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# A REANALYSIS OF THE NATIONAL FLOOD LOSS DATABASE

Mary W. Downton*, J. Zoe Barnard Miller, Roger A. Pielke Jr.
National Center for Atmospheric Research, Boulder, Colorado

## 1. INTRODUCTION

Historical flood loss data are essential for any study that seeks to understand the role that climate, population growth, land use, and government policies play in determining trends in damaging floods. Yet, little historical damage data is available. There are no uniform guidelines for estimating flood losses, and there is no central clearinghouse to collect, evaluate, and report flood loss information. The National Weather Service (NWS) conducts the only comprehensive and continuous effort to collect flood damage information for the entire country. Its damage data consist of rough estimates, compiled from a variety of sources for nearly a century.

If comparisons of flood damage in different times and places are to be valid, damage estimates must be based on reasonably consistent criteria and methods. Therefore, an evaluation of the data should consider both the accuracy of the estimates and their consistency over many years and many locations.

This study reviewed and evaluated NWS flood damage data sets by examining archived information, interviewing people who collect the data, identifying sources of error and inconsistency, and performing error analyses. The resulting reports will provide corrected flood damage estimates, explain likely errors and limitations, and recommend appropriate uses of the data. The data sets to be provided are:

(1) Estimated annual total flood damage in the United States, 1926-79 and 1983-99;

(2) Estimated annual flood damage in each state, 1955-79 and 1983-99; and

(3) Estimated annual flood damage by river basin and drainage, 1933-75.

* Corresponding author address: Mary W. Downton, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307; email: downton@ucar.edu.

## 2. NWS FLOOD DAMAGE ESTIMATES

The NWS collects damage estimates for "significant flooding events" through its nationwide system of field offices (NWS-HIC 2001). The estimates include only direct damages due to flooding that results from rainfall or snowmelt. They do not include flooding due to winds, such as coastal storm surges. Types of damage included appear to have been fairly consistent, at least since 1948. Before 1948, a small proportion of indirect damages (loss of business and wages) were included. It is less clear whether there have been changes over the years in judgments as to which flood events are "significant" enough for inclusion.

### 2.1 *Overview of Historical Estimates*

The NWS has published flood damage estimates almost annually since 1934. From 1934 to 1975, reporting units were defined by natural boundaries (river basins), which corresponded to local planning issues such as water supply, agriculture, and flood control. Two formats were consistently used for summarizing losses, one during 1934-47, the other during 1948-75. In 1955, annual summaries of damage by state were added. The consistent administration, methodology, and format are indications that these data form a reasonably homogeneous time series.

During 1976-1979, reduction of funding led to cutbacks in collection and processing of flood damage data. Annual summaries were not published. Data collection was consistent with prior years, but there appears to have been less checking and updating of initial damage information.

In 1980, the NWS stopped collecting flood reports in its archive. During 1980-82, the only regularly collected NWS records of flood damage were those published in *Storm Data* (a monthly NOAA publication).

In 1983, Congress ordered the U.S. Army Corps of Engineers (USACE) to provide annual reports of flood damage suffered in the U.S. The USACE contracted with the NWS to provide the

required data. NWS estimates of flood damage in each state have been published annually since 1983 by the USACE. The NWS Hydrologic Information Center has gradually improved its procedures for collecting, checking, and compiling the damage estimates.

This history reveals a major change in the purpose of collecting flood damage data. Through the mid-1970s, damage estimates were reported by river basin and designed to be useful for local and regional planning. Today, estimates are reported by state, designed for use by Congress in budgetary decision-making related to federal programs such as the USACE and the Federal Emergency Management Agency (FEMA). Flood damage information is no longer aggregated in the ways that are most useful for diagnosing local and regional flood problems.

