Natural Hazard Research

LOSSES FROM NATURAL HAZARDS

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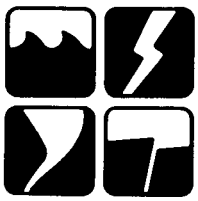

Working Paper #10

PREFACE

This paper is one in 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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LOSSES FROM NATURAL HAZARDS *

In the last two decades, interest in natural hazards and their impact on human society has grown more widespread and more intense. Concern within the government is no longer confined to the Corps of Engineers, while in the academic world psychologists, sociologists, anthropologists, economists and others have joined engineers, climatologists, hydrologists and geographers in working on one or another aspect of the problem.[1]

Several reasons for this increased research activity may easily be found. First, of course, the ability of television to bring the impact of natural disasters (literally) home to large numbers of people has created a background climate of awareness, sympathy and concern about possible local occurrences of these same disasters. A second spur to natural hazard research activity is the hypothesized similarity, in their impacts on human society, between some of the more violent climatic and geologic crises and a nuclear attack on one or more cities. This line of inquiry has seemed especially interesting to students of the phenomena of leadership, group interaction, etc., in such disciplines as sociology and social psychology.[2]

A third reason for increasing public and private investigation of natural hazards is the feeling that advancing technology will, in the fairly near future, give us some measure of control over a number of presently untamed hazards, such as lightning, tornadoes and even hurricanes.[3] While

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some of the earlier optimism relative to effective weather control has evaporated in the face of persistently unimpressive experimental results, there is still reason to hope for eventual success and hence to begin now to tackle the complex social issues involved.

Finally, there has been growing pressure from both within and without government for improvement in the criteria on which public expenditure decisions are made. This general reforming trend has implied quickened specific interest in natural hazards, since many governmental projects are designed to protect against or warn of natural events such as flood, drought, hurricane and tornado, and the benefits to be attributed to such projects are the losses avoided over the future. Thus, flood control works are intended to reduce future flood losses; public surface water supply systems are designed to increase the level of withdrawals possible from a given stream or watershed during a dry spell of a particular severity; hurricane tracking and tornado warning systems are efforts to reduce losses of life and property from these presently uncontrollable events by providing people in the probable path sufficient warning to accomplish some "battening down" and to evacuate the area if necessary.

It is our aim in this paper to discuss some of the principles and problems associated with the estimation of losses from natural hazards. We begin by attempting to clarify the distinction between natural "hazards" and other natural events. This leads us directly to the statement of a fundamental principle of loss estimation which seems to us to have been ignored in many past efforts at measurement. To anticipate, in a brief way, our later comments, we suggest now that a particular level or severity of natural event becomes

a hazard only in relation to existing human adjustments. Thus, if human society moved sufficiently far up the slopes of our flood plains, future history (for any finite period) would never again record the occurrence of the hazard "flood." This would be true even though very heavy streamflows did occur, spilling far over normal banks. Floods occur because of the combination of heavy stream flows and human encroachment on flood plains. There are, in general, no strictly physical definitions of what levels of severity of natural events constitute "hazards."[4] And, as a corollary, we note that actual estimates of losses are always based on a combination of a particular natural event and an existing state of human adjustment.

Losses, then, are a measure of the relative success of human adjustment to variable nature. But the word relative is important here; we are not interested in the absolute size of annual losses "to whomsoever they may accrue," but in the annual losses under one adjustment set relative to those under another adjustment set. We suggest, then, that losses from a natural hazard should, in principle, always be measured with some future adjustment to that hazard in mind. The discussion and amplification of this principle will be a significant portion of our task in this paper.

Now, the fact that we concentrate on the central role of human adjustments to natural events in defining hazards and measuring losses, suggests that it will be valuable to explore more fully the range of available public and private adjustments and to discuss the relation between the two sets; in particular, the problems of incentives created by public institutions aimed at private decision makers. Here we must also deal with the relation between individual perception of a hazard, private adjustment to it and prevailing

social views of the losses suffered. A subsidiary issue which arises here is that of the appropriate social view of actual "losses" when there are no public or private adjustments available for a particular class of natural events save to take future expected effects into account in planning.

