical Problems

If this line of research has aided in formulating new public policy to deal with flood losses in the United States, it might be worth applying to a broader range of hazards than hitherto considered. Extension probably would be socially profitable into areas outside North America, including non-western cultural areas, where different patterns might be found and where comparisons with experience already noted might be mutually helpful. As this work expands, it may be expected to bring social benefits of an immediate kind. In the long run it should also contribute to the understanding of at least two sets of critical problems.

1. Natural and other hazards. Research to date has concentrated heavily on floods and other geophysical hazards. This reflects the disciplinary bias of geographers and in hindsight seems justified because the magnitude of energy

involved in such hazards creates a need for a wider range of adjustments and because they are more readily isolated as independent variables in a complex web of relationships. It is not yet clear to what extent insights gained in the study of one particular natural hazard can be applied to others, including the biological hazards which we have not studied. There is some evidence for a natural hazard syndrome. Perhaps men do respond to different natural hazards in somewhat similar ways and in ways distinct from responses to non-natural hazards. How do attitudes and decisions vary in relation to natural or non-natural hazards? There is, for example, some indication that men develop anxiety to a significantly greater extent in dealing with non-natural hazards than with the natural ones that we have mainly considered.

To what extent do verified generalizations about geophysical hazards obtain elsewhere? Is the focus of this research a separate universe of problems or is it a sub-set of all the situations of threat and uncertainty that confront mankind? The dichotomies between nature and nurture, natural and artificial, the act of God and the negligence of man appear to be very pervasive notions. To put the question another way, do human beings behave in fundamentally the same way towards the uncertain possibility of a business failure (artificial hazard), a

period of smog (quasi-natural hazard), or a flood (natural hazard)?

This issue raises interesting speculations about the design of social responses. A Nationwide Natural Disaster Warning System is being established (1), and an all natural hazards insurance program is under discussion. To what extent can such responses be modelled on systems for dealing with non-natural hazards (or vice-versa) or how do they require modification to function effectively?

2. Uncertainty, crisis, and technology. A provocative relationship among uncertainty, crisis and technology emerges from a study of the human ecology of natural hazards. Evidence from a wide compass suggests that variability in human behavior relative to natural hazards is a partial function of uncertainty. For example, greater variation in the rate of adoption of individual adjustments is found in those flood and drought situations where the stimulus from the environment is more ambiguous.

Human response to hazards in the public arena has been crisis dominated. Crisis generated decisions often appear to be hastily made and may lead to policies which in turn create a new crisis. On the other hand, crisis does play a positive role in stimulating action that might never be taken in inducing society as well as individuals to experiment with new ways of doing things.

Occupance of hazard zones has been made more feasible and more attractive by applications of technology, but the rising component of flood losses occurring in disastrous proportions underline the increasing susceptibility of advanced societies to catastrophes. The Northeast blackout of 1965 suggests that the safety of fail-safe mechanisms will be cause for increasing concern in hazard research. More knowledge is clearly needed of the complex interplay of crisis, technology, and uncertainty and of the consequences of their operation upon man in society.

This is related to the fundamentals of the man/environment relationship. Extreme variations in nature may provide a handle by which to grapple with the role of risk and uncertainty in the affairs of men. Crucial tests of our knowledge of the psychology of perception may be formulated in terms of environmental hazards. We share with students of international relations a concern about the role and significance of crisis. There is wide interest also in the impact of scientific and technological advance on nature and the consequences for society. None of these issues can yet be subjected to satisfactorily controlled investigation and none of them can even be adequately defined in operational terms. We can only join forces with others working around the periphery of these issues and pursue our studies of extreme geophysical events in the intuitive belief that this will lead to new insights into man and nature and the nature of man.

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