January 1993

Guidelines for the uniform definition, identification, and measurement of economic damages from natural hazard events: With comments on historical assets, human capital, and natural capital

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with
Comments on Historical Assets, Human Capital, and Natural Capital

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Program on Environment and Behavior
Special Publication No. 28

Institute of Behavioral Science
University of Colorado
1993

Natural Hazards Research and Applications Information Center
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Cover photo: The Quinesaug River washes away both approaches of the Pomfret Street Bridge in Putnam, Connecticut, during flooding from Hurricane Diana in 1955. *Photo courtesy of the U.S. Army Corps of Engineers, Office of History.*

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Preface

This brief set of guidelines has been distilled from a larger project entitled *Uniform Framework and Measurement Guidelines for Damages from Natural and Related Manmade Hazards*, funded by NSF Grant CES-8717115. That project also produced the more extensive *Natural Hazard Damage Handbook*, authored by Howe, Cochrane, Bunin, and Kling, dated August 1991 and available from NTIS; an updated *Natural Hazards Data Resources Directory*, available from the Natural Hazards Research and Applications Information Center, University of Colorado; and a user questionnaire, *Assessing Damages from Natural and Manmade Hazards: A Survey of User Practices and Needs.*

It is our hope that these guidelines will be helpful to those who are faced with the difficult tasks of field estimation and to the international effort to establish a global disaster data base for the International Decade for Natural Disaster Reduction. The authors express their appreciation to Jane E. Bunin of Natural Science Associates, Inc. and Robert W. Kling of Colorado State University, our colleagues in writing the handbook and whose materials underlie sections on damages to natural capital and damages to historical monuments, respectively.

We also want to thank Dr. Eleonora Sabadell, Director of the Natural and Manmade Hazards Mitigation Program of NSF, who encouraged this work and provided advice throughout the project. Only the authors are responsible for remaining shortcomings.

Introduction

This set of guidelines is intended as a primer for personnel responsible for the identification and measurement of damages from natural hazard events. The writing style, orientation, and level of detail were shaped in part by the results of a user survey in the U.S. that indicated a majority of those gathering and using damage data were trained in engineering or a related technical fields. The respondents generally felt that insufficient budgets and the complex nature of loss measurement methods limit their ability to gather and make better use of damage data. A sizable majority indicated that they were involved in flood hazard assessments.

The need for such guidelines arises from the ad hoc measures that are often presented to the public as "damages" or impacts of natural hazard events. The problems with existing damage data can be illustrated by quotes from studies of the quality of U.S. flood damage data carried out by Thomas P. Grazulis regarding the documentation of national annual flood losses:

> The most widely quoted overall "loss" numbers are from the [National Weather Service,] Office of Hydrology . . . There is currently no plan of attack or any set of guidelines for filing, refining, or using that data base. Numbers of varying quality are inserted with no reference as to where they came from or exactly what "loss" was estimated or measured. This data base is a curious combination of intelligent, well-meaning and hard working people being given minimal time to maintain a poorly conceived system with unsubstantiated data on a low priority basis. I haven't found anyone within the flood research community [who] actually believes the NWS numbers (Memo to NSF Advisory Committee, February 2, 1989).

Thus, it is important to establish a standard set of definitions of and measurement methods for natural hazard damages and to create institutional frameworks that have the capability and resources to follow such guidelines.

The Definition Of Natural Hazard Damages

Impacts

At a purely physical level, we speak of the *impacts* of a natural hazard event: an impact is any measurable physical change in geological, ecological, atmospheric, or human systems attributable to that event. Among the impacts of a flood are changes in alluvial materials in the valley; changes in the numbers and types of the various plants and animals; permanent shifts in the direction, volume, or velocity of water flows; physical destruction of crops and livestock; changes in buildings; losses of human life; and deferral or abandonment of production processes. What principle underlies the identification and measurement of these impacts? It is the *with-without principle*:

> **We seek to identify and measure all changes between the system as it evolves *with* the natural hazard event having taken place and as it would have evolved *without* the occurrence of the natural hazard event.**

It must be noted that this principle does *not* mean identifying and measuring a set of variables at points in time before and after the event. Changes attributable to the event can be dynamic and continue over time, so that the "with-without" difference must be cumulatively measured by monitoring the system over time. In addition, the *continuation of changes* that were occurring prior to the event must be measured. For example, assume that annual corn production in the Wabash River Valley in the year preceding a flood amounted to one million tons. In the year of the flood, corn production amounted to 500,000 tons. Is the change of 500,000 tons attributable to the flood? Not necessarily, for there might have been a downtrend (or uptrend) in corn production due to market or climatic factors that would have reduced production to 750,000 tons even in the absence of a flood. Then only a loss of 250,000 tons can be attributed to the flood.

If we carefully apply the with-without principle to a system affected by a natural hazard event, we can identify and (in principle) measure the impacts of that event. Yet, even minor natural hazard events have innumerable impacts. We are concerned with those impacts that involve changes in human well-being (i.e., changes in values).