Hazards and Events: Natural Forces and Human Adjustments

Nature is always with us in the sense that natural "events" are always occurring: the sun is shining or the sky is cloudy; the earth's crust is in perceptible motion or it is not; streams are flowing at particular rates. Over a somewhat longer run, an "event" might be the culmination of precipitation or the hours of sunshine, for some period. Some of these events pass essentially unnoticed; they are merely the backdrops for normal life. Such "normal" events usually correspond in some way to the long-run average experience of the people and place in question. A few events, on the other hand, are characterized as hazards, crises, catastrophes, and we should be clear about the ways in which such events differ from "normal" natural events. In particular, is it possible to characterize "hazards" purely in terms of the qualities of the events themselves?

At first glance, there would seem to be one clear difference between hazards and non-hazards for a particular time, place and population.[5] That is, hazardous events tend to be extreme events, to be found far out in the tails of the relevant probability distributions of the particular kind of event. Thus, floods are, in a general sense, characterized by very high streamflows; droughts by extremely low cumulations of precipitation over given periods. But even this line may not be pursued too far; some of the most

dangerous snow storms in terms of social disruption are very common in terms of the snow falls involved. This example, indeed, points out to us that hazards can be defined only in terms of impact on human society, and hence that they must be seen as the joint product of the events occurring in nature and the existing human adjustments to those events.[6] Since "hazards" are so named because they cause economic damage and social disruption, the level and type of economic activity existing in an area, the institutional framework of the society in that area, and the previous decisions about specific adjustments to the natural event in question are all involved in assessing that event's hazardous character.

For example, that streamflow which is exceeded only 5% of the time (the 20-year flood) will have very different effects in different basins depending on such variables as the degree of channel encroachment and the extent of commercial occupance of the lower levels of the flood plain. A rainfall shortage so severe that only 1% of such events can be expected to be worse may well wreak havoc with farmers without irrigation, while scarcely being felt by city people served by a large enough surface water storage system. There is no wind speed--wave height combination beyond which a tropical cyclonic storm is inevitably a hazard to us (though there is such a line to separate "gale," "storm" and "hurricane"). If a most severe storm comes ashore in a relatively deserted area, it need prove a minor inconvenience only, while a far weaker storm hitting a heavily built up and poorly protected resort can do enormously costly damage. The same amount of snow, falling over the same hours, will cause very different degrees of disruption in Washington and Boston or in Chattanooga and Montpelier. Thus,

while we may say that in the same human setting, a more severe natural event will cause greater damage and disruption, once we allow that setting (the result of past adjustments) to vary, no such simple statements need hold.

If we wish to extend our understanding of natural hazards, it is necessary to introduce the general notion of the relative adequacy of existing human adjustments. A measure of relative adequacy shows, in general, the relation between man's "demands" on nature and his ability to deliver. For example, in the study of the impact of drought on municipal water supply systems, one possible measure of the relative inadequacy of man's existing adjustment is the ratio of potential demand to system safe yield.[7] Potential demand is the amount system customers would (on the average) like to withdraw from the system for a given price, etc. Safe yield is the amount the system is able to deliver under all but some small per cent of the possible low flow events (often 5%). Thus, if demand is relatively much greater than safe yield, a low flow event less severe than the 5% event will be sufficient to create shortage, and vice versa. As another example, consider a possible measure of adequacy of adjustment to snow storms. Take a city with M feet of streets of average width W feet. Assume that from historical data it is determined that only 5% of all snowfalls can be expected to be worse than one depositing T tons per square foot per hour. Then the "5%" snow fall event would be one depositing M x W x T tons per hour on the city's streets. This becomes a probabilistic reference point with some obvious similarities to system safe yield. Here, however, we might say that the aim of adjustments is to keep the roads as free as possible of accumulations of snow, so that M x W x T measures the probabilistic demand for snow removal service. If the city has,

at a given time, the ability to remove (by chemical or physical means) R tons per hour, the ratio of (or difference between) R and M x W x T is a measure of the adequacy of the city's adjustment to the snow hazard. The greater R relative to M x W x T, the more improbable a storm severe enough to accumulate snow at a rate greater than the removal capacity of the city (and hence, presumably, to cause traffic delays, accidents, etc.).

Adjustment and Loss: The Principle of Relevance

The above examples hopefully make it clear that to attribute losses to a natural event alone is misleading. At the least, loss studies must recognize explicitly that losses are the joint product of man and nature. Thus, though it may be of some intrinsic interest to display losses "from" some natural event in relation to a measure of the severity of the event's physical impact (e.g. water shortage for a drought; snow depth on highways after 6 hours for a snowstorm) it is necessary to be clear that this measure of physical impact reflects both the actual severity of the event and the state of human "preparation" for the event.

