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Overview of Flood Damages Prevented by U.S. Army Corps of Engineers Flood Control Reduction Programs and Activities

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This paper provides a concise description of the methodology employed by the U.S. Army Corps of Engineers in its estimates of "damages prevented" by Corps flood control activities. This paper notes both the strengths and potential areas of improvement for this performance measure, which is used to demonstrate the effectiveness of some of the nation's investments in water resources infrastructure. These investments provide social benefits that are realized when Corps projects are available to accommodate public demands. To the end, this paper is organized into the following sections: Background; Contents of Annual Flood Damage Reduction Report to Congress; Congressional Intent of Legislation for Annual Report; Magnitude of Flood Damages Prevented; Description of How Flood Damages Are Calculated, including Floodplain Inventory; Difference between Estimates of Flood Damages Prevented and Actual Flood Damages; Potential Ways to Improve Flood Damage Estimates; Conclusions.

Background

House Report No. 98-217—as part of Congressional documents for the Energy and Water Development Appropriation Bill of 1984—directs the U.S. Army Corps of Engineers to issue an annual report to Congress on floods, flood damage, hurricanes, and other natural disasters requiring Corps intervention. These reports include a state-by-state as well as Corps division and district assessment of flood damages, acres inundated, property damage, loss of life and damages prevented by previous flood control measures undertaken. These same reports include assessments of damages resulting from other natural disasters that occurred during the previous year.

Contents of the Annual Flood Damage Report to Congress

USACE Headquarters requests each Corps district to supply annual flood damage reports (AFDR) on a yearly basis. Damages prevented are reported in three parts: damages prevented by reservoir projects; damages prevented by levee or other type of projects; and damages prevented by emergency operations. Data on flood damages prevented are provided by states and by districts. When a portion of a state lies within a district, only damages for that portion of the state are reported. In addition the following information is required

1. Storm location/basin and storm date and description including the amount of precipitation
2. Names of projects involved in reducing flood level
3. Percentage of flood control space filled for reservoir projects
4. Amount of stage reduction (feet) at key locations
5. Area (acres or square miles) protected from inundation by this flood event
6. Flood recurrence interval

7. Number of homes or business kept from being flooded
8. Lives lost as a result of the flood event
9. First time flood control operation or record pool levels for reservoir projects
10. Damages prevented for this flood event (amount may be only part of the whole year)

In addition, these narratives generally contain details about any other substantial hydrologic events such as droughts, hurricanes, blizzards or flash floods.

According to its field directives, each Corps district must provide a local National Weather Service (NWS) or a River Forecast Center office with all of the damage data it collects. The NWS headquarters compiles and analyzes this information and combines it with data from other sources to arrive at the final damage statistics for the year. The final survey on damages suffered and lives lost are provided to the Corps and become part of the AFDR to Congress. In addition, a narrative of the AFDR highlights is required when the total damages for a given state (or portion of the state within a district) exceed 200 percent of its 10-year average. If damages prevented from multiple small floods allow a state to meet the above criteria, but no exceptionally large flood event took place, no narrative is required.

The report represents preliminary estimates on a state-by-state basis using data available at the end of the fiscal year. The data are derived from a variety of Federal and non-federal sources. Because the Corps is responsible for all federal flood control storage, the report includes damages prevented by Corps-owned projects and non-Corps projects that have federal flood control storage (e.g., United States Bureau of Reclamation). Regardless of the project owner, the Corps has responsibility for all federally-owned flood control storage.

Information in the report is intended to provide a broad national picture of storm events and the extent of national beneficial flood damage reduction produced by Corps. Because of the general nature of the subject and the rapid compilation of the preliminary data estimates, the report's accuracy and completeness are considered preliminary and not intended for detailed research.

Before 1983 Flood damage reduction information was included in the Annual Report of the Chief of Engineers on Civil Works Activities tabulated by Corps districts. (Reports are available on the web: http://www.usace.army.mil/inet/functions/cw/cecwe/.)

