APPENDIX 1
ECONOMIC ASSUMPTIONS AND EQUATIONS

The economic assumptions and equations which define the benefit-cost analysis of Riverine Flood hazard mitigation projects are summarized in this appendix.

Benefit-Cost Program

The benefits of a Riverine Flood hazard mitigation project are the avoided future damages and losses (i.e., the extent to which the mitigation project is effective in reducing expected future damages and losses). The net present value of benefits accounts for the time value of money. Benefits are expected to accrue in the future: dollars received in the future have a present value which is less than dollars received immediately. The expected net present value of a flood hazard mitigation project is the sum of the present value of net benefits expected to accrue each year over the life of the project, minus the initial cost of the mitigation project. The expected net present value, NPV, is defined as:

$$NPV = \frac{B_1}{1+i} + \frac{B_2}{(1+i)^2} + \ldots + \frac{B_t}{(1+i)^t} + \ldots + \frac{B_T}{(1+i)^T} - INV$$

where:

- NPV is the expected net present value of the hazard mitigation project;
- B_t is the expected annual net benefit of the hazard mitigation project for year t;
- i is the annual discount rate;
- T is the length of the planning horizon (useful life of the hazard mitigation project); and
- INV is the initial investment (the cost of the project).

Each year's expected net benefit is discounted to its present value, then all years' expected net benefits are summed together to yield the total expected net present value. The planning horizon, or useful lifetime, of the hazard mitigation project varies depending on the type of project, with 30 to 50 years being common for building projects. The discount rate corrects benefits expected to be received in the future to their net present value.

If expected net benefits are constant each year over the life of the project, the expected net present value equation is simplified to the constant annual benefits and one discount term representing the present value for the entire planning horizon. With this simplification, the expected net present value equation is reduced to:

$$NPV = B_t \left[\frac{1-(1+i)^{-T}}{i} \right] - INV$$

This is the underlying equation which is used for the benefit-cost program in this report.

For completeness, we mention two other factors which could be included in the expected net present value calculation: the salvage value of the mitigation investment at the end of the planning horizon and the annual costs to maintain the effectiveness of the mitigation project. However, the present value of the salvage value of flood hazard mitigation projects is generally quite small, because of the long planning horizons appropriate for building projects. Thus, salvage value is not considered in the program. The annual maintenance costs of typical Section 404 or 406 flood hazard mitigation projects are generally small, but may be significant, especially for levee projects. Therefore, for completeness, the annual maintenance costs are included in the benefit-cost program.

Economic Assumptions for Modeling Benefits

Underlying Assumptions

The benefits of a Riverine Flood hazard mitigation project are the reduction in damages that would otherwise be expected. Expected annual benefits are defined as the sum of expected avoided damages and losses. There are three different types of damages which are considered: scenario damages, expected annual damages, and expected annual avoided damages. Definitions of these terms are:

Scenario Damages:

the expected damages per flood of a given flood depth at the building,

Expected Annual Damages:

the product of scenario damages and the expected annual number of floods of a given flood depth at the building, and

Expected Annual Avoided Damages:

the product of expected annual damages and the effectiveness of the mitigation measure in reducing damages at the building.

A schematic example illustrating these damage terms is given below:

Table 1

Flood Depth (ft)	Scenario Damages	Expected Annual Number of Floods	Expected Annual Damages	Effectiveness of Mitigation Measure	Expected Annual Avoided Damages
-2	$20,000	.10	$2000	100%	$2,000
-1	$25,000	.05	$1250	80%	$1,000
0	$35,000	.02	$700	50%	$350
1	$50,000	.01	$500	25%	$125
2	$85,000	.005	$425.	15%	$64

In this example, the scenario damages indicate the expected damages each time a flood of the given depth occurs at the building site. Scenario damages do **not** depend on how frequently such floods are expected to occur. The annual flood probabilities indicate the degree of flood-related risk at the specific site under consideration. The expected annual damages are the product of scenario damages and annual flood

probability. Expected annual damages are the best estimate of the **average** damages per year expected at this site; such estimates do not indicate that these damages will occur every year. Expected annual damages are those damages which are expected to occur **without** undertaking the mitigation measure. The effectiveness of the mitigation measure is an estimate of how much expected damages will be reduced by the mitigation measure under consideration.

Benefits are AVOIDED Damages

The expected annual avoided damages (i.e., the annual benefits) are the product of expected annual damages and the effectiveness of the mitigation measure. The expected annual **avoided** damages are thus the expected annual **benefits** of undertaking the mitigation measure.