It seems, however, desirable to go beyond recognition of the general character of the losses measured during and after natural events. Because man decides on the adjustments which affect his losses, the matter of real interest is the future, not the past. The losses we are after are those which will be avoided in the future if we make this or that decision now. The purpose of measuring past losses is, then to estimate the relationship among natural variation, extent (adequacy) of adjustments and resulting losses. The losses, to be of value, must be those relevant to contemplated adjustments,

present or future.[8] If, as is often the case, these adjustments are to be made by public authorities for an airshed, river basin or other region, a corollary to our principle states that subsequent private reactions to the public program must be taken into account in assessing future costs and benefits. If there were no conceivable future adjustments to deal with the losses connected with a certain natural event, loss estimates would be as irrelevant as the proverbial spilled milk. If, on the other hand, there were no historic record of losses but still a potential hazard, it would be valuable to attempt to construct synthetic estimates of possible losses, using ingenuity and available data on roughly similar events.

Loss estimates are virtually never totally irrelevant simply because a hazard to which some further adjustment is not possible is almost inconceivable. One example which does, roughly, convey the flavor of this kind of situation may, however, be suggested. We may think here of the costs imposed on society by certain accepted features of the "normal" environment, since generally the only possible adjustments for reducing these costs involve tremendous expense and/or great social or political complications. For example, consider the costs of home heating and insulation imposed by nature on those choosing to live in the Northeast. The range of adjustments which might avoid some or all of these costs includes wholesale movement of people out of the region, enclosure of entire towns in plastic bubbles, imposition of requirements for the construction of specific kinds of easily heated houses, and requirement of centralized heating plants. All of these involve either great expense, great interference with traditional areas of freedom of individual choice, or both. Thus, though the costs of heating and insulation may not represent gains

to society,[9] their measurement is not a useful extension of hazard research.[10]

An example of a potential hazard to which adjustment may be desirable (and feasible despite high costs), yet for which essentially no loss record exists is that of the active and long-dormant volcanoes of the Cascade Range in the Pacific Northwest.[11] Some of the mountains, including Hood, threaten substantial surrounding populations and capital accumulations with cataclysmic disasters. The estimates of possible losses under various scales of eruption, and the evaluation of the probability of these occurrences should be made now. The relevant adjustments for these loss estimates might at least include sensitive warning systems to allow some evacuation time and zoning regulations applying to probable lava paths and areas of cinder deposit. Large-scale intra-region movement of population might even be considered as one conceivable adjustment in this case.

The point of the principle of relevance is not that we should have fewer or even less comprehensive loss studies; it is merely that studies which ignore the role of human adjustment are, at best, of very limited usefulness and at worst may be seriously misleading guides to public expenditure. The most familiar violations are those which purport to tell us "the average annual losses" from this or that natural hazard suffered by the United States. These studies, appearing both in the popular and professional literature, implicitly assume a stable average correspondence between natural events of particular severities and human adjustments of a particular adequacy. This assumption will of course be more nearly correct the longer the period over which data has been available, but will be almost certainly invalid when only one or two years (or storms, or earthquakes) have been sampled. In

any case, stated in this broad way, the losses reported are relevant only to adjustments totally ridding the nation of the particular hazard. While this is never really even possible, it is certainly never a contemplated alternative.

In the flood control field, ignoring the role of human adjustments in creating losses has led to an expensive program of public investments accompanied by an escalating total of annual losses. Here, the problem has been that general public sympathy for those who suffered in the dramatic floods of the thirties was translated into public investment in reservoirs, flood walls, etc. erected with minimal arrangements for the sharing of costs with those benefitting. These measures have been augmented by public and private relief programs for ex post assistance to flood "victims." The combination has been sufficient to encourage rapidly increasing private investment in and occupance of flood plains, for the costs of such private decisions has, in effect, been publicly borne. Very little has been done by way of flood plain zoning or the provision of incentives for private flood proofing of individual structures.[12] "Adjustments to adjustments" have thus confounded the original goals of the program by apparently increasing expected annual losses for virtually every basin even while massive structural works have changed the frequencies of occurrence of flooding of key parts of the flood plains. A truly relevant flood loss study would take account of these private adjustments, but not just by projecting increased use of protected (or semi-protected) areas and hence raising both the benefits of the structural measures and the expected losses from catastrophic floods. Rather, flood losses should be related to mixes of private and public actions;

to private flood-proofing as well as public control reservoirs.[13] Recognizing explicitly that flood losses depend on private decisions and not only on variability in streamflows might dampen some of the enthusiasm for the programs presently distorting the decision processes of individuals. Discussions of the proper size of and appropriate mechanism for redistribution toward those inhabiting flood plains could be freed from the present rhetoric about victims who bear losses "for" the rest of society.