Values and Policy

Value changes are more complex than physical impacts. *Values* are rates at which individuals or groups are willing to trade off one thing for another. For example, suppose investigation has shown that reducing the ocean catch of tuna by one million tons per year would allow the dolphin population to increase by one million. One could interpret this scientific information to say that the cost of one more dolphin in the permanent population is one ton of tuna foregone. That is still not a value statement. However, the statement that human society *would be willing* to give up one ton of tuna to raise the dolphin population by one is a value statement. In this case, the combination of physical data and human values imply that a policy decision to decrease tuna fishing and allow the dolphin population to increase would be desirable.

Economic values have been classified into two groups: 1) use values, and 2) non-use values. An object or service has use value if it is *directly* involved in interactions with individuals. A sandwich has use value to a hungry person, while a painting has use value to people even though the painting is not consumed in the process. Use value is manifested in peoples' *willingness to pay* to acquire or access the object. Data on use values usually come from market prices, but also can be derived from surveys of peoples' willingness to pay.

Non-use values represent concern for the continued existence of assets and environmental conditions (e.g., fertile soil or clean water) in situations where the person or group valuing the asset is not actually using the asset. Such values are especially important in assessing damages to natural areas and historical monuments or artifacts. Some of these non-use values can be estimated in terms of the relevant public's willingness to pay for preservation (see Mitchell and Carson, 1989; Krutilla and Fisher, 1975; Greenley, Walsh, and Young, 1982).

Natural hazard policy questions always involve tradeoffs among values. For example, flood policy seeks answers to the questions:

1) What are the benefits (values gained) and costs (values given up) of various programs of flood control?
2) Who gains and who loses from each?
3) In the light of both, which alternative should be undertaken?

Hazard damage measurement is part of the hazard policy process because it measures the *loss of values* caused by natural hazard events, some of which could be avoided through mitigation programs. Hazard damages are thus losses of human-centered use and non-use values that result from natural hazard events.

Estimating Damage Values

Some impacts have values directly associated with them. A loss of 1,000 tons of grain due to a windstorm usually will have a *market value* determined by the market price of grain. Market prices usually are the best value measure, but sometimes they require adjustment. Data on damages often are drawn from the accounting records of businesses, units of government, and the national income accounts. To be incorporated in these systems, natural hazard impacts must be reducible to monetary values. Private accounting systems record and monitor asset values and revenues and costs. National income accounting as practiced in the United States produces such common economic measures as gross domestic product, personal income, consumption, and savings, but omits many environmental and social values and costs. National income accounting does not maintain records of the values of stocks of public and private assets, although it does record the amount of private asset depreciation to permit calculation of net (as opposed to gross) domestic product. These national accounting concepts have been extended down to multi-state regions (regional accounting) and to the state level (e.g., gross state product, state personal income, and state disposable income). Large-scale natural hazard events can have significant impacts on these highly aggregated measures.

Many dimensions of the environment are valued directly or indirectly by the population. For example, water pollution increases cities' and industries' water intake costs while also destroying recreational fishing and aesthetic enjoyment. This broadening of policy-relevant environmental and social values has led to:

1) methods to extend monetary valuation to environmental goods and services that have no explicit market value (e.g., recreation on public land, health and aesthetic values from cleaner air, and existence values);
2) the development of environmental and social indicators to record changes for which economic values seem inappropriate; and
3) the development of multiple-objective evaluation procedures into which both economic values and non-economic impacts could be fit.

Multiple-objective planning and evaluation, developed during the late 1960s and early 1970s through the work of the U.S. Water Resources Council and its consultants (Principles and Standards for Planning Water and Related Land Resources, *Federal Register* 38, 174, September 10), recognized this widening set of economic, environmental, and social values by providing decision makers and the public with data on market economic values, non-market economic values (e.g., monetized value of non-priced recreation, values of health improvements, and existence values), as well as environmental and social indicators. Decision makers then choose "weights" to be placed on each of these variables to rank policy alternatives. In this way, the policy process can deal with both monetized values and non-monetized impacts. It remains the responsibility of technical personnel to provide the best damage data allowed by time and budgets and, if important damages are not being considered, to call them to their superiors' attention.

The discussion to date has been cast in terms of damages physically linked to a natural hazard event, even though they may occur over some period of time. Other damages occur indirectly as a result of natural hazard events. For example, suppose a flood prevents the planting of a crop on river bottom land. At the farm level, the direct damage would be measured by the net income the farm would have realized from the crop: sales value less the value of all inputs and harvesting cost. In addition, there may be *secondary* damages to the suppliers of farm inputs and processors of agricultural output. They may lose profit or wage incomes. Since there is greater uncertainty about these damages, very conservative estimates should be used. The reader can consult the *Natural Hazard Damage Handbook* (1991), Bendavid (1972), or Pleeter (1980) for appropriate methods.

In sum, natural hazard economic damages are represented by the traditional market and national income measures and asset values and supplemented by relevant non-market values and appropriately measured secondary damages.