### 2.2 *Present Data Collection Methods*

The NWS now operates approximately 120 field offices throughout the U.S. A staff member in each office is responsible for submitting monthly reports on severe storm events, including deaths and estimates of damage to property and crops. The field office information is published in *Storm Data*, with only minimal checking for obvious errors. A meteorologist at the NWS Hydrologic Information Center (NWS-HIC) does follow-up checks on flood events to assure that all significant floods are covered and to correct estimates that appear unreasonable. Reports are issued for each fiscal year (October - September), giving the total flood damage in each state and several U.S. territories.

The NWS field offices differ in the regularity and completeness of their damage reports. Historically, field office personnel obtained their damage estimates primarily from newspapers. Today, they still make use of newspapers but typically obtain their estimates from local experts, such as emergency managers, insurance agents, local officials, and agents of the U.S. Department of Agriculture. In most cases, all damage information is collected within three months after the flood event.

## 3. REANALYSIS OF THE ESTIMATES

NWS-HIC staff provided copies of their data sets and access to their historical archives. We obtained additional information from staff members at the NWS and state emergency management offices, as well as independent damage estimates from reports of federal and state agencies.

Intensive efforts were made to collect supplementary flood damage estimates for 1976-82. Data and confirmatory evidence were found to complete state and national damage estimates for 1976-79. (In 1979, a few states do not have individual estimates but are included in multi-state regions.) However, little data was available for 1980-82 and large errors were found in the rough approximations supplied by NWS-HIC; therefore, estimates for 1980-82 are not included in the reanalyzed data sets.

### 3.1 *Consistency of the Data Series Over Time*

Published NWS reports of flood damage are uniform in format and content for extended periods, indicating that fairly consistent methods were used within the periods 1934-79 and 1983-present. Before 1980, estimates were aggregated by river basin and calendar year; after 1982 they were aggregated by state and fiscal year. In the reanalyzed data, national estimates are presented by fiscal year (Oct.-Sep., corresponding to water years) for the entire period. It is not possible to do the same for state estimates; therefore, they are presented by calendar year for 1955-79 and by fiscal year for 1983-99. River basin estimates (available only for 1933-75) are presented by calendar year.

NWS policies on what losses to include have changed somewhat over the years. Damage estimates published through 1975 focused primarily on damage to property and crops, but included some indirect losses. Present policy is to focus exclusively on physical damage to property and crops. However, the estimates come from diverse independent sources, so other types of loss are likely to be included occasionally.

It is often impossible to separate damage by flood and other storm-related causes. Typically, the full amount is labeled as flood damage if heavy rain or river flows are considered to be the primary cause. Conversely, flood damages may be omitted if the major cause is wind (hurricanes, tornadoes), hail, snow, or ice. These uncertainties can lead to incompatibility with data from other agencies.

The NWS process of collecting damage data has always focused more attention on larger floods. At least since 1990, intensive efforts have been made to obtain estimates in floods that appear to involve over $1 million damage.

However, the field offices differ greatly in the amount of effort put into collecting damage estimates. Damage in small floods is frequently underestimated or ignored.

In the judgment of the authors, the methods and objectives of the NWS in collecting flood damage estimates have been reasonably consistent from 1934 to the present, although the coverage of smaller floods may have varied over time. Somewhat larger errors can be expected in the estimates for 1976-79 and 1983-84 because of the curtailment of data collection and the need to establish new procedures when reporting resumed in 1983.

### 3.2 *Accuracy of the Estimates*

Potentially the most serious source of error is the unsystematic approach to obtaining damage estimates from each NWS field office. The estimates are collected by staff members who have little or no training in damage estimation and who rely on diverse sources. Estimation methods used by their sources are unknown. Estimates are usually obtained within three months after a flood event and are not compared with records of actual damage costs. An overall tendency to underestimate total damage is expected because of incomplete reporting and the omission of some floods.