A largely untouched field of research, the analysis of weather modification benefits, provides us with a second example of the implications of the principle of relevance. Consider, for example, one of the hazard-control programs within this area, say that involving attempts to influence hurricane tracks. Let us assume that the adjustment being contemplated involves taking actions which will deflect hurricane tracks up to 10 degrees in either direction with some probabilistic level of assurance.[14] Since, of course, the entire matter of track prediction is uncertain, and since, realistically, any attempt to alter the track may succeed, not succeed, or work in reverse, with some probabilities, we are really talking about substituting one "fan" of possible tracks weighted by forecasting probabilities, for another such fan.

The purpose of track deflection would be primarily to cause any land-bound hurricanes either to veer off to sea or at least to strike at relatively undeveloped and unpopulated areas. The first question of interest here would be the relation between the severity of hurricane impact (wind speed, rain accumulation, wave height, tide height above normal highs), the adequacy of human adjustment (types of buildings, their value and location in relation to tides and waves; provisions for storm runoffs; vulnerability of utility

transmission lines, bridges, etc.) and the extent of damage. The next question would be the relation between track diversion and severity of impact, hence between track diversion and damage reduction. (These relations would, of course, involve complicated probability statements.) In particular, the relevant losses are those actually avoided when some track diversion is achieved. Note that, for example, wave and tide heights may be relatively insensitive to diversions involving less than 100 miles of change in the hurricane's closest point of approach to a given area. Also to be considered symmetrically here, of course, are any losses imposed by track diversion; for example, losses from water shortages in areas depending on spent hurricanes for much of their annual rainfall.

In this contemplated program, however, an even more difficult problem looms. Because of the nature of the program, there would be very great difficulties in the way of fixing and collecting fees for the service or for reimbursing those experiencing a disservice. This will imply that private actors will tend to view the program as a costless change in their environment and to embark on a whole set of private adjustments to the new environment as they perceive it. In particular, there will probably be increased capital and population movement into the "protected area." The analogy to the flood-control problem is clear; similar problems of estimation, incentive creation and so forth would seem to lie in store for us when weather modification programs receive more complete attention.

Private and Public Adjustments to Natural Events

The adjustments possible in the face of variable (and sometimes hostile) nature may be categorized in any number of ways. Some consist largely of fixed investments (flood control dams), while others involve primarily recurrent expenses for personnel, etc., with only a relatively small capital base (weather forecasting). Some are inherently public (zoning regulations), others private (flood proofing of individual structures). Some involve physical interference with the actual natural events (weather modification), others are merely attempts to smooth out the effects of natural variations (reservoirs), and still others involve only the control of human society (parking regulations for snowstorms). As our discussion above has pointed out, one of the key questions to be asked in any natural hazard study is the extent to which contemplated adjustments interact; that is, particularly, the extent to which certain public measures serve as spurs to other private adjustments which may or may not be in the direction of reducing the expected future costs. Clearly some public measures do aim at affecting private decisions directly and pushing them in the direction of lower expected costs (e.g. zoning laws and building codes).[15] But others, more or less intentionally, set the stage for private actors to move in the wrong direction. An obvious example is one we have used: flood protection works built without provisions for cost bearing by those benefitting. Others will be found wherever the public-good aspect of the adjustment is important, for this will tend to make cost sharing seem unfeasible (because of hold-out strategies, etc.) and encourage public bodies to absorb costs in their own budgets. Another example which may become far more important as time goes on is the relation between public efforts to

increase the amount of (or dependability of) precipitation in a region. It will again be difficult to arrive at a workable cost-sharing arrangement and hence there will be some tendency for those in the region to create privately the conditions for increasing sensitivity to rainfall deficiency or variation, as by planting more sensitive crops or allowing water storage systems to grow relatively very inadequate. The situation will be quite analogous to that described in the flood literature, and to our earlier hurricane example. The legacy of growing government expenditures for rain making will be higher losses in periods of rainfall deficiency. (Here the catastrophic flood may have its counterpart in the extremely stable drought, when cloud seeding is of no particular use over fairly long periods.)