The Identification And Measurement Of Direct Economic Damages

Monetization of Impacts in the Computation of Damages

In order to monetize (provide dollar values for) physical impacts caused by a natural disaster, market prices most often are used. However, do prices exist for all the assets, commodities, and services that are relevant? When prices do exist, do they reflect the values we want to capture? The following situations are encountered:

1) market prices exist for many assets, commodities, and services in situations where the prices correctly reflect social values;
2) market prices exist, but need to be adjusted to reflect social values correctly;
3) market prices do not exist, but credible methods exist for estimating the prices needed for program or project evaluation; or
4) market prices do not exist, and no general, credible methods for simulating those values exist.

Naturally, analysts (especially economists) differ about where the dividing line should fall between any two of the above situations. How do we know whether or not a price is "right" or whether it needs to be adjusted before being used in damage estimation? This is explained by the roles that prices ideally play in the organization of a well-functioning economic system: prices are intended to indicate to the *user* of a unit of a good or service (producer or consumer) the real cost of making that unit available, while prices should indicate to a *producer* the value placed by society on another unit of output. In competitive economies, markets will encourage production to be extended to levels at which incremental costs just equal incremental social values, with both reflected in market prices.

Under what circumstances do market prices *fail* to reflect the appropriate opportunity cost and/or marginal social value of a commodity? Unfortunately, this failure occurs under many real life circumstances. The agricultural sector—which produces crops, livestock, and dairy products—is usually cited as the ideal manifestation of competition because it contains many relatively small producers and many buyers. Yet *domestic* agricultural prices are severely distorted by price support programs that keep market prices far above marginal social values by directing part of farm output into government storage (usually to be dumped on international markets). Wages may fail to reflect the real cost (opportunity cost) of labor under minimum wage regulations. Prices of products produced by only a few producers who tacitly collude in the setting of prices are likely to exceed producer unit costs and thus overstate real costs to buyers (e.g., airline services, cable TV services, automobiles). Thus, prices may need adjustment before being used to estimate economic damages. In practice, only major distortions can be corrected.

Many lost services and amenities do not have market prices, such as recreation on public lands, improvements in air and water quality, beautiful landscapes and views, and enjoyment of public gardens. In some cases, it is possible to estimate prices (unit values) for such services so they can be included in economic assessment. One major method consists of survey techniques called *contingent valuation methods* that ask people what they would be willing to pay for some non-marketed good (Mitchell and Carson, 1989; Cummings, Brookshire, and Schulze, 1986). Another approach would be the *travel cost method* of valuing recreation (Knetsch, 1972). Placing dollar values on outdoor recreation represents the most frequent application of these methods and has gained general acceptance. The federal courts have accepted values for such amenities estimated by contingent valuation methods (see U.S. Court of Appeals for the D.C. Circuit, July 14, 1989, No. 86-1529), but many public officials still prefer physical description rather than attempting to monetize all costs. Trying to place a value on the loss of human life is one such case.

Conceptual Framework for Identifying and Measuring Direct Economic Damages

The productive resources of society consist of the stocks of accumulated human-made capital (buildings, equipment, inventories, and scientific and technological knowledge), human capital (skills and energy), and natural capital (soil, forests, minerals, water, and environmental conditions). The measurement of direct economic damages centers on six types of effects: 1) damages to human-made capital; 2) interruptions of production processes; 3) identification of economic activities to be monitored over time: 4) damages to historical monuments and historical assets; 5) damages to human capital (i.e., human illness and mortality; and 6) damages to natural capital.

Damages to Human-Made Capital

We turn to the "balance sheet" of assets in the form of human-made capital. The majority of quantifiable losses from natural hazard events occur due to damage to such assets. Human-made assets can be classified as:

- long-lived business and government physical assets,
- business and government inventories of physical goods,
- non-business residential properties, and
- other non-financial personal property.

Financial assets are omitted from damage evaluation since they really represent underlying real asset values and related income flows. For example, if a company's factory is destroyed, the value of the factory is counted but not the decrease in the value of the company's shares on the stock market. It is important to avoid *double counting* financial asset values and the underlying asset and profit values. Thus, financial assets should be omitted from further consideration.

Long-lived assets typically have "book values" in the accounting records of private businesses. Households do not keep asset accounts, but insurance and realtors' records are valuable sources of residential values. Government asset records generally are poor and depreciation accounting is not practiced, so *book* values of government assets are either nonexistent or irrelevant. Long-lived business assets are entered at their purchase price and then depreciated over time according to one of several traditional formulas, with the annual depreciation treated as a business expense and a deduction from the asset value. Because of price level increases over time, most book values are out of date and may even be irrelevant to damage calculations. Modern management accounting (as opposed to financial accounting—frequently several sets of books are kept) updates long-lived asset prices on a "depreciated replacement cost" basis. Table 1 lists some of the major considerations in measuring damages to assets.

If an asset is totally destroyed, the first question is whether or not it will be replaced. If so, the next question is: What will replace it? The replacement could be an asset of similar age and depreciation or a new asset. The theoretically correct measure of damage would be the *change* in present value of anticipated capital outlays. Partial destruction of assets leads to the same question: Will the asset be rehabilitated? One must know what is meant by "rehabilitation," but let us assume the objective is to upgrade the damaged asset to the same productivity and remaining life as the original asset at the time of damage. The cost of such an upgrading appropriately measures the damage. If a partially destroyed asset is not worth rehabilitating but is still worth keeping in operation, the damage will be captured by the *reduction* in the present value of the income stream caused by lesser productivity or a shortened asset life.