Ideally, estimation errors would be measured by systematically comparing estimates with actual costs, which often are not known until long after a flood event. Unfortunately, actual loss data are seldom collected in a form that can be compared with estimates made at the time of the flood. This study examined estimation errors in two ways: (1) by comparing estimates with actual costs in one large flood disaster (the 1998 California El Nino disaster), and (2) by comparing NWS estimates with estimates from five states in many flood events. (The states are California, Colorado, Michigan, Virginia, and Wisconsin). The following conclusions are drawn from those comparisons. All dollar amounts are reported in inflation-adjusted 1995 dollars.

(1) *Individual damage estimates for small floods or for local jurisdictions within a larger flood area tend to be extremely inaccurate.*

In the 1998 event, with actual costs in the $1 - 30 million range, a large proportion of estimates are found to be in error by at least a factor of two and sometimes much more. When damage in a state is estimated to be less than $50 million, estimates from NWS and state sources frequently disagree by more than a factor of two.

(2) *Damage estimates become more accurate at higher levels of aggregation. Thus NWS estimates totaled over large geographic areas or many years are likely to be reasonably reliable (within about a 50% margin of error).*

Errors tend to average out, as long as the local estimates are not systematically biased. For example, the sum of estimates from many counties in a large flood area are found to be quite close to the actual total costs for the area as a whole. When damage in a state is estimated to be greater than $500 million, disagreement between estimates from NWS and state sources are relatively small (40% or less). The relatively close agreement between NWS and state estimates in years with major damage is reassuring, since the most costly floods are of greatest concern and make up a large proportion of total flood damage.

(3) *Floods causing moderate damage are occasionally omitted, or their damage greatly underestimated, in the NWS data sets.*

When discrepancies between NWS and state estimates are large, most often the state estimate is the higher one. Occasionally, NWS estimates are missing for floods in which the state claims as much as $50 million damage. Such omissions would have little effect on national total damage estimates. However, they might be important in analyses of damaging floods at the state or river basin level. Researchers studying flood damage in states or river basins should be aware that the NWS estimates occasionally overlook some locally significant damage.

## 4. EXAMPLES OF THE REANALYZED DATA

Figure 1 shows the reanalyzed estimates of total U.S. flood damage (1995 dollars). To study trends in flood damage over time, it is important to normalize the damage estimates to account for changes in population, land use, or development. For example, selection of the years of greatest damage is somewhat different depending on whether one considers total damage (Figure 1) or damage per capita (Figure 2).

The flood damage estimates for California (Figure 3) and Illinois (Figure 4) illustrate how states differ in damage patterns. California suffers severe flood damage relatively frequently. The

Fig. 1: National Flood Damage
(1934-1999)

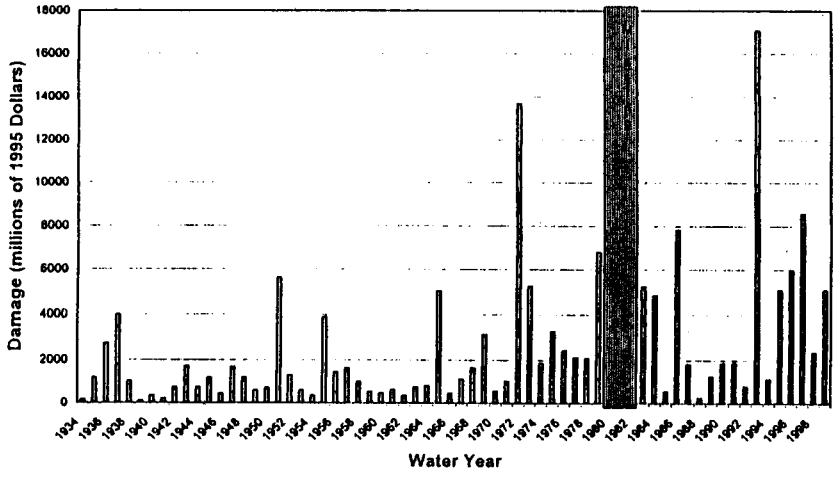



Fig. 2: National Flood Damages per Capita
(1934-1999)