Congressional Intent of Information

Congressional intent of the legislation directing the Corps of Engineers is vague. House Report 98-217 states, "the Corps of Engineers is directed to submit to the Committees on Appropriations of the House of Representatives and the Senate an annual report on floods, flood damages, hurricanes and other natural disasters requiring Corps intervention." No information either in Congressional hearings or other documents presents the rationale for this report.

Magnitude of Flood Damages Prevented

The construction and operation of 383 flood control reservoirs and 8,500 mile of levees has resulted in substantial amounts of flood damages being avoided. It has been estimated that these structures have prevented about $710 billion in flood damages from 1928 to 2000 when adjusted for inflation. In addition, flood damage prevented by the Corps averaged $21.7 billion annually for fiscal years 1993 through 2002. This figure represents flood damage reduction B/C ratio of $6.35 in benefits for every $1.00 invested (in year 2000 dollars). Each year the benefits continue to grow because annual O&M costs are only about 7% of the annual benefits.

Deriving Flood Damages Prevented Estimates

The effect of reservoir operations on downstream flow (damages prevented) is determined by routing (the calculations, travel time diversions, etc.) and comparing regulated and unregulated (i.e., natural or without-project) river stages for selected sites. This involves comparison of the observed flows and damages with the flood reduction structure with the unregulated flows (those that would have been observed without the flood control dams) and the potential resulting damages. The reduction in river stage or flow that resulted from reservoir operations may be used to index the value of damages prevented.

Steps in Determining Damages Prevented

In general terms, flood damages prevented are determined in the following manner:

1. Elevation of a given flood stage is determined at a gauged location at National Geodetic Vertical Datum (NGVD) or other measuring reference tools such as North American vertical Datum High Point (NAVD88)
2. A theoretical elevation or level of water without the project (dam, levee) is established
3. A derived stage-damage function or curve is estimated for both the actual and theoretical elevations
4. Difference in damage estimates represents damages prevented

The stage-damage curve estimation, referred to above in step three, is based on statistical procedure for predicting damage to individual flood plain structures (and property) as a function of river stage and the probability of reaching that stage during a particular flood event. The stage-damage curve is a rating curve within a river reach that shows the amount of damage that would occur for different river levels. It is developed before a flood occurs, usually when the project is in the planning stage. To develop the curve, potential damage is estimated using topography along the river to determine the areas and the number of houses or other structures that would be inundated at a given flood level. This procedure is repeated for various flood levels and the results are plotted on a curve. The number and type of structures that occur along the river often change over time, causing the curve to become out-of-date. All of the curves are indexed for inflation, but few are updated to reflect developing in the flood plain. Since many projects are about 50 years old, changes in the flood plain are often very significant. As a result, underestimation of benefits is common.

To more precisely calculate annual expected flood damages, each Corps district also uses another function or curve called a *depth-damage curve*. The application of the depth-damage relationship to the floodplain inventory is used to develop the stage-damage curve or relationship. Depth-damage curves are used to describe damages to specific types of structures. The aggregates of these depth-damage curves make up the stage-damage curve. Because national depth-damage functions do not exist, damage functions developed by the Federal Insurance and Mitigation Administration, formerly the Federal Insurance Administration (FIA) in the early 1970's have been widely used by the Corps of Engineers. Much of the data for the development of the FIA depth-damage functions are based on a combination of theoretically determined damage functions, modified by records of historical flood claim data. National generic residential damage functions from Institute of Water Resources (IWR) Damage Data Collection Program have been issued for structures without basements (in 2000) and structures with basements (in 2003).

In general non-residential depth-damage data are not readily available and are costly to collect. Individual districts such as New Orleans have developed non-residential depth-damage curves for several businesses through an OMB survey method of sampling and applied them to all commercial property.

Depth-damage curves are based on a number of assumptions, including the following: the derivation of the damage function; a description of the type of flooding occurring in a given geographical region of the United States; a list of the types of buildings from which functions have been derived; the structure definition and method for structure value determination; the content definition and method for content value determination; the structure damage definition and method for structure value determination; and the content damage definition and method for content determination.