Table 1
Analyzing Damages to Human-Made Capital Assets

Alternative Values for Assets:

book values (may be outdated),
depreciated replacement value (appropriate),
market values of similar assets, or
insurance and realtor records

**Complete Destruction of Long-Lived Assets:
Will They be Replaced?**

Yes → damages = market value of similar asset

No → damages = present value of income losses resulting from loss of the asset

**Partial Destruction of Long-Lived Assets:
Will They be Rehabilitated?**

Yes → damages = cost of rehabilitation

No → damages = present value of income losses over the remaining operating life of the asset

The formula for the present value of incomes lost is:

$$(1) \qquad PV = L_0 + \frac{L_1}{(1+r)} + \frac{L_2}{(1+r)^2} + \ldots \frac{L_T}{(1+r)^T}$$

where L_0 is income lost in the current year, L_t is the income lost in year t, L_T is the income lost in the last year of the project's expected life, and r is a discount rate—usually the borrowing rate of the governmental unit or business making the computation.

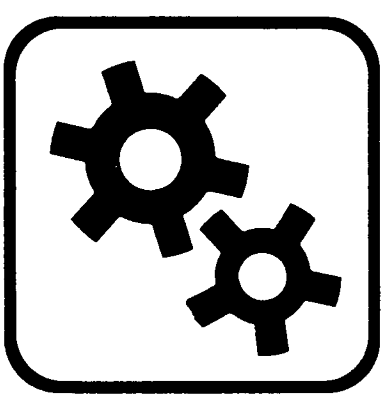
It is not uncommon for government loss estimates to violate these principles. The cost of the Loma Prieta earthquake on the San Francisco and Oakland freeway systems, for example, was stated by transportation authorities to include the costs of seismic upgrading.

> It will cost $60 million just to reopen San Francisco's quake damaged freeways, and state highway engineers say it will cost hundreds of millions more to bring them up to safety standards of the 1990s.

> Caltrans recently told the state Legislature that the post-quake highway network in the Bay Area would require an infusion of $1.7 billion . . . Because the 7.1 [temblor] of Oct. 17 remains fresh in the minds of the legislators, Roberts said, "We will be able to finish in four years what prior to the earthquake would have taken forever" (*San Francisco Examiner*, November 21, 1989).

Retrofitting to make freeways and structures *safer* is *not* a cost of the earthquake. The temporary repairs of $60 million to the Embarcadero, Interstate 880, the Oakland Bay Bridge, and U.S. 101 *are* attributable to the earthquake. The $1.7 billion worth of seismic upgrades *is not*. Since the design changes reflected in higher construction costs are not a product of the earthquake, they should not be counted as a cost of the earthquake. It is appropriate to count only the cost of restoring the freeways to their pre-event condition.

One final point concerns the treatment of land. It is important to distinguish between damage to structures and a possible reduction in the value of building sites. In most areas, the value of real estate depends mostly on location, with building improvements contributing only a part of the property's overall value. Occasionally, damage assessments incorrectly count the *total* market value of land and structures. This is incorrect since the land still has value, although that value may differ from the pre-event value.



Interruptions of Production

Such items as labor services, raw material, and use of equipment are combined to produce goods and services that can be used for consumption, investment, provision of government services, exports to other countries, and other things. *Value added* in a production process is the difference between the market value of the product produced and the market value of inputs purchased from other producers. (This is shown in equation 2). Value added is thus equivalent to the sum of income payments made directly by the firm to human, natural, and human-made capital. When a natural hazard event occurs, production processes are interrupted, resulting in a reduction in these payments over some time. *For natural hazard damages, it is the reduction in value added plus the value of damages to the stocks of capital that constitute the damages to a business firm from the hazard event.* Table 2 presents a breakdown of situations and analytical considerations.

(2) Value added = **market value of the product produced, less the value of inputs purchased from other producers**

= **accounting profits plus depreciation expenses, wages and salaries and taxes.**

The full value added is really delayed or lost only if the productive resources (e.g., labor and land) are left completely unused (unemployed) during the production interruption. If all or some of these resources find alternative employment during the production interruption, then only the *difference* between the original income payments to these resources and the new temporary income rate is used in calculating lost value-added.

Table 2
Analyzing Interruptions in Production

Production Processes Frequently Interrupted by Natural Hazard Events

- agricultural production
- commercial fishing
- manufacturing operations
- transportation systems
- service industries (health, recreation, etc.)
- government operations and services

Will interruptions in production be made up?

Yes → damage = present value of *delays* in value added (usually small)

No → damage = loss of total *value added* until resumption of production, adjusted for temporary earnings from other employments of the inputs

Whether or not interrupted production can be *made up* is an important consideration (Tablc 2). If it can, then the value added (business net incomes and other factor payments, mostly wage and salary payments) generated by that production is merely delayed. For delays of less than six months, the actual losses will be small.