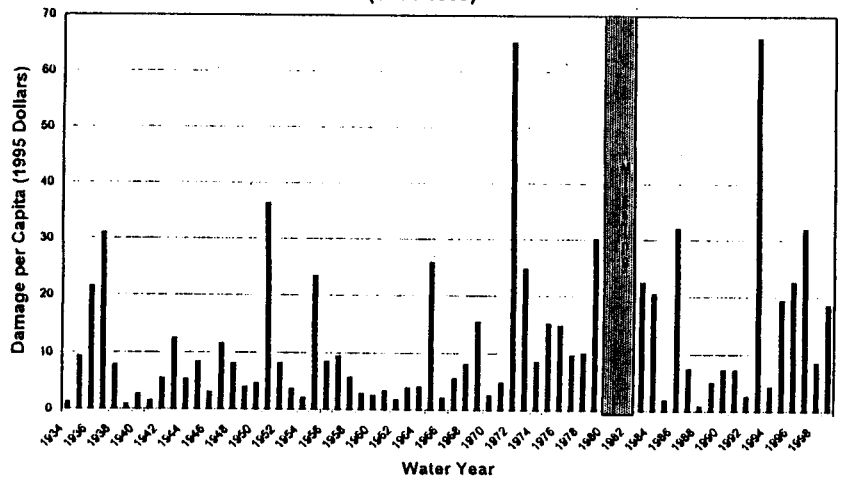



Fig. 3: California Flood Damage
(1955-1999)

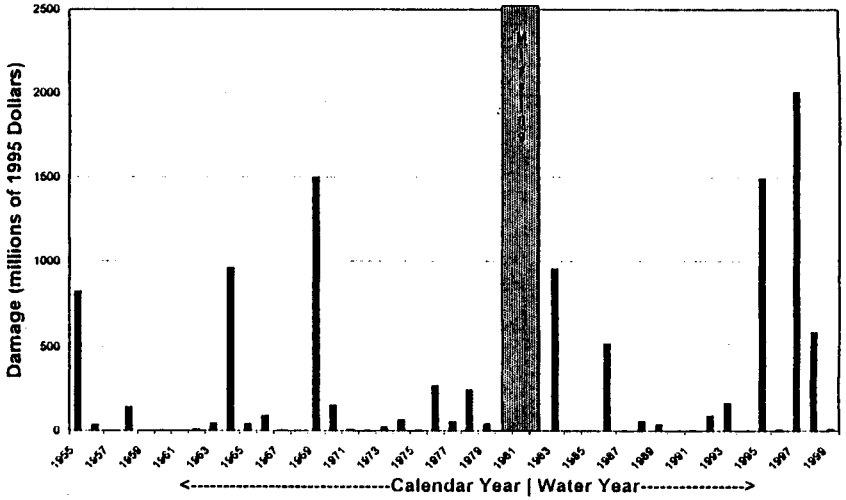
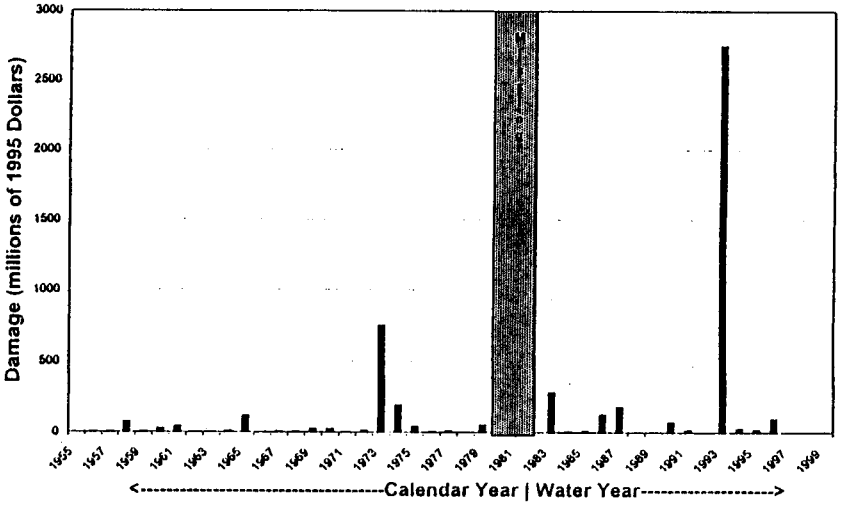



Fig. 4: Illinois Flood Damage
(1955-1999)



Illinois pattern is more typical, with only one or two severe floods in the 42 years of data.