In a 1991 survey conducted by the IWR, more than half of the Corps' 38 districts and two divisions indicated that they used depth damage curves based on Flood Insurance Rate Reviews developed by FIA. Individual districts also used in-house surveys as well as synthetically derived depth-damage functions where no FIA data were available or applicable.

Floodplain Inventory

A floodplain inventory is one of the most important components of the stage-damage curve and, consequently, the damages prevented estimate. In general, older and out-of-date floodplain inventories will probably underestimate the actual value of the damages avoided or prevented due to the presence of a flood-control structure because more development is likely to take place in a floodplain afforded such protection.

Components of Floodplain Inventory

A flood plain inventory is a list of floodplain property. It is used to determine the number and type of structures, their value, and their first floor elevations (where water enters the structure). An inventory is usually accomplished through contour mapping or USGS maps to establish for ground elevations; for new developments, elevation certificates are obtained from local government offices to establish surveyed first floor elevations. Field surveys are then used to obtain the above ground height of structures, from the centerline of streets using hand levels. Associated with the inventory is the development of an applicable flood depth-percent relationship for each structure type.

The number and type of structures are important parameters in estimating potential flood damages. The number of structures in the study floodplain area includes detached garages, sheds, barns, and similar structures. Structure types are defined as residential, commercial, industrial, and public. Residential structures are further classified as single or multi-family or mobile home, with their number of stories, split level and with-or-without-basements.

Structure value analysis is also included in Corps floodplain inventories. These values reflect the replacement costs minus depreciation to the existing (pre-flood) structure. Replacement cost is the cost of physically replacing the structure subjected to flooding. Depreciation accounts for deterioration occurring prior to flooding and variations in remaining useful life of the structure.

The third element involved in this inventory is usually a determination of the structure's content value. In general, the content value for residential structures is equal to some percent of the structure's value determined by survey. The national generic content depth-damage functions are based on a percentage of structure value and content and do not require estimation.

Difference between Estimates of Flood Damages Prevented and Actual Flood Damages

In general, the principal distinction between the Corps estimates of "damages prevented" and actual flood damages reported by the National Weather Service and other agencies (both federal and non-federal) may be stated as "calculated" versus "sustained."

Estimates of damages prevented are calculations of damages that would have been avoided due to the presence of some type of flood control structure (dam, levee, etc.) protecting part of a floodplain. On the other hand, reported flood damages are those an area actually sustained. Both estimates represent attempts at establishing some national or regional estimate of damages caused by riverine or coastal flooding.

One problem with estimates of flood damages prevented as a performance measure is that they are based, to some extent, on the fact that development in a floodplain would have occurred even if the flood control structure (dam, levee, etc.) had not been constructed. Thus, damages prevented may be considered a performance measure, since they gauge how much damage was prevented by the presence of a dam or levee. On the one hand, the very presence of such structures may encourage people to build in a flood-prone area, thus negating any contribution that these structures make to the mitigation of flood-induced damage. On the other hand, an argument could be made that the presence and protection afforded by flood control measures makes lands economically viable that otherwise would not be.

Comparing actual flood damages with those predicted by theoretical models (damages prevented methodology) is difficult because a wide variety of random variables have to be included in such an analysis. Some of these include: timing in collection of both Corps and non-Corps data (e.g., FEMA flood claims, etc.); the fact that rainfall rather than a stage on gauging station may be the determining factor of flooding (concentrated heavy rainfall or downpour

occurring in an area absent a rain gauge); and the reality that many people will not have flood insurance.

Problems Associated with Collection and Interpretation of Flood Losses

Accurate flood loss estimates require a concerted effort, based on the availability of substantial resources. There is no central clearinghouse to report flood losses. Our social infrastructure almost guarantees poor estimates. State and municipal losses are often self-insured. Some portion of the cost to repair a washed out road or bridge might be covered in a budget line item for routine maintenance. Another portion may be financed by a separate line item in the next year's budget. In some cases, a structure may be replaced by one of higher quality, costing more than the replacement value or repair costs of the original structure. Finally, for situations where a governmental entity (i.e., city, county, state, etc.) carries no third party insurance, it may decide to forgo repairs.