Losses of the activities of the government sector (local, county, state, federal, and special districts) are more difficult to monetize since there really is no market for government services. Government services are principally of two types: 1) general administration, maintenance of order, etc., and 2) the provision of services (e.g., education, libraries, recreation, health services, and utilities). Both types of public services are critical to the performance of the economy, and the interruption of these services can have severe impacts on individuals and the other sectors of the economy.

How do we measure the direct economic losses from the interruption of government services? While we can measure the *cost* of government services, it is difficult to measure the *value* of the services as we do for the private sector since there are no charges for many services (general administration, libraries, education, recreation), and the charges for others are frequently unrelated to their costs. National income accounting values government outputs by their costs. Thus, *losses of government services can be valued conservatively as the costs not incurred*, but this is likely to result in a large understatement of lost value.

Some types of government administration expenditures *rise* as a result of natural hazard events, especially for activities that mitigate damages. These increases in government administration and public safety expenditures are *costs* caused by the natural hazard event and should be counted as damages.

It is important to note that if government costs are used as a proxy for the value of lost government services, then lost government *revenue* cannot also be included. To do so would double count impacts.

An Inventory of Economic Activities to Be Monitored

The preceding sections have provided guidelines for the measurement of lost real assets that were either damaged or were no longer able to contribute to value added as a result of natural hazard events. It is useful to have a checklist of economic activities or sectors that may be impacted by natural hazard events to help in the identification of damages. Such a checklist for commercial and government activities is provided by the U.S. Standard Industrial Classification (SIC), used by all U.S. federal data gathering agencies for the classification of data.

We propose that each agency with responsibility for natural hazard damage data collection construct a subset of the two-digit SIC economic activities that are present in their jurisdiction as a checklist of commercial and government activities that should be monitored for damages. Table 3 presents the two-digit activities, but it may be worthwhile to use the more detailed three- and four-digit categories that can be copied from the SIC manual. While the SIC covers all production activities, it does not have categories for all types of assets (e.g., it has residential construction but no residential units per se).

The big SIC omission is the *household sector*, including both "household production" and household assets. As already noted, damages to residences and their contents constitute a major form of natural hazard loss and are canvassed by various agencies. In addition, whenever there is significant damage to residences, household production processes are interrupted: food preparation, laundry, provision of rest, relaxation,

Table 3
Standard Industrial Classification (Two Digit) of Economic Activities for Purposes of Damage Data Classification

A. Agriculture, Forestry, and Fishing
- 01. Agricultural Production-Crops
- 02. Agricultural Production-Livestock
- 07. Agricultural services
- 08. Forestry
- 09. Fishing, Hunting & Trapping

B. Mining
- 10. Metal Mining
- 12. Gas Mining
- 13. Oil and Gas Extraction
- 14. Nonmetallic Minerals, Except Fuels

C. Construction
- 15. General Building Contractors
- 16. Heavy Construction, Excavation Building
- 17. Special Trade Contractors

D. Manufacturing
- 20. Food and Kindred Products
- 21. Tobacco Products
- 22. Textile Mill Products
- 23. Apparel and Other Textiles
- 24. Lumber and Wood Products
- 25. Furniture and Fixtures
- 26. Paper and Allied Products
- 27. Printing and Publishing
- 28. Chemicals and Allied Products
- 29. Petroleum and Coal Products
- 30. Rubber and Miscellaneous Plastics
- 31. Leather and Leather Products
- 32. Stone, Clay and Glass Products
- 33. Primary Metal Industries
- 34. Fabricated Metal Products
- 35. Industrial Machinery and Equipment

Table 3 (continued)

36. Electronic and Other Equipment
37. Transportation Equipment
38. Instruments and Related Products
39. Miscellaneous Manufacturing Industries

E. Transportation and Public Utilities

40. Railroad Transportation
41. Local and Interurban Passenger Transit
42. Trucking and Warehousing
43. U.S Postal Service
44. Water Transportation
45. Transportation By Air
46. Pipelines, Except Natural Gas
47. Transportation Services
48. Communication
49. Electric, Gas and Sanitary

F. Wholesale Trade

50. Wholesale Trade-Durable Goods
51. Wholesale Trade-Nondurable Goods

G. Retail Trade

52. Building Materials and Garden Supplies
53. General Merchandise Stores
54. Food Stores
55. Automotive Dealers and Service Stations
56. Apparel and Accessory Stores
57. Furniture and Home Furnishings
58. Eating and Drinking Places
59. Miscellaneous Retail

H. Finance, Insurance, and Real Estate

60. Depository Institutions
61. Nondepository Institutions
62. Security and Commodity Brokers
63. Insurance Carriers
64. Insurance Agents, Brokers, and Services
65. Real Estate
67. Holding and Other Investment Offices

I. Services

70. Hotels and Other Lodging Places
72. Personal Services
73. Business Services
75. Auto repair, Services
76. Miscellaneous Repair Services
78. Motion Pictures
79. Amusement and Recreation
80. Health Services
81. Legal Services
82. Educational Services
83. Social Services
84. Museums, Botanical, Zoological Gardens
86. Membership Organizations
87. Engineering and Management Services
88. Private Households
89. Services, NEC

J. Public Administration

91. Executive, Legislative, and General
92. Justice, Public Orders, and Safety
93. Finance, Taxation and Monetary
94. Administration of Human resources
95. Environmental Quality and Housing
96. Administration of Economics Programs
97. National Security and Int. Affairs

K. Nonclassifiable Establishments

99. Nonclassifiable establishments

and recreation. The reduction in household value added occasioned by natural hazard events *should* be included in damages. The problem in valuing household value added is that there is no market test of the value; however, that need not preclude the development of some rules of thumb. An example would be to allow $N per day per adult displaced from his or her residence. Some of this loss is reduced by the provision of emergency services for food and housing. At present there is no accepted standard for valuing loss of household production and amenities, but this should be changed.