## 5. RECOMMENDATIONS FOR USERS

"Estimate" is the key word for describing these data. They do not represent an accurate accounting of actual costs, nor do they include all of the losses that might be attributable to flooding. Rather, they are rough estimates of direct physical damage to property, crops, and public infrastructure. Damage estimates for individual flood events are often quite inaccurate, but as estimates from many events are added together the errors become proportionately smaller.

### 5.1 *Limitations of the Data*

Individual floods should be compared only in general terms. For example, in California (Figure 3) flooding clearly caused more damage in 1995 and 1997 than in 1992 and 1993. But the NWS estimates are not accurate enough to say with confidence that 1997 floods caused more damage than those in 1995, or that 1993 floods caused more damage than those in 1992. Other information would be needed to support such conclusions.

Typically, a state or river basin suffers little flood damage in most years and severe damage in only a few years (Figure 4). In times of relatively low damage, year-to-year variability in the NWS damage estimates is likely to be dominated by estimation errors. Our error analysis suggests that the proportional errors can be quite large in damage estimates as high as $50 million, with estimates from different sources frequently differing by a factor of two or more. It is unlikely that a valid climate signal, for example, could be detected in the interannual variations of estimates below the $50 million level.

### 5.2 *Appropriate Uses*

Estimates that are highly aggregated appear to be reasonably reliable. The national annual damage totals are sums of many flood events; hence, estimation errors can be expected to be reasonably small. The frequency distribution of national totals during 1934-99 approximates a log normal distribution.

Annual damage estimates for the states have larger estimation errors, and their distributions are not easily defined. Estimates of state damages from different sources may disagree by as much as 40% even when flood damages are large (above the $500 million level). During 1955-99, many states had only one or two years of severe flood damage; and damage estimates in the other years are not particularly reliable.

Using a high level of aggregation is the key to making reasonable comparisons. To compare flood damages between states or river basins, it is advisable to aggregate the damage estimates over many years and compare the sums. To compare damage between years, it is advisable to aggregate yearly state damage estimates over multi-state regions. Although aggregation helps to reduce the estimation errors, the user still needs to be aware that some of the variability is caused by error, and interpret the results accordingly.

### 5.3 *Possible Inconsistencies With Other Sources*

The NWS defines flood damage more narrowly than many other agencies. Emergency management agencies generally include both river and coastal flooding whenever water rises to overflow land which is not normally submerged. In contrast, the NWS estimates include only flooding whose primary cause is rainfall, snowmelt, or river flows, excluding flooding caused by wind-driven waves associated with coastal storms or hurricanes. For example, FEMA records show a Presidential disaster declaration of type "flood" for Massachusetts in February 1978, and the USACE reports $520 million flood damage due to storm surge and huge waves (USACE 1979, converted to 1995 dollars), but that damage is not included in NWS flood damage estimates.

## 6. CONCLUSION

The reanalyzed NWS flood damage estimates will be made available soon at http://www.esig.ucar.edu/. We hope they will be useful to researchers and decision makers in understanding the changing character of damaging floods in the United States. In climate research, the data sets can contribute to understanding the relationship between climatic influences and damaging floods (cf. Pielke and Downton 2000). For emergency managers and policy makers, they can be used in evaluating the effect of flood mitigation measures and public policies related to management of flood hazards (cf. Downton and Pielke 2001).

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