Clearly one important aspect of a study of hazard, adjustment and loss is the identification of this sort of situation and the allowance for it in calculations about the future. It seems quite possible that appropriate variants of the flood insurance scheme suggested by Krutilla (op. cit.) may be useful in other areas of man's interaction with variable nature.[16]

There are, however, two other interesting sets of questions concerning adjustments. First, consider the situation in which no adjustments to reduce future expected losses are feasible. What, then, is the conceptual role of an estimate of expected annual losses? What other forms of adjustment are open to private actors? What should be the public (social) stance? Second, in discussing private adjustments of any sort, it is necessary to keep in mind the conditions under which decisions about such adjustments are made. We are interested particularly in private attitudes toward nature and natural variation as these may be expected to influence private coping with potentially

hazardous natural events.

It may be that there are no feasible adjustments which will reduce future losses from a particular type of natural occurrence for a particular individual or group of individuals. One adjustment is, of course, in principle open to every individual in an open society; that is, he can move away from the particular hazard. But moving is far from costless, and we may assume for our discussion that the present value of the expected losses to be avoided by moving to the next most advantageous place is smaller than the moving costs involved. What, if anything, remains for the individual to do in such a situation? Essentially, one may suggest that some form of spreading of losses either spatially or temporally will improve individual welfare. This spreading may take any of several forms. Compulsory insurance against the risk, with premiums based on expected losses, would reduce the variance of every individual's income and presumably result in an increase in welfare so long as those involved are risk averters.[17] If the insurance scheme covered the same risk in widely scattered areas with independent natural events, expected value would be a sufficient measure of risk and the overall variance of losses would be reduced as in the familiar theorems about insurance. Some provision for insurance might be made even within a single area (e.g. hail insurance in a single county) if sufficient allowance were made for the between-year variance of losses, either in the size of premium payments (e.g. by paying premiums such that the probability of exhausting the insurance fund in any year would be less than or equal to some small number), or in establishing a sufficiently large and long-term line of credit to prevent ruin. With the same qualifications, an individual might undertake self-insurance in

an attempt to even out his time stream of income.

In such a situation, new decisions about locating in the region should allow for the expected annual losses from the unavoidable "hazard." Thus, the proper price to pay for forest or farm land in a region with known precipitation distribution (presumably both inter- and intra-year) would reflect the discounted sum of expected annual earnings allowing for droughts.[18] Similar statements would hold for other enterprises (and even for private homes with weather-sensitive lawns) to the extent that they depend on the availability of direct precipitation. The situation changes, of course, when it is feasible to store and pipe water. These are adjustments which will reduce average annual drought losses, and the question becomes one of the proper degree of adjustment. (It may still be worthwhile to insure in some way against residual losses.)

Note that if an insurance scheme is in existence for the area and risk in question, this expected earnings calculation will be an easy and obvious one for the most hard-headed man of business, for the insurance premiums will be an annual "cost of doing business." It is, of course, where no external expert opinion is made available in the familiar form of insurance that the second of our question sets becomes relevant, for it is here that human perception of nature will be central to the risk allowance decided upon. But individual knowledge and perception will also be important to every type of private adjustment including those aimed at decreasing future expected losses, so long as the individual is not required to "buy" a particular expert, actuarial view. Thus, the impact of our remarks below goes far beyond the problem merely of coping with unavoidable losses.