The failure to recognize important personal costs and the value of lost leisure is clearly illustrated by the events occurring after the October 17, 1990, Loma Prieta earthquake. The collapse of the Cyprus Structure of Interstate 880, damage to the Embarcadero Freeway, and the temporary closure of the Oakland Bay Bridge disrupted Bay Area traffic patterns for one full month. The resultant daily commuter delays, lasting as much as four hours, were costly to both area firms and their employees, but the costs to commuters have been ignored. Longer commutes consumed more energy, increased risks, and often resulted in frustration and lost family and leisure time. These costs should be monetized and counted as damages.

Damages to Historical Monuments and Historical Assets

Every community, region, and country has certain assets that are valuable in giving that society a sense of historical continuity and cultural identity. Such cultural assets often are unique and irreplaceable, and also have the character of *public goods*; therefore, market prices either are unavailable or inappropriate to use in valuing the assets. Because valuation is difficult, cultural assets often are undervalued or, worse, omitted altogether in a tally of damages from natural hazards.

Society values cultural assets at many levels. Some portion of the population benefits directly from such assets in the way of personal visits or other direct experience; this benefit generates *use value*. Members of society, both direct users and non-users, also attach non-use values to these assets (sometimes subdivided as option, bequest, or existence values). Cultural assets contribute to the integrity and continuity of social identity in a way that enhances the quality of life for all members of society, giving those assets *tradition* or *existence value*. Each component of the value of the benefits generated by cultural assets can be important and must be considered in calculating overall values lost.

Methods for estimating the value of cultural assets are not highly developed. Appraisers can estimate *market values*, but such prices often will understate the full social value of the asset. Therefore, it is necessary to develop proxies for market prices, that is, indirect measures of what people are willing to pay for an asset. One approach is to estimate the *costs* society has shown itself willing to bear for preservation of an asset. In this case, one must be careful to single out the *net value* (i.e., aggregate willingness to pay less preservation costs) that would be lost by destruction of the asset. Other methods of non-market valuation can be adopted from environmental economics: the *travel cost* method, which is a variation of the opportunity cost method; and the *contingent valuation* method, which uses survey techniques to estimate a population's willingness to pay for an asset.

Damages to Human Capital: Valuing Human Morbidity and Mortality

When an individual is injured or becomes ill due to a natural hazard event, the major impacts take the form of 1) the loss of the individual's productivity in the household, 2) the loss of the individual's productivity in market-related production activities, and 3) the disutility of physical and psychological malaise. As noted earlier, loss of household productivity typically is ignored. Market-related productivity losses will be picked up in terms of losses of value added in business activities. Measures of physical and psychological malaise would be ideally determined by the individual's willingness to pay to avoid discomfort, but this is a difficult task. Thus, a *lower bound* on human discomfort can be taken to be the value of the cost of medical care given to the individual.

Valuing lost lives is a contentious activity. Certainly the protection of human life is the major concern of natural hazards policy. The procedure of capitalizing (calculating the present value of) lost income is now recognized as inadequate. The relevant concept of human life is not that of a particular person after the natural hazard event, but that of an increase in *expected* life losses before an event. Survey methods to elicit persons' willingness to pay for a reduction in risk, stated as a reduction in the *expected* number of deaths, are now considered the appropriate measure (e.g., Mitchell and Carson, 1989). In cases where monetized values must be used, values from numerous studies are available. For practical purposes, it should be adequate to report the number of deaths and the locational and socioeconomic characteristics of the victims.

Damages to Natural Capital

Some damages to natural capital (e.g., rivers, lakes, forests, and other natural areas) can be included with the economic damages due to loss of household and market-related productivity. If recreational activities are interrupted or permanently destroyed, or if valuable standing timber is destroyed, survey valuation techniques or market prices can be applied to the physical measures of damage. However, current concern for thc cnvironment goes beyond monetized ecosystem damage. This section provides a brief summary of noneconomic measures of changes in ecosystems brought about by natural hazard events.

Natural hazard events impact the environment in many ways. A volcanic eruption may pollute the air and cause sedimentation in streams. Tidal surges and tsunamis may contaminate coastal lands and aquifers with salt water. Some of these impacts lead directly to monetizable damages and should be included in the economic assessment section of the multiple-objective appraisal of the event. Other impacts on the environment may not produce discernible damages following the event, but may set in motion subsequent environmental changes that may cause later damages. For example, the collapse of a remote mountain dam following an earthquake may not immediately affect any human activities, but the deposition of rocks, gravel, and silt in adjacent valleys may eventually modify available grazing lands for wild or domestic stock or change flood-flow pathways. Such ecosystem changes need to be recorded, described, and monitored; they can be recounted in the environmental section of the multiple-objective assessment of the natural hazard event and should include economic losses related to the environmental changes.