Some homeowners and businesses will not have insurance or be under insured. The costs for this sort of repair are almost impossible to estimate. For those that are insured, claims may not fully reflect actual losses. Agricultural losses are also hard to accurately estimate.

Loss/damage estimates are reported in many different ways. Totals are available on states and counties. Depending on what state agency is providing them, they may not include all damages. In addition, industry-wide estimates (e.g., river transportation/barges, railroads, etc.) covering multiple states are often available. Funding and aid supplied by various agencies of the federal government (e.g., FEMA, Department of Agriculture, Small Business Administration, etc.) may also provide regional losses information. Often there is usually not enough information to easily determine the degree of overlap among these various sources. Flood losses that "fall between the cracks" of the current system could, however, compensate for possible "double counting." Unfortunately, there is usually no easy way to reconcile information from different reporting systems.

Potential Ways to Improve Flood Damage Estimates

A few Corps districts (New Orleans, Baltimore, and Mobile) frequently suggest that flood inventories need to increase the accuracy of stage-damage functions (and curves) and hence flood damages prevented. As discussed earlier, older floodplain inventories probably underestimate the actual amount of damages prevented. For example, damage estimates for a 1977 flood in Frankfort, Kentucky increased by about 270% when updated depth-damage curves were used by the Louisville District, Corps of Engineers according to a flood damage report completed in 1981.

The principal reason for the continued use of inventories that do not reflect recent developments in floodplains is the lack of funding for updating. Depending on size and development of area, these surveys can be expensive. A representative from one Corps district (New Orleans) has concluded based on some preliminary assumptions, that it would cost about $500,000 to fully update the stage-damage relationship developed for each Water Resource Unit (WRU) or geographic area having unique hydraulics. A few years ago the Baltimore District estimated that it would cost about $4 million to recalculate its depth-damage curves for the Susquehanna Basin. The Mobile District has estimated that approximately $200,000 to $300,000 would be needed to adequately complete necessary field survey work to increase the reliability of its flood damages prevented estimates. In addition, the Galveston District is spending quite a bit of money updating the inventory along Buffalo Bayou, which flows through the middle of Houston and is the outfall for the Addicks and Barker flood protection dam.

To more fully realize the benefits of flood control activities through the continued use of flood damages prevented as a performance measure, the Corps should, at a minimum, survey all districts to ascertain how much funding would be required to update major floodplain inventories. After such a figure is obtained, the Corps can weigh the benefits of funding this initiative.

Post-flood assessments and studies offer another way to improve the usefulness of estimates of flood damage prevented. To some extent, such studies provide confirmation of the accuracy of the stage-damages curves used to predict damages prevented.

However, these studies need not be performed by every district with flood control reduction structures in place. To more effectively and efficiently utilize resources, sample post flood assessments could be done in a few districts (10 or so). This sampling could be based on such factors as geographical region, type of flooding, intensity of population in floodplain, and land use.

A minimal amount of funds should be set aside for districts to develop post-flood assessments or reports. These reports should include measures of emergency spending by the local, state, and federal governments on infrastructure and clean up following storm events. Each report should also document FEMA flood claims related to the storm. Because the Red Cross sends teams immediately after a storm to determine the number of structures damaged, their data can be used to determine the number of structures damaged whether or not the owner carried insurance. Finally, county agents have estimates of crop damages following a storm.

The accuracy of some district depth-damages curves is based on the availability and use of updated software. Some Corps districts have not taken full advantage of the improved flood damage estimation programs, such as HEC-FDA produced by the Hydrologic Engineering Center in Davis, California.

In addition to HEC models, it should be noted that districts may soon be able to more accurately forecast damages prevented using software developed by the U.S. Amy Institute for Water Resources, the Corps of Engineers Floodplain Inventory (CEFIT). This program should permit district planners and economists to make more reliable estimates of structure value based on building characteristics. The Corps of Engineers Floodplain Inventory Tool is a computer application that contains 960 depth-damage functions for residential structures. Damages are estimated for 16 inundation levels, based on foundation type, structure style, number of stories, and exterior wall construction. The program has a floodplain inventory tool that allows the user to enter specific building characteristics and calculate depreciated structure and content values as well as depth-damage calculations.

