APPENDIX B

Understanding the FEMA Benefit-Cost Analysis Process

The Stafford Act authorizes the President to establish a program to provide technical and financial assistance to state and local governments to assist in the implementation of hazard mitigation measures that are cost effective and designed to substantially reduce injuries, loss of life, hardship, or the risk of future damage and destruction of property. To evaluate proposed hazard mitigation projects prior to funding FEMA requires a Benefit-Cost Analysis (BCA) to validate cost effectiveness. BCA is the method by which the future benefits of a mitigation project are estimated and compared to its cost. The end result is a benefit-cost ratio (BCR), which is derived from a project's total net benefits divided by its total project cost. The BCR is a numerical expression of the cost effectiveness of a project. A project is considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs. Although the preparation of a BCA is a technical process, FEMA has developed software, written materials, and training to support the effort and assist with estimating the expected future benefits over the useful life of a retrofit project. It is imperative to conduct a BCA early in the project development process to ensure the likelihood of meeting the cost-effective eligibility requirement in the Stafford Act.

B.1 Risk

Risk is defined in terms of expected probability and frequency of the hazard occurring, the people and property exposed, and the potential consequences. To estimate future damages (and the benefits of avoiding them), the probabilities of future events must be considered. The probabilities of future events profoundly affect whether a proposed retrofit project is cost effective. For example, the benefits of avoiding flood damage for a building in the 10-percent-annual-chance of flooding floodplain will be enormously greater than the benefits of avoiding flood damage for an identical building situated at the 0.001-percent-annual-chance of flooding level. In addition to the probability of the future flood events, it is just as important to consider the consequences associated with said event on a building. Estimated flood damages for a one-story building will typically be greater than that of a multi-story building or a building with a closed versus open foundation. The damages sustained by existing buildings exposed to flood hazards include site damage, structural and nonstructural building damage, destruction or impairment of service equipment, and loss of contents. These types of damage, along with loss of function are avoided if buildings are located away from flood hazard areas and/or built to exceed the minimum requirements.

Many people may not be aware of the hazards that could affect their property and may not understand the risk they assume through decisions they make regarding their property. Property owners must understand how the choices they make could potentially reduce the risk of it being damaged by natural hazards. Property owners often misunderstand their risk; therefore, risk communication is critical to help them understand the risk that they assume. One common misperception is the 1-percent-annual-chance flood, or 100-year flood. There is a 1-percent chance each year of a flood that equals or exceeds the 100-year flood event elevation. Many property owners believe that being in the 1-percent-annual-chance floodplain means that there is only a 1-percent chance of ever being flooded, which they deem a very small risk. Or, they may believe that the 100-year flood can only happen once every 100 years. Unfortunately, these misperceptions result in a gross underestimation of their flood risk. In reality, over the course of a 30-year mortgage, a residential building within the Special Flood Hazard Area has a 26-percent chance of being damaged by a flood, compared to a 10-percent chance of fire or 17-percent chance of burglary. The discussion of risk with the homeowner can be difficult. It is important to find methods to convey the natural hazard risks for a site and how those risks may be addressed by retrofitting the building. The best available information should be examined, including FEMA Flood Insurance Rate Maps (FIRM), records of historical flooding, and advice from local experts and others who can evaluate flood risks.

B.2 Benefits

The benefits considered in a retrofitting measure are the future damages or losses that are expected to be avoided as a result of the proposed mitigation project. Benefits cannot be determined exactly because the precise number and severity of future flood events is unknown. As a result, benefits are estimated based on experienced or hypothetical flood events of various magnitudes. Benefits for flood retrofit projects typically fall into the following categories:

NOTE

A depth damage function (DDF) is an estimation of direct damage to the building based on a depth of flooding calculated as the percent damage to structures. DDFs are compiled from a variety of sources, including FEMA and the U.S. Army Corps of Engineers (USACE). DDFs typically vary based on the building type (i.e., one-story versus two-story), foundation (i.e., open versus closed), and occupancy type (i.e., residential versus commercial).

- **Building:** reflect damages to the structure and are typically estimated using a depth damage function (DDF) and the building replacement value or historical damage records (e.g., flood insurance claim data); Figure B-1 illustrates that as floodwaters rise, more damage is done to the structure.
- **Content:** reflect damages to the contents within a building and are typically estimated using a DDF and the contents value or historical damage records (e.g., flood insurance claim data).
- **Displacement:** reflect the extra costs incurred when occupants of a residence are displaced to temporary housing due to a flood event. Displacement costs may be incurred for residential, commercial, or public buildings. Displacement occurs only when damages to a structure are sufficiently severe that the structure cannot be repaired with occupants in place.

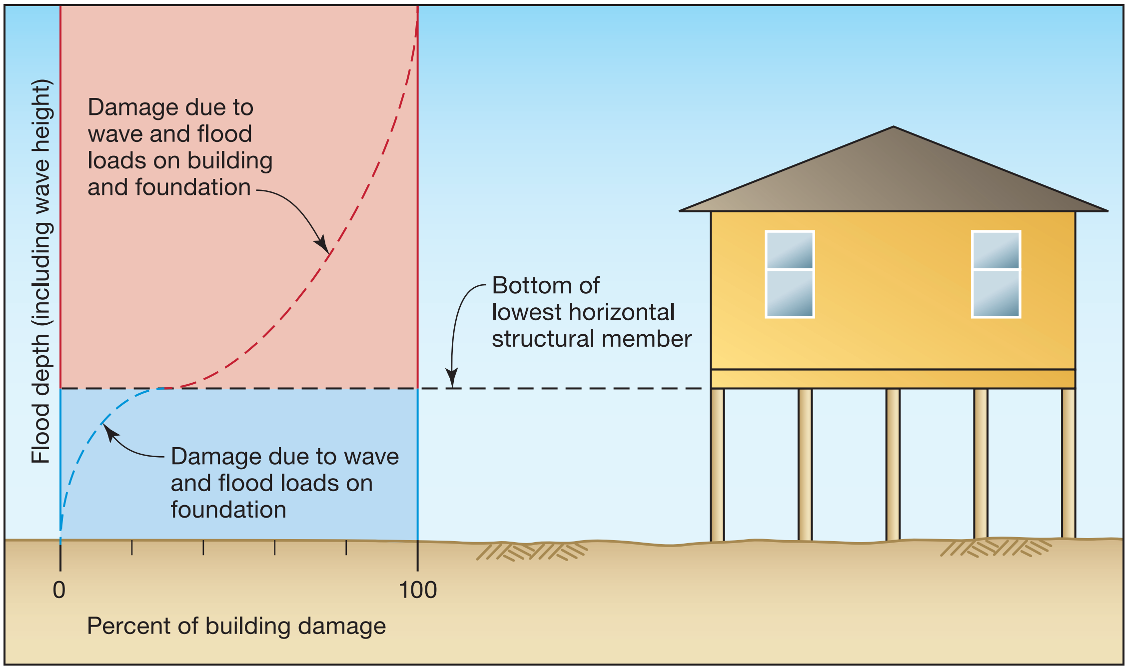

Figure B-1. The graph on the left illustrates how increases in flood depths increase the value of the DDF. The DDF is a relationship between the flood depth and the finished floor elevation of the building and not the elevation of the adjacent ground.

- **Loss of Business or Rental Income:** reflect the impact that may occur when damages are severe enough to result in a temporary closure of a business operating within a facility and estimated based on the net income lost during that closure.
- **Value of Service:** reflect the loss of function of a facility and quantify the service typically provided from the structure. Typical services include public services like law enforcement, fire rescue, medical, general government administrative operations, and public library, as well as utilities like electricity and water treatment.
- **Other:** reflect damages that are not usually estimated in the previous categories. Some typical benefits may include debris removal costs and emergency management costs.

B.3 Estimating Benefits

The calculation of benefits for a proposed mitigation project entails estimating the present value of the sum of the expected annual damages over the useful life. The process takes into consideration:

- probabilities of various levels of flooding events and associated damages;
- useful lifetime of the mitigation project; and
- time value of money.

Some helpful terms to consider when estimating benefits are:

- *Expected annual damages* are the damages per year expected over the life of the structure or useful life of the mitigation project. "Expected annual" does not mean that these damages will occur every year.
- *Scenario damages* indicate the estimated damages that would result from a single flood of a particular depth at the building under evaluation. For example, the scenario damages for a 3-foot flood are the expected damages and losses each time a 3-foot flood occurs at a particular site. Scenario damages do not depend on the probability of floods at that location.
- *Historical damages* are based on actual recorded damages (versus being estimated) and typically associated with a flood frequency to help estimate the probability of occurrence.

The scenario (or historical) damages and the expected annual damages before mitigation provide, in combination, a complete picture of the vulnerability of the building to flood damage before undertaking a mitigation project. Expected annual damages will generally be much smaller than scenario or historical damages because they are multiplied by the probabilities of occurrence. A building with high expected annual damages means that not only are scenario damages high, but also that flood probabilities are relatively high. If expected annual damages are high, then there will be high potential benefits in avoiding such damages. Damages after mitigation depend on the effectiveness of the mitigation measure in avoiding damages. The expected annual damages and losses after mitigation also depend very strongly on the degree of flood risk at the site under evaluation. For some mitigation projects, such as acquisition, the scenario damages and expected annual losses after mitigation will be zero. For other mitigation projects, such as elevation or flood barriers, scenario damages, and expected annual losses after mitigation will be lower than before mitigation, but there is always some chance of flooding so the after mitigation damages cannot be zero.

The expected annual benefit for a project is given by Equation B-1.

EQUATION B-1: EXPECTED ANNUAL BENEFIT

$$EAB = EAD_{Before\ Mitigation} - EAD_{After\ Mitigation}$$

where:

EAB = Expected annual benefit

$EAD_{Before\ Mitigation}$ = Expected annual damages before mitigation

$EAD_{After\ Mitigation}$ = Expected annual damages after mitigation

In order to compare the future benefits to the current cost of the proposed mitigation project, a discount rate is applied over the life of the project to calculate the net present value of the expected annual benefits. For FEMA-funded mitigation projects, the discount rate is set by the Office of Management and Budget. Equation B-2 shows how to calculate the project benefits using the annual discount rate.

EQUATION B-2: PROJECT BENEFITS

$$B = EAB\left[\frac{1-(1+r)^{-T}}{r}\right]$$

where:

B = project benefits

EAB = total expected annual net benefit

r = annual discount rate used to determine net present value of benefits

T = estimated time the project will be effective, Project Useful Life

To evaluate cost effectiveness, a project's total net benefits are divided by its total project cost, resulting in a project *BCR*, as shown in Equation B-3. A project is considered to be cost effective when the *BCR* is greater than or equal to 1.0, indicating the benefits are sufficient to justify the costs.

EQUATION B-3: BENEFIT-COST RATIO

$$BCR = \frac{Project\ Benefits}{Project\ Costs}$$

where:

BCR = benefit-cost ratio

Project Benefits = total project net benefits

Project Costs = total project cost

B.4 FEMA BCA Software

FEMA's BCA program is a key mechanism used by FEMA and other agencies to evaluate certain hazard mitigation projects to determine eligibility and assist in Federal funding decisions. Visit http://www.bcahelpline.com/ for the latest BCA guidelines, policies, software program, user guides, training materials, and other resources, including http://www.fema.gov/government/grant/bca.shtm#0.