Assessing ecosystem change can be straightforward if the ecological effects of the natural hazard event are primarily direct effects. However, changes that are delayed, indirect, or cumulative are often of greater importance than direct effects and require assessments that involve predictions of ecosystem behavior. Also, predictions of the pattern and rate of ecological recovery are necessary if mitigation of ecosystem damage is being considered. In other words, both predictions of ecosystem behavior and identification and measurement of direct ecological effects may be important in assessing the impacts of natural hazard events.

Choosing the most applicable spatial scale for observing the landscape greatly impacts the perceived effects of the natural hazard event. At a regional scale, the local loss of a few windblown trees could be negligible; however, at a local scale, the same loss of a few trees could constitute ecological damage if, for example, locally important wildlife habitat is destroyed. The concept is equivalent to taking the appropriate *accounting stance.* A national accounting stance (i.e., large-scale ecological boundaries) could fail to show a locally important effect, while a local accounting stance (i.e., small-scale ecological boundaries) could show a serious impact that is not, however, an impact at the regional scale.

Environmental impacts should be examined in the context of the natural hazard event cycle. The pre-event stage is the long-range planning and preparation stage in which baseline data should be gathered on the characteristics of the ecosystem. These data may also help predict impacts on valued ecosystem components. If predicted impacts are severe enough, it may be necessary to undertake a mitigation strategy to reduce or eliminate undesirable effects or plan a rehabilitation strategy.

In the immediate pre- and post-event stage, the main concern is the preservation of environmental attributes valued by humans, for example, when deciding which locations receive higher priority in containing an oil spill.

In the post-event stage, assessing what damage has occurred to valued ecosystem components is a major task. Assessment involves prediction of indirect, delayed, and cumulative impacts as well as measurement of direct impacts. The assessment should include a prediction of whether natural recovery processes will restore the ecosystem to a state considered desirable by society in an acceptable period of time. (The ecological effects of and recovery from the 1980 eruption of Mt. St. Helens have been the subject of numerous studies that documented the post-event changes that took place.) If damage is severe enough, and the natural recovery process is not satisfactory, rehabilitation strategies must be specified.

Assessment of ecological damage following a disturbance will be considerably more accurate and informative if baseline data have been gathered prior to the event and if monitoring continues during the recovery phase. Checklists should enumerate types of potential impacts and include guidelines for impact identification and evaluation. Within each impact type, particular ecosystem parameters should be listed and measured to indicate the size of the impact. Simple checklists are useful in the early phases of environmental impact assessment. An example of a useful checklist is found in Table 4.

The natural hazard event can also be treated as an experiment, particularly if it created major impacts and their outcome is uncertain. A program to monitor the effects of the event or its mitigation can detect unexpected impacts, which can then be used to adjust future responses (Beanland and Duinker, 1986; Munn, 1985; National Research Council, 1986; Ward, 1978). Holling (1978) suggested adaptive management, which bases decisions on the need for increased knowledge and includes experimentation designed to increase information about ecological effects.

Recent developments in remote sensing, geographic information systems, and computer modeling provide some powerful methods that will aid us in predicting future impact scenarios and understanding better the contribution that natural hazard events make to spatial patterns and landscape mosaics. Geographic information systems (GISs) are modeling systems using computer mapping and data tables to generate layers of information about ecosystems. Models can also produce data predicting ecosystem behavior. Some studies have also used a geographic information system with various species-habitat and spatial-population models.

Both the natural hazard event and the ecosystem need to be measured in the proper context. What is the nature of the disturbance? For example, is it a 100-year flood? Is it a severe crown fire? What is the nature of the ecological system at the site? Is it an old-growth forest? Is it an overgrazed grassland? What existing data are there? In many cases, a field survey will be needed to collect on-site information.

It is important to identify temporal and spatial boundaries early in the environmental assessment. Boundaries are critical to designing the study, interpreting results, predicting effects, and determining impact significance. Response and recovery times must also be considered when planning the time frame of the study. In addition, the observed effects of a natural hazard event can be critically affected by the spatial scale employed to evaluate the landscape.

Continued study of an affected site is necessary to determine whether predictions of the impacts from the event or from human mitigation activities are correct. Such knowledge allows preparation for future events and any needed adjustments (Holling, 1978). Monitoring should continue at least for the recovery period. Monitoring programs need to be well planned so that they use a minimum of time and money and focus on the most valued or least understood components (Beanland and Duinker, 1983).

The ecological damage assessment guidelines are intended to be adaptable to the needs of particular agencies and types of natural hazard events. Past success in evaluating ecological impacts has been poor; therefore, a systematic approach should be taken. There is substantial need for both intra- and inter-agency coordination in designing environmental evaluations. Impacts should be conceptualized at appropriate scales for managing natural resources; these scales should not necessarily bear relation to the scale of agency jurisdictions. At inappropriate scales important ecological effects, including cumulative impacts, may be missed.