While the above-suggested improvements to flood damage estimation could be accomplished through in-house Corps initiatives, an important element of the computations used in these estimates is the prerogative of another federal agency, the United States Geological Survey (USGS). The continued availability and accuracy of depth gauges is dependent upon information collected by the USGS. Due to cutbacks in some river basins, the USGS has scaled back maintenance or has been unable to fund some of the gauging stations. With regard to Corps projects, the cutbacks have been in the amount of funding supplied to the USGS by the Corps of Engineers. The choice of reduced services and exact gauges eliminated has been a Corps decision.

Use of Geographic Information Systems (GIS) Data

Many municipalities have data that could be useful for a floodplain inventory in a GIS database. For example, the mapped delineations of properties usually include those of structures. The footprints could be used to determine the square footage of a building and then be multiplied by a square footage price to derive a value estimate. These data could be stored in a GIS database along with contour data for the elevation of structures in the inventories. These data combined with the hydrologic data and depth-damage curves could be used by a flood damage program to calculate damages and damages prevented. The combination of a statistical sampling technique and 2000 Census Block information that include values and number of structures could be used to reduce the cost of developing a large floodplain inventory. The program HAZUS (Natural Hazards Loss Estimation Methods) developed by FEMA, now contains 2000 census block data for assessing the flood damages. In conclusion, the advances in technology, GIS and HAZUS as well as better statistical techniques for collecting data should make the job of reporting damages prevented less costly and more accurate.

Conclusions

1. House Report No. 98-217 as part of the Congressional documents for the Energy and Water Development Appropriation Bill of 1984 directs the U.S. Army Corps of Engineers to submit an annual report to Congress on floods, flood damage, hurricanes, and other natural disasters requiring Corps intervention. These reports include a state-by-state and Corps

Division and district assessment of flood damages, acres inundated, property damage, loss of life and damages prevented by previous flood control measures undertaken.

2. The construction and operation of 383 flood control reservoirs and 8,500 mile of levees has resulted in very substantial amounts of flood damages being avoided. From 1928 to 2000 it has been estimated these structures have prevented about $710 billion in flood damages when flood damages estimates have been adjusted for inflation. For every dollar spent on the construction of flood reduction projects, about $6 in potential damages from flooding has been averted during the past six decades.

3. There is an apparent need to update flood inventories in a number of Corps districts increasing the accuracy of stage-damage functions (or curves) and consequently estimates of flood damages prevented. Older floodplain inventories probably underestimate the actual amount of damages prevented.

4. Damages prevented estimates are calculations of damages that would have been avoided due to the presence of some type of flood control structure (dam, levee, etc.) protecting part of a floodplain. Reported flood damages are damages that an area has actually sustained. Both estimates represent attempts to establish some national or regional estimates of the magnitude of damages caused by riverine or coastal flooding.

5. In the wake of actual flood events, there is a need for post-flood assessments and studies to improve the usefulness of estimates of flood damages prevented. Such studies provide confirmation of the accuracy of the stage-damage curves used to predict damages prevented.

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James J. Comiskey received his master's degree in urban and regional planning from Rutgers University, New Jersey in 1973. Since then, nearly all his professional work in the planning arena has centered on water resources development and management issues, primarily at the Federal level. He has been employed as an outdoor recreation planner for the U. S. Department of the Interior, a water resources specialist for the U. S. General Accounting Office and has participated in the development of EIS studies for the Mitre Corporation. In addition, Mr.Comiskey has served as a senior environmental scientist/planner with the U.S. Army Corps of Engineer Institute for Water Resources, Alexandria, Virginia for the past 23 years. In this capacity, he was responsible for the completion of numerous studies in such areas as cost reallocation for federal reservoirs, fish and wildlife management at Corps projects, water infrastructure management on military installation and formulation of project benefit studies for flood control reduction activities. Mr. Comiskey can be contacted at (703) 428-9068 or at James.J.Comiskey@USACE.Army.mil.

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