Detailed Economic Assumptions and Equations

Scenario Damages

Scenario damages (**SCD**) are the total damages per flood event. Thus, scenario damages are the sum of building damages (**BD**), contents damages (**CD**), displacement costs (**DIS**), lost business income (**LBI**), rental income losses (**RENT**), and the value of lost public/nonprofit services (**VLS**) for floods of each depth per flood event (scenario). Scenario damages are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$SCD = BD + CD + DIS + LBI + RENT + VLS$$

where:

SCD	is the total scenario (per flood event) damages;
BD	is the total building damage per flood event;
CD	is the total contents damage per flood event;
DIS	is the total displacement costs per flood event;
LBI	is the total lost business income per flood event;
RENT	is the total rental income losses per flood event; and
VLS	is the total value of lost public/nonprofit services per flood event.

Building Damages

Building damages (**BD**) are estimated as the product of the modified depth damage function (**MDDF**), the floor area of the building (**FA**), and the replacement value of the building per square foot (**BRV**). Building damages are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$BD = (MDDF)\ (FA)\ (BRV)$$

where:

BD	is the total amount of building damage per flood event;

	MDDF	is the modified depth damage function (including the demolition threshold percentage), expressed as a percentage of building replacement value for each flood depth;
	FA	is the building floor area in square feet; and
	BRV	is the building replacement value per square foot.

Contents Damages

Contents damages (**CD**) are estimated as the product of the contents depth-damage function (**CDDF**) and the total building contents replacement value (**CRV**) for each flood depth. Contents damages are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$CD = (CDDF)\ (CRV)$$

where:

CD	is the total contents damage per flood event;
CDDF	is the contents depth damage function, expressed as a percentage of contents replacement value for each flood depth; and
CRV	is the total building contents replacement value.

Displacement Expenses

Displacement expenses (**DIS**) are the product of displacement days necessary (**DD**), the total displacement costs per square foot per day (**DC**), and the total area occupied by the owner agency or public or nonprofit agencies (**TA**). Displacement costs are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$DIS = (DD)\ (DC)\ (TA)$$

where:

DIS	is the displacement cost per flood event;
DD	is the estimated number of displacement days expected for each flood depth;
DC	is the displacement costs per square foot per day; and
TA	is the total area occupied by the owner agency or public or nonprofit agencies.

Lost Business Income

Lost business income (**LBI**) is included if all or a portion of the building are rented to commercial businesses. Lost business income (**LBI**) is the product of the net income of commercial businesses per day (**NICB**) and the number of days of functional downtime (**FDD**). Lost business income is calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$LBI = (NICB)\ (FDD)$$

where:

LBI	is the total business income lost per flood event;
NICB	is the net income of commercial businesses per day; and
FDD	is the estimated number of days of functional downtime expected for each flood depth.

Rental Income Losses

Rental income losses (**RENT**) are included if all or a portion of the building are rented to private tenants. Inter- or intra-agency rents within the federal, state, or local governments are **not** counted because such payments are generally transfers; loss of such payments does not represent a true economic loss. Other private sector economic losses (such as lost wages) are not considered because they are assumed to be generally negligible for public/nonprofit buildings.

Rental income losses (**RENT**) are the product of displacement days necessary (**DD**) and the daily rental rate (**DRR**). Rental income losses are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$RENT = (DD)\ (DRR)$$

where:

RENT	is the total rental income lost per flood event;
DD	is the estimated number of displacement days expected for each flood depth; and
DRR	is the daily rental rate.

Public/Nonprofit Services Lost

For public/nonprofit sector buildings, the value of services lost (**VLS**) when the building becomes unusable during a flood must be included. Public/nonprofit services are valued using the Quasi-Willingness to Pay (**QWTP**) model. **QWTP** is a simple methodology that assumes that public/nonprofit services are worth what we pay to provide the services.

VLS is the product of the total value of lost services per day (**VOLS**) and the number of days of functional downtime (**FDD**). The period of lost services depends on the agency's ability to find alternative quarters and to establish normal functions. This period may vary depending on the structure, size and function of the agency and the availability of suitable quarters after the flood. Note that the period of loss of agency function may be much shorter than the period of displacement necessary due to flood damage, because agencies will resume their functions in temporary quarters. The value of public/nonprofit services lost is calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$VLS = (VOLS)\ (FDD)$$

where:

VLS	is the value of lost agency services per flood event;
VOLS	the total value of lost services per day; and
FDD	is the estimated number of days of functional downtime expected for each flood depth.

Expected Annual Damages

Expected annual damages (**EAD**) are the product of scenario damages (**SCD**) and the expected annual number of floods of a given depth (**EAE**). Expected annual damages are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$EAD = (SCD)\ (EAE)$$

where:

EAD	is the expected annual damages;
SCD	is the total scenario damages (as defined previously); and
EAE	is the expected annual number of floods of a given depth.

Expected Annual Benefits

Expected annual benefits (**EAB**) are the product of expected annual damages (EAD^B) before mitigation and the effectiveness of the mitigation measure (**EFF**). Expected annual benefits are calculated separately before and after the mitigation measure for each flood depth from -2 to 18 feet:

$$EAB = (EAD^B)\ (EFF)$$

where:

EAB	is the expected annual benefits;
EAD^B	is the expected annual damages before mitigation; and
EFF	is the effectiveness of the mitigation measure in reducing expected damage from a flood of a given depth.

Equivalently, expected annual benefits (EAB) are the difference between expected annual damages before mitigation (EAD^B) and expected annual damages after mitigation (EAD^A). Expected annual benefits are calculated for each flood depth from -2 to 18 feet:

$$EAB = EAD^B - EAD^A$$

where:

EAB	is the expected annual benefits;
EAD^B	is the expected annual damages before mitigation; and
EAD^A	is the expected annual damages after mitigation.

Total Expected Annual Benefits

The total expected annual benefits (**AB**) of a flood hazard mitigation project are the expected annual benefits (**EAB**) summed over the full range of damaging floods considered (i.e., -2 feet to 18 feet):

$$AB = \sum_{D=-2}^{18} EAB$$

where:

AB	is the total expected annual benefits of a flood hazard mitigation project;

D	is the range of flood depths considered;
-2	is the minimum damaging flood depth considered in the Benefit-Cost Program, -2 feet;
18	is the maximum flood depth considered in the Benefit-Cost Program, 18 feet; and
EAB	is the expected annual benefits from each flood depth being considered.

Benefits

The benefits (**B**) of a flood hazard mitigation project are the net present value of the total expected annual benefits (**AB**) over the useful lifetime of the hazard mitigation project (***T***) at an annual discount rate (***i***):

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

where:

B	is the benefits of a flood hazard mitigation project;
AB	is the total expected annual benefits of the hazard mitigation project;
T	is the useful lifetime of the hazard mitigation project; and
i	is the annual discount rate.

Costs

The total mitigation project costs (***C***) is the sum of the mitigation project costs (***PC***), the present value of the annual maintenance costs (***PVAMC***), and the relocation costs for the mitigation project (***RC***):

$$C = PC + PVAMC + RC$$

where:

C	is the total mitigation project costs;
PC	is the mitigation project costs including construction and other costs but excluding relocation costs;
PVAMC	is the net present value of the annual maintenance costs of the mitigation project; and

	RC is the relocation costs necessary for construction of the mitigation project.
Present Value of Annual Maintenance Costs	The net present value of the annual maintenance costs (***PVAMC***) is the product of the annual maintenance costs (***AMC***) and the present value coefficient (***PVCOEFF***):

$$PVAMC = (AMC)\ (PVCOEFF)$$

where:

PVAMC	is the net present value of the annual maintenance costs of the mitigation project; and
AMC	is the annual maintenance costs of the mitigation project; and
PVCOEFF	is the present value coefficient, which depends on the discount rate and project useful lifetime.

Relocation Costs

Relocation costs (***RC***) are product of the relocation time in months (***RT***) times the sum of rental costs per month (***RCOST***) and other relocation costs per month (***OCOST***):

$$RC = (RT)\ (RCOST + OCOST)$$

where:

RC	is the relocation costs necessary for construction of the mitigation project;
RT	is the occupant relocation time in months necessary for construction of the mitigation project;
RCOST	is the rental costs per month for temporary space during construction of the mitigation project; and
OCOST	is the other relocation costs per month which may be incurred during the temporary relocation.

Benefit-Cost Ratio

The benefit-cost ratio (***BCR***) is the benefits of the mitigation project (***B***), divided by the costs of the mitigation project (***C***):

$$BCR = (B)/(C)$$

where:

BCR	is the Benefit-Cost ratio of the hazard mitigation project;
B	is the benefits of the hazard mitigation project; and
C	is the total mitigation project costs.