Table 4
Outline of Potentially Useful Field Survey Data
(expanded and modified from Ward 1978)

Ecosystem Structure (Components)

- *Species composition, abundance, and growth form and stature*—can be measured by looking at ecological density for entire area; density for specific habitat; relative abundance (e.g., number of rabbits seen in *x* time at *y* place); normal fluctuations; growth form (e.g., tree, shrub, tall herb, or low herb); and relationship and connectedness to substrate
- *Feeding relationships among species*
- *Ecological dominance and key species*—(important in maintaining the particular structure and overall functions of a community). Ecological dominance refers to a species that controls a major portion of community energy flow (e.g., high abundance, biomass, or productivity). Key species are species that have strong influences on most other organisms in a community, and, if removed, would drastically change community. Elements can initially be identified by visual identification.
- *Species diversity*—can be affected by many variables and does not provide an accurate indicator of the health of an ecosystem. Must be careful not to overestimate. Recommend using number of species rather than other measures.
- *Indicator species and ecological indicators*—used to evaluate prevailing conditions. It is better to use several species than a single species. More reliable to use a more general characteristic or a direct measure than an indicator. Recommend *not* measuring a small species population with high turnover.
- *Size, shape, and heterogeneity of disturbed areas, and, if more extensive, boundaries of the resources affected by the natural hazard event*
- *Physical factors*, such as topography

Ecosystem Function (Processes)

- *Productivity equals rate of production of organic matter*—this measure indicates the capacity of a physical system to support life. Should measure total rate or one component. Most commonly measured function is "net primary," which measures gross (total photosynthetic) minus respiratory use. The standing crop or biomass on-site is not equal to productivity, but is acceptable if producers are large and long-lived and immediate consumption of products is minimal.

Table 4 (continued)

- *Trophic structure and energy flow*—energy acts in an open system (e.g., solar = input, heat dissipation = output). Goal is only to estimate, to see whole system and biological importance of components. Nutrition relations make up the food web. Recommend grouping species with similar nutritional needs.

- *Nutrient relationships*—occur in a closed system (e.g., pools of nitrogen, phosphorous, etc.). Nutrient concentrations, pathways, and rates of transfer may change due to natural hazard event. These changes may affect species composition.

- *Decomposition processes*—difficult to study, but are important and complex. Temperature and water are important factors. These processes are not usually studied in environmental impact assessments. These processes occur via physical and biological action, with biological actions occurring primarily due to bacteria and fungi. Can either study certain organisms or total activity.

- *Succession and development of communities*—succession is reasonably directional change in species structure of a community over time. Look at population age and size structure and reproductive success of species.

- *Individual species characteristics* (e.g., reproductive strategies, success, and health of organisms)

Other

- *Disturbance event characteristics* (e.g., intensity of the event)
- *Evidence of other or potential natural hazard events*
- *Evidence of or potential for cumulative impacts*
- *Evidence of patterns and rates of recovery*
- *Characteristics of neighboring ecosystems and organisms that may colonize or affect the disturbed area*
- *Evidence of controlling or limiting environmental factors (resource availability) or driving physical/chemical forces on ecosystem*

Summary

Identifying and measuring directly imposed economic damages are the most important steps in quantifying natural hazard damages. The objective is to monetize the "real" damages that take two main forms: 1) damages to natural, human-made, and human assets, and 2) delays or losses of value added in production processes. Double counting of real damages and their financial reflections (e.g., changes in stock values) must be avoided.

The measure of damage to human-made capital assets is complicated by the irrelevance of most accounting book values. If there is complete destruction and full replacement with new assets is warranted, damages ideally are measured by the depreciated replacement value or the market price of similar used assets.

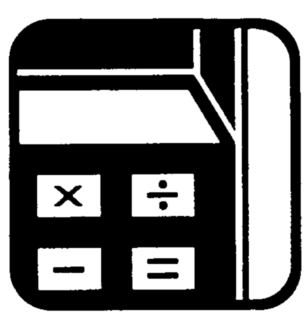
If assets are damaged and rehabilitation to previous status is warranted because the gain in benefits will exceed costs of rehabilitation, a practical lower bound is the cost of rehabilitation. If no rehabilitation is warranted, then damages must be measured as the present value of the loss of value added.

When production is interrupted by a hazard event because of unavailability of purchased inputs, damage to the production site, or inability to sell the product, it must be determined whether the production has been permanently lost or just delayed. Value added that is merely delayed but will be made up results in a much lower present value of damages than value added that is permanently lost.

Value added in the public sector (government administration or service activities) that is lost due to a hazard event is generally measured by the cost of the services, since there usually is no market price for such services. When special public sector hazard response services are required by a hazard event, the added costs of these services constitute damages attributable to the event.

The dangers of double counting or over counting damages must be emphasized. A common and incorrect practice is to count the *total* value of production delayed or lost rather than just the value added. Another incorrect example is found in flood damage estimates that contain both lost production and lost incomes from the same production.

A national accounting stance is almost always appropriate. However, local jurisdictions will be interested in past or prospective relief programs that reduce the local incidence of costs. Relief payments and rehabilitation subsidies reduce the damages borne by the locality, but not the real damages.



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Special Publication #28