

## **APPENDIX D. ECONOMIC ANALYSIS**

HUNTINGTON FLOOD DAMAGE  
REDUCTION STUDY

CAMERON RUN

FAIRFAX COUNTY, VIRGINIA

FLOOD DAMAGE REDUCTION PROJECT

APPENDIX D

ECONOMIC ASSESSMENT

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NEW ENGLAND DISTRICT

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**ECONOMIC ASSESSMENT**  
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## INTRODUCTION

The purpose of this report is to provide an economic analysis of potential flood damage reduction benefit in the Huntington flood plain. Expected annual damages are calculated for both the natural and modified conditions. The difference in these magnitudes is a measure of flood damage reduction. Plans to reduce flooding damages are evaluated. For each plan annual benefit is divided by annual cost to determine a benefit cost ratio. This ratio must be equal to or greater than one to one for federal participation in water resource improvement projects. The plan with the greatest difference between annual benefit and annual cost is identified. This plan usually defines the extent of Federal interest in a project.

## METHODOLOGY

Benefits and costs are made comparable by conversion to average annual equivalents. An interest rate of 4-5/8% as specified in the Federal Register is to be used by Federal agencies in the formulation and evaluation of water and land resource plans for the period 1 October 2008 to 30 September 2009. All costs and benefits are stated at the 2007 price level. The project period of analysis is considered to be 50 years. The analysis of costs and benefits follows standard U.S. Army Corps of Engineers procedures. The reference documents used in the benefit estimation process are ER 1105-2-100, Chapter 6, Section IV, NED Benefit Evaluation Procedures: Urban Flood Damage and ER 1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geo-technical Stability, and Economics in Flood Damage Reduction Studies.

## FLOOD DAMAGE ESTIMATES

Flood damage estimates were developed using depth damage relationships developed by the Institute for Water Resources (IWR) and the National Flood Insurance Administration (NFIA). The IWR depth damage curves were developed for residential structures. These are supplemented with the NFIA curves for and nonresidential structures, such as commercial, industrial and public buildings.

These depth damage relationships are used to develop a stage damage function for each structure in the floodplain for each possible flood stage. The floodplain includes residential and public structures. The stage or elevation at which flood damage begins was determined for each property. Estimates of potential damages were then made from the starting point, in one-foot increments of stage, to a level of at least 6 feet above the first floor. Dollar value estimates were made for physical damages to site, structure, contents and utilities. Damages were assumed to start in a building when water reached the first opening. Seepage through the bottom of the foundation was not assumed as the start of damage. Estimates for temporary housing and food were made for residential occupants.

## AFFECTED AREA

### FLOOD DAMAGE COMPUTATION

Flood damage estimates were developed using the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) computer program. Stage-damage information was input for each structure. The elevation of the first floor and the elevation at which damage starts were also input for each structure. Water surface profiles for eight frequencies for each cross section in the hydrologic zone were then input. The computer model combined stage-frequency data and stage-damage information to compute damage frequency distributions and expected annual damage by cross sections. Single flood event damage was determined for several events.

### RISK AND UNCERTAINTY

Corps regulations require the use of a risk and uncertainty (R&U) analysis for flood damage reduction studies at the feasibility level of detail. The purpose of R&U is to provide decision-makers more information with which to select the appropriate size of the project.

R & U is encountered in two broad areas in a flood damage reduction study; 1.) hydrology and hydraulics, and 2) economics. The first is discussed in detail in the Hydrologic and Hydraulic Analysis Appendix. The economics portion of risk and uncertainty pertains to the extent of damages associated with different levels of flooding. Flooding damages are developed by stage or height of water over the ground. However, estimates of damages are subject to error. The risk and uncertainty analysis attempts to describe that error and present the results to the decision-maker in terms of project reliability. The major sources of uncertainty in property damage are in the elevations that mark the start of damages and the first floor, in the values of the structure and its contents, the percentage of damage that occurs by depth of flooding, and in hydrologic variables.

Errors may exist in enumerating and classifying structures. Within structure classifications, the depreciated replacement value of structures and content will vary from structure to structure due to size, building material, inside construction, condition and age. The depreciated replacement value may be obtained through structure valuation services, real estate assessments or recent sales prices.

The depreciated value of structure contents may be obtained by applying contents to structures value ratios from Federal Flood Insurance (FIA) claims data or by conducting a survey in the floodplain. FIA claims data do not reflect depreciated replacement costs and thus need to be adjusted before use. This adjustment procedure is a potential source of error. If the floodplain residents are surveