Appendix D
ASSUMPTIONS AND LIMITATIONS

D.1 Benefit-Cost Analysis of FEMA Mitigation Grants - Assumptions

D.1.1 Overall

Risk neutrality. This is a benefit-cost analysis, which requires the assumption of risk neutrality.

Seventeen categories of costs and benefits. Benefits were calculated as the expected present value of reduction in uncertain future losses. Costs were calculated as the expected present value of the cost to undertake a mitigation measure. Ten categories of benefit and seven categories of cost were considered, as listed in Tables 2 and 3 of the scoping study report for the benefit-cost analysis of FEMA mitigation grants (ATC, 2003a). Other benefits and other costs were ignored.

Constant 50-year or 100-year planning period. Unless otherwise noted, property mitigation efforts were assumed to be effective for 50 years for ordinary structures or 100 years for important structures and infrastructure, regardless of the age of the property mitigated. For convenience, mitigation efforts were treated as if they became effective on January 1, 2002 and remain effective until December 31, 2052.

Constant discount rates. Future economic values were brought to present value at time-constant discount rates of 2%, and results were sensitivity tested to discount rates between 0% and 7%. Value of human health was not discounted.

Present value of past prices per Consumer Price Index (CPI). All past prices were brought to present value (as of January 1, 2002) per the Consumer Price Index (U.S. Dept. of Labor, Bureau of Labor Statistics, 2004).

D.1.2 Repairs, Casualties, and Environmental Impacts

Accuracy of FEMA data. This project used as input three FEMA resources: the NEMIS database provided on July 23, 2003, geocoded information on flood projects provided on February 9, 2004, and data gleaned from FEMA grant applications. These data were assumed to be correct. (Note that limited Quality Control was performed on these data, per Porter [2004a]).

Accuracy of USGS and California Geologic Survey (CGS) site soil data. The US Geological Survey and the California Geological Survey have compiled GIS maps of site soils in California and elsewhere. See, e.g., Wills et al. (2000). These data were assumed to be accurate.

Accuracy of HAZUS-MH. The project team relied on the use of HAZUS-MH for estimates of mean annualized losses for earthquake and hurricane wind losses. While its accuracy remains to be fully proven over the course of time, it nonetheless, represents the only available national standard multi-hazard loss-estimation tool. The project team did not undertake testing or validation of the software.

Estimation of Flood Losses. Because the flood module in HAZUS-MH was in a pre-beta state at the time these analyses were conducted, the project team had to develop a less sophisticated and more empirically-based approach for estimating flood losses for large property portfolios. This new development pertained mainly to the estimation of flood depths. The project team, however, utilized the damage functions that are contained in the HAZUS flood module to estimate expected damage given a particular flood depth.

Adequacy of assumed hazard strata. The project team assumed that hazard levels can be stratified as low, medium, or high, for each of three perils: flood, earthquake, and wind. The stratification scheme for wind and earthquake is defined in the scoping study report for the benefit-cost analysis of FEMA mitigation grants (ATC, 2003a); the flood hazard stratification scheme is defined in an internal written communication (Porter, 2004b).

Value of human health per FHWA assumptions. Values were assumed for unpriced resources, most notably the environment and human health. For human health, values for statistical deaths and injuries per FHWA (1994) were assumed.

Constant hazard levels. Unless otherwise noted, hazard levels were assumed to be time-invariant as codified in HAZUS-MH.

Projects approved before 1 January 1994 were ignored. Per McLane (2004), the project excluded from its scope of work all projects with an approval date of December 31, 1993 or earlier.

No interaction between projects. Unlike the Community Studies, The benefit-cost analysis of FEMA mitigation grants assumed no interaction between mitigation efforts, i.e., mitigation effort X does not increase or reduce costs or benefits for mitigation effort Y, for different X and Y.

D.2 Benefit-Cost Analysis of FEMA Mitigation Grants - Limitations

D.2.1 Repairs, Casualties, and Environmental Impacts

Sociological benefits are probably underestimated. The major limitations in evaluating the sociological benefits of mitigation are: (1) sociological benefits are not easily quantifiable; (2) sociological benefits are very rarely included in cost-benefit analysis and as a result, there are not state-of-the-art models to build from; (3) sociological data are not readily and easily available; and (4) because of the difficulties of data collection, the quantifiable sociological benefits of mitigation are limited to two major variables: casualties and displaced households. As a result, sociological benefits of mitigation are probably underestimated.

Environmental benefits may be underestimated because of lack of data. The major limitation in evaluating the environmental benefits is the lack of information on the environmental effects of any given mitigation project. Without this information, the project team assumed that the environmental benefits are zero or a very small component of the total benefits. As a result, environmental benefits will tend to be underestimated.

D.2.2 Direct Business Interruption

1-3 year old Business Interruption (BI) data. Most input data for direct business interruption calculations are 1-3 years old. There is no known bias, although accuracy is less by some unknown amount than if current BI data were available.

Several HAZUS default values used. The following variables will always require the use of HAZUS default values: relocation costs, repair duration, building recovery time, rental income, and recapture factor. See Table 2 of the *Project Pilot Study: St. Agnes Medical Center* (ATC, 2003b) for the location of HAZUS default values. There is no known bias, although accuracy is less by some unknown amount than if site-specific data were available.

Reliance on some recent IMPLAN I-O variables. The following variables were adapted (data transfer) from value-added composition of the most recent U.S. IMPLAN Input-Output Table: capital-related income, wages and salaries, and rental income. There is no known bias, although accuracy is less by some unknown amount than if site-specific data were available.

Direct BI not applicable for residences. Direct business interruption losses are not applicable to residences directly impacted by the hazard. The project team believes this is a reasonable assumption that does not bias the results.

D.2.3 Indirect Business Interruption

Regional economy delineated by county or county group. The regional economy is delineated as a county or county group (metropolitan area) that incurs physical damage, when, in fact, most economic regions, or trading areas, do not conform precisely to political boundaries. The political boundary is likely to be larger than the trading area. The result is that estimates of the regional economy are biased upward, with accuracy less than if regional economy mapped with more attention to each individual case. At the same time, indirect business interruption impacts are limited by the same boundaries, with the result of a likely downward bias.

Transfer payments set to zero. To exclude transfer payments, outside aid (government aid, private philanthropy, and insurance payments) are set at zero. Note, this still allows for reconstruction spending, but it is offset as individuals and businesses repay loans or replenish savings. This is a controversial point; whether it produces any bias has not yet been determined.

Use of HAZUS Level-1 "synthetic" regional input-output tables. These tables were developed from a sample of actual IMPLAN regional I-O tables in three categories for earthquakes and wind hazards: (1) manufacturing/service, (2) service/manufacturing, and (3) service/trade. Two additional categories relating to agriculturally-based economies are included in the HAZUS flood version. This improves the accuracy of the flood module relative to the wind and earthquake models. The HAZUS input-output (I-O) algorithm is superior to standard I-O formulations. It retains the standard limitations: (1) lack of input substitution, and (2) absence of the explicit role of prices, both of which reduce accuracy. The effect is a bias toward higher indirect business interruption losses. The use of HAZUS Level-1 I-O tables offers greater accuracy than the standard I-O model, in two respects: (1) flexible import and export structures, as well as inventories, to eliminate shortages and surpluses, and (2) explicit constraints on capacity, especially with regard to construction.

1-3 year-old I-O data. Most input data and the I-O tables are 1-3 years old. Accuracy is reduced, with an unknown bias.

Unemployment rate is used as a proxy for excess capacity. Accuracy is reduced, and BI impact estimates experience an upward bias.

HAZUS default values used. The following variables will always require the use of default values (see Table 3 of the *Project Pilot Study: St. Agnes Medical Center* [ATC, 2003b]): (1) import capability - all sectors, though differentiated, (2) export capability - all sectors, though differentiated, (3) restoration of function - all sectors, though differentiated, and (4) rebuilding pattern - all sectors, though differentiated. Accuracy is reduced, but there is no known bias.

Best available data used for other parameters. The following variables are specified with best available data: (1) inventory demand - all sectors, though differentiated, (2) inventory supply - all sectors, though differentiated, and (3) discount rate. Accuracy is reduced, but there is no known bias.

Indirect business interruption losses are not applicable in several cases. These cases are those where the mitigation grant is confined to: (1) residences (reasonable assumption, no known bias) or (2) individual or small in-city groups schools, libraries, hospitals, and fire houses (reduces accuracy, downward bias). In most instances, these cases have no forward linkage to business and backward linkages are maintained by the absorption of their activity by similar units within the region.

D.3 Community Studies — Assumptions

D.3.1 Overall

Scope of Quantification. The main charge of the quantitative side of the community studies is to evaluate benefit-cost ratios for FEMA grants, including market spillover effects when they occur, and spin-offs of these grants. The community studies provide only qualitative accounts of allied or collateral risk-reduction activities. In many cases, as for process grants, qualitative cost-effectiveness accounts were provided.

Interaction between the benefit-cost analysis of FEMA Mitigation Grants and the Community Studies. Local data and circumstances were much richer for the community studies than for the benefit-cost analysis of FEMA mitigation grants. Quantitative studies performed in the community studies provided a feedback loop for the benefit-cost analysis of FEMA mitigation grants in the sense that details found in the field often assisted in clarifying and supplementing more national data. Moreover, the community quantitative studies served as a vanguard for the benefit-cost analysis of FEMA mitigation grants to the extent that quantitative procedures were developed for several unexpected situations. These included consideration of tornado risks, debris flow risks, chlorine releases, underground flood risks to wastewater and storm drain systems, central business district spillover effects, various flood structural mitigations such as diversions, berms, and detention ponds, various flood acquisition and elevation risk reduction activities in cases in which local flood hazards are challenging to model, and localized distress in emergency services when floods cut a community into two isolated areas.

Use of Local Results. In some cases, The community studies found that the risk evaluation tools used by local practitioners are sometimes far more advanced than the more economic methods used in the community studies. Some tools used locally have been exercised over years and sometimes decades by specialists. Small libraries of technical reports sometimes exist that provide support for decisions made. In some cases, owing to resource constraints, all pertinent activities could not be analyzed in the community studies (e.g., acquisitions made for properties in over a dozen riverine basins). In all cases, however, the community studies provided an independent check of general results for a community. In no cases were local results, however credible, used as the sole basis for this independent check.

Treatment of Uncertainties. The community studies have in some instances exposed rather than reduced uncertainties in risk evaluations. Even when risk evaluation tools are mature, but even more clearly when these tools are less mature, the number and variety of possible sensitivity evaluations can become very large (see Porter et al., 2002, Taylor et al., 2004).

Identification of Key Parameters for Benefit-Cost Estimation. Representations of results will stress the primary issue of the credibility of favorable versus unfavorable benefit-cost outcomes. Hence, sensitivity evaluations focused on some of the major parameters affecting this determination.

Acceleration of Pre-Disaster Mitigation Activities. Evaluations of instances in which risk-reduction activities are moved forward in time (i.e., accelerations), are consistent with principles implied by Carol Taylor West (2004).

Discount Rates. Same as assumed for the benefit-cost analysis of FEMA mitigation grants.

Risk Neutrality. Same as assumed for the benefit-cost analysis of FEMA mitigation grants. Exceptions were considered especially on private expenditures for such matters as safe rooms. The assumption that concave elements (risk averse elements) in preference functions play a key role in local and private investments has long been emphasized in the literature (see Markowitz, 1959).

Interaction Between Project Grants. The community studies considered interactions among project grants. This was accomplished through an analysis of spin-off and/or collateral risk reduction activities.

*Augmentation of NEMIS Data. F*ield data were found to clarify or modify as needed NEMIS data on such matters as actual costs.

Useful Life of Projects. Fifty-year time horizons for projects were assumed unless field data suggested otherwise. Some sensitivity evaluations on this matter were made for benefit-cost outcomes for which this assumption may be critical.

Present Value Calculations. Same as assumed for the benefit-cost analysis of FEMA mitigation grants.

D.3.2 Direct Loss Estimation

HAZUS®MH. The community studies relied on HAZUS®MH in all cases in which it is mature with respect to materials and practices for developing risk evaluations. These cases include its use for evaluating earthquake risks, and the response of buildings to severe winds. For estimating flood losses, the project team had to develop a less sophisticated and more empirically-based approach that uses HAZUS damage functions but alternative methods for estimating flood depths.

D.3.3 Indirect Loss Estimation

Indirect Losses. Same as assumed for the benefit-cost analysis of FEMA mitigation grants. Grants pertaining to residential structures were assumed not to be subjected to indirect loss estimation. None of the first seven communities studied yielded grants or spin-offs that would induce the use of indirect loss estimation tools.

D.4 Community Studies - Limitations

Limitations in Loss Estimation Modeling. The maturity of risk assessment tools in cases where HAZUS cannot be used in its entirety ranges from poor to good. Less mature tools are often those in which risk evaluations are often made with either tools dependent on very localized information or in which risk judgments are often made more qualitatively. (See ALA, 2002, especially Section 2, on how models for diverse natural hazards compare in terms of the maturity of risk evaluation practices.) Additional qualifications on results were added to this report to convey the state-of-the-practice in cases in which HAZUS is not used in its entirety.