Present Value Criterion

The present value criterion (***PVC***) is the benefits of the mitigation project (***B***), minus the costs of the mitigation project (***C***):

$$PVC = B - C$$

where:

PVC	is the present value criterion of the hazard mitigation project;
B	is the benefits of the hazard mitigation project; and
C	is the total mitigation project costs.

Technical Economic Terms

Benefit-Cost Analysis

Benefit-cost analysis provides estimates of the "benefits" and "costs" of a proposed project or change. The term "benefit-cost analysis" is used to denote economic analyses that apply either the maximum present value criterion or the benefit-cost ratio criterion to evaluate prospective actions. Both costs and benefits are discounted to their net present value. The maximum present value criterion subtracts costs from benefits to determine if benefits exceed costs. Benefit/cost ratios provide an alternative evaluation: prospective actions in which benefits exceed costs have benefit-cost ratios above one. The logic of benefit-cost analysis requires that benefit-cost ratios, and/or the present value criterion, be compared across competing alternatives.

Cost-Benefit Analysis

Cost-benefit analysis has identical economic assumptions to benefit-cost analysis and differs only in the nomenclature used to describe the analysis. Subtle differences in meaning between benefit-cost and cost-benefit analysis have been discussed (Hurter et al., 1982). These authors prefer the term benefit-cost for three reasons:

1. Determining benefits is often the most difficult aspect of the analysis; if costs are placed first, the emphasis is wrong;

2. When ratios are used to compare projects, the ratio used is benefit-cost, not cost-benefit; and

3. Placing the word "costs" first seems to suggest a negative attitude toward projects. It should be noted, however, that economic concepts, particularly as reflected in benefit-cost analysis, are completely neutral with respect to the undertaking of projects.

Cost-Effectiveness Analysis

Cost-effectiveness analysis identifies the least-cost way to achieve a stated objective; it is strictly a comparison among means to a given end (Andrews, 1982). Thus, cost effectiveness is the ability to achieve a given benefit at a minimum cost. In cost effectiveness analysis, the merits of the objective itself are not evaluated in economic terms. This approach is typically used to select methods of achieving specific environmental standards.

The Stafford Act uses cost-effectiveness when it means that benefits exceed costs in §404, Hazard Mitigation, and §406, Public Assistance.

Economic Efficiency

Economic efficiency is attained when the economy is functioning in a way that maximizes the value of society's consumption over time (Ward and Deren, 1991). Economic efficiency may also be viewed as the contribution to overall social welfare (Leman, 1989). It is generally accepted that a benefit-cost ratio above one indicates an improvement in economic efficiency. Benefit-cost analysis however does not indicate whether the project is the "most efficient" allocation of scarce resources for two reasons. First, benefit-cost analysis is an average rather than a marginal concept. The ratio indicates the relationship between benefits and costs for a given project size. Economic efficiency, however, requires that a project be sized where marginal benefits equal marginal costs, which maximizes the total net benefits. Second, the typical project benefit-cost analysis does not survey the complete array of spending alternatives for all public projects/programs unrelated to the project under analysis. Economic efficiency under a budget constraint would require that the marginal benefits for all public spending alternatives be equal.

Economic Impact Assessment

Economic impact assessment is both simpler and broader than either benefit-cost analysis or cost-effectiveness analysis in that it does not necessarily require aggregation or even categorization of effects as costs or benefits. It requires only the projection of economic effects of proposed actions and the listing of these for consideration. Impact assessment is broader than benefit-cost or cost-effectiveness analysis because it includes identification of all economic impacts: the changes in total (direct, indirect and induced) regional employment and income created by the proposed project. The inclusion of indirect and induced regional economic benefits and costs in the formal benefit-cost analysis is not generally accepted by the economics profession. Many economists maintain that such indirect and induced economic impacts represent a change in the distribution of economic activity and should not be confused with true gains in economic efficiency.

Informal Benefit-Cost Analysis

Informal benefit-cost analysis embraces an indefinite range of procedures for the general identification and balancing of desirable and undesirable effects of proposed actions on society. Thus, informal benefit-cost analysis simply approximates pure common sense, and it should not be compared with formal economic analyses of prospective projects.

Risk-Benefit Analysis

Risk-benefit analysis compares the economic benefits of a proposed project with the environmental and/or health-safety risks that are also created by the project. Ideally, the environmental and/or health-safety risks should be quantified in economic terms which in many cases is almost, if not impossible.

References

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