One last matter, however, needs to be cleared up in relation to unavoidable losses. That is, given that private actors have open to them a number of ways of improving the time pattern of such losses, what should be the social view of the losses suffered in any given year? Of the long-run average of such losses? Basically what is important here is the ability of society to transfer real income over time in such a way as to smooth aggregate social welfare, as the insurance-type transfer payments we have discussed smooth the income streams of groups within the society. At one extreme in this respect, we may conceive of a society in which the unavoidable expected (annual) losses in real outputs are known and which has a system for accumulating stocks of these outputs in "good" years for use in "bad." The rate of accumulation of these stocks would be a function of the variance of losses, depending on the degree of assurance the society wished to maintain that it would not be "ruined," and on the availability of "foreign aid." (We note here that Joseph's problem was relatively simple because he was faced with a determinate nature. Our locusts--drought, floods, earthquakes--are less reliable.) In such a society, the relevant indices of economic welfare would be those calculated net of provisions for future losses, for such netting out would reflect the true state of society's relation to nature. Since we have assumed no further adjustments to be possible, such an index could be uniquely defined using the annual product under natural conditions optimal for the existing state of adjustment.[19]

At the other extreme, a primitive society with no means of storing its products (e.g. a hunting/gathering society without means of preserving meat) has no particular reason to be concerned with expected losses since it has no

"smoothing option." Indeed, here the entire concept of "loss" is of doubtful usefulness. It would seem that concern with losses from natural hazards is something relevant only to groups having at least the option to make allowances in advance for such events.[20]

If a society is in a position at least to anticipate (on the average) the losses it cannot avoid, then actual year-to-year occurrences of loss will have already been allowed for. The level of economic activity enjoyed in a particular year is not so important as the average level sustainable in the face of nature (for the given adjustments). Indeed, here again, the word "losses" will seem less useful given the (assumed) unavoidable nature of the average difference between optimal and actual production. What may very well be discussed as loss (or gain) is the difference between some anticipated stream of production over a relevant planning horizon and the actual results achieved. If, over 50 years, the initial projections of average production prove optimistic, it seems quite natural to say that the society has suffered a loss. To say this, however, in relation to a single year for which the results are worse than average is to imply that "gains" are made in each year that production is above average, and essentially to ignore the whole business of self-insurance we have postulated.

Perception and Adjustment: Human Views of Nature

For our discussion of the losses attributable to a particular combination of natural variation and human adjustment, two facets of man's general view of nature are of considerable interest. First, since efficient adjustment to nature requires explicit recognition of the random quality of certain natural

events, we should like to explore some common human perceptions of natural "randomness." Second, because, as we have pointed out, the usefulness and, indeed, the very meaning of "losses" from material events hinges on the ability of society to adjust either to avoid or insure against them, it will be worthwhile to mention certain relevant cross-cultural variations in views of man's relation to nature.

Kates and others have found that people living with a very real natural hazard, flooding having been most thoroughly studied, tend to adopt one or another view of the future denying the randomness of the size and timing of the events.[21] Some of the more common approaches used to reduce the perceived uncertainty are:

(i) to view the hazard as a repetitive, cyclical event. This implies no need to worry about floods until just before the repetition is due.

(ii) to use a naive law-of-average approach, claiming that the occurrence of a flood in year t reduces the probability of experiencing one in year $t + 1$.[22] This has a similar, if less dramatic, implication for action as (i). For some time after the occurrence of some "bad" event, we are relatively safe from its recurrence.

(iii) to wish away the hazardous character of the event by renaming it or lowering its amplitude to the commonplace. Thus, a flood becomes a "spring freshet" or just "high water."

(iv) to avoid thinking about the event at all by invoking a higher power --in particular by referring to "God's will." It does no good (and may actually do harm depending on one's view of God's resentment

over meddling humanity) to attempt to deal rationally with what is clearly part of the unfathomable plan of an infinitely superior "mind."

These strategies all work in the direction of discouraging private adjustment to avoid expected losses. Since, in fact, events such as floods do not seem to be cyclical or to behave as the naive "law of averages" would suggest, those who are anxious to avoid probabilistic views are likely to be caught out time and again. This probably encourages an emphasis on "losses," since nature has been more than merely random, it has been actively perverse.

The contributions to American culture of the northern European peoples seem to have included a view of man as a master of nature. There is certainly evidence that such a view tends to be the dominant one among the rural white protestants so important in our agricultural sector.[23] It seems likely that a feeling of mastery over nature is even more highly developed among city-dwellers, whatever their cultural backgrounds, for they are very largely cut off from direct contact with a harsh nature. Occasionally, they experience a flood, snowstorm or heat wave which suggests the power of nature to disrupt human affairs, but a far more pervasive influence in their lives is the evidence of the advance of science and technology which they see and read about every day. It may be hypothesized that these people are, in general, unwilling to see nature as other than man's servant. A stress on losses from natural hazards arises easily from a vague faith in the ability of science to find and apply controls to even the most spectacular events. The Federal Government presumably reflects the stress on the containment of nature which we may guess is a widespread attribute of the American character. Since a

rather ill defined "something" should be done, an equally defined study of losses may be the actual guide to action vis-à-vis a particular hazard.

On the other hand, a view of nature stressing man's "oneness" with her forces might be expected to accompany relatively primitive technology and food-provision systems. As we suggested above, a hunter-gatherer society without the means to store food over seasons or years is, in a very real sense, a part of nature. The more possible it becomes for the society at least to allow in advance for bad years, the less pronounced we should expect this feeling of oneness to become. The view that man is "under" nature would seem to be related not to the relative ability of society to adjust to nature, but to its view of the personal or impersonal quality of that nature. If a society is convinced that there is some anthropomorphic spirit behind natural events ready to react, perhaps whimsically or perversely, to human adjustments, this would seem to encourage a view of subjection to nature. This view does not, however, so readily fit into our observations.

In general, it seems reasonable to characterize our society as one in which a view of man as the master, actual or potential, of all of nature, goes hand in hand with a general refusal to think in probabilistic terms about natural events. It is not sufficient that man's adjustments be regarded as changing probability distributions of undesirable events; there is a great need to see these actions as eliminating hazard entirely. Hence, flood works make the protected area "safe"; water systems have "safe yields"; and weather forecasters are urged to say that it either will or won't rain--not that the probability of rain is 4 in 10. The pressures arising from this combination of views seem clearly to favor programs aimed at nature directly rather than

at man; indeed, programs which provide no incentive for efficient adjustment by private individuals. These same individuals tend to dismiss their own danger by stressing the "safety" of public adjustments and the predictable nature of extreme natural events. When the unpredicted event occurs or the event more extreme than the adjustments can handle, it is understandable that public sympathy for the losers is relatively great and that programs of redistribution in favor of these "victims" are conceived or expanded.

In general, the society's handling of extreme natural events could be significantly improved by an educational campaign stressing the modification of some key ideas. First, it would be an important contribution to more phases of our lives than only our relation to nature if some way could be found of persuading the "average" man to think rationally about random events. Purging the naive law of averages will not be easy; our tendency to personify inanimate objects (and, of course, nature) encourages us to give memories to coins we are tossing as well as to the forces that spawn hurricanes, floods and earthquakes. This done, however, we might find the society more receptive to an accurate description of the relative adequacy of existing and projected adjustments. If, in addition, our ideal of mastery over nature could be realistically modified to allow us to admit that some losses will inevitably occur, we might be able to discuss more carefully the desirable level of those expected losses as against the costs of further adjustments to avoid them.

NOTES

1. For an introduction to this rapidly evolving field an excellent source is Burton, Kates and White, "The Human Ecology of Extreme Geophysical Events," Working Paper No. 1, Natural Hazard Research, Toronto, 1968. (Mimeographed.)

2. See, for example, Wolfenstein, M., Disaster: A Psychological Essay (Glencoe, Ill.: Free Press, 1957); and Baker, G. W. and Chapman, D. W. (eds.), Man and Society in Disaster (New York, N. Y.: Basic Books, 1962).

3. For a set of papers relevant to weather control and its impact see W.R.D. Sewell, Human Dimensions of Weather Modification, Research Paper No. 105 (Chicago: Department of Geography, University of Chicago, 1966).

4. Similarly, there are no purely man-made hazards. Man may opt for (or have forced on him) relatively less adequate adjustments to some natural phenomenon; this will in general increase the frequency and severity of hazard occurrence by lowering the necessary level of severity. Nature still must act, however.

5. Clearly certain events which would be extreme hazards for one group may be the stuff of normal routine for another. We only need think of ourselves living with the eskimo or the desert beduin to see this.

6. Professor Robert W. Kates suggested this definition to the author in connection with a study of the recent Northeast Drought. The same idea is clearly at the heart of the flood studies conducted by various of the geographers associated with Gilbert White and the University of Chicago.

7. See Russell, Arey and Kates,"Drought and Water Supply: The Implications of the Massachusetts Experience for Municipal System Planning," 1968. (Mimeographed.)

8. The word "contemplated" is to be interpreted in the widest sense to include any conceivable adjustments, not just those now technologically or politically feasible. Clearly loss studies aimed at potential benefits from "far out" schemes will have much to do with whether or not the schemes become seriously considered.

9. These costs may be seen in the same light as those of urbanization (commutation, etc.) and others discussed by Kuznets in criticizing the welfare significance of the traditional national accounts. See Simon Kuznets, Economic Change (New York, N. Y.: Morton, 1953).

10. It is interesting to note here that technology in the area of housing, heating, etc. has historically favored individual decisions about adjustments to cold and individual bearing of the costs of decisions to locate in cold regions. This is in distinct contrast to the situation for other hazards, notably floods, where technology has favored public projects and where the costs of flood plain location have been borne by taxpayers in general, rather than by the occupants.

11. See The New York Times, November, 1968.

12. See, for example, G.F. White, Papers on Flood Problems, Research Paper No. 70, and Changes in Urban Occupance of Flood Plains in the U.S., Research Paper No. 57 (Chicago: Department of Geography, University of Chicago, 1961 and 1958).

13. See L. James, A Time Dependent Planning Process for Combining Structural Measures, Land Use and Flood Proofing to Minimize the Economic Loss of Floods, Report EEP-12, Stanford University Institute in Engineering-Economic Systems, 1964.
For a suggested compulsory insurance scheme to force private decision makers to face the costs implied by their decisions to occupy the flood plain, see J. V. Krutilla, "An Economic Approach to Coping with Flood Damage," Water Resources Research, Vol. 2, No. 2, 2nd Quarter, 1966.

14. This is the kind of program discussed by Hendrick and Friedman in "Potential Impacts of Storm Modification on the Insurance Industry," in Human Dimensions of Weather Modification, W.R.D. Sewell, ed., Research Paper No. 105 (Chicago: Department of Geography, University of Chicago, 1966).

15. Whether or not these attempts succeed is another question. There are a number of reasons for harboring doubts on this score; for example: the discontinuities implied by zoning, the lack of good information on which to base these laws, and even the general lessons of the theory of the second best.

16. We shall have more to say about insurance below.

17. And, as Krutilla has discussed (op. cit.) such a scheme could serve as the basis for efficient allocation of costs if and when some loss-reducing adjustment did become feasible.

18. Allowance for the variance of the return may or may not be necessary depending on the relative importance for the buyer of the income stream involved. For example, a large paper company with forests all over North America could almost certainly ignore variance. A small lumber firm relying entirely on a single wood lot probably could not.
The expected annual earnings would probably be different from the earnings associated with average annual rainfall. If diminishing returns of tree growth to rainfall hold, the expected annual earnings will be less than the annual earnings from average rainfall (all ignoring intra-year distribution).

19. These observations are relevant to the usual indices of aggregate economic activity such as GNP. Here the problems of dealing with natural hazards are complicated by present conventions which include the investment/saving total for each year as an addition to welfare for that year, and the future streams of production from the investments in the years of accrual. At least, however, it should be recognized that what is of interest is the

expected annual level of such an index, net of unavoidable expected annual losses from randomly occurring natural events. Year-to-year fluctuations in GNP due to such events do not reflect corresponding fluctuations in aggregate welfare to the extent that rational provision has been possible. Since overall for the society, no other adjustments are possible, we may simply view the stream of expected product as a measure of the value of the existing natural world in which the society finds itself.

20. This observation is of some interest in connection with our brief discussion below of man's view of his relation to nature. A society without even our "smoothing" option is very much like a part of nature rather than something different from, and partly in control of, her.

21. See Kates, Hazard and Choice Perception in Flood Plain Management, Research Paper No. 78 (Chicago: Department of Geography, University of Chicago, 1962); and Burton and Kates, "The Perception of Natural Hazards in Resource Management," Natural Resources Journal, Vol. 3, No. 3 (January, 1964), pp. 412-41.

22. Note that there are hazards for which serial correlation of events is important and well established. For example, if streamflows are known to be low in year t, it is more likely that they will be low in year t + 1, than we would predict from the long run percentage of low-flow years (the Markov properties with positive serial correlation).

23. See, for example, Kluckhohn and Strodtbeck, Variations in Value Orientations (Evanston: Row Peterson, 1961); also E.Z. Vogt, Modern Homesteaders (Cambridge: Harvard University Press, 1955); and W. Firey, Man, Mind and Land: A Theory of Resource Use (Glencoe, Ill.: Free Press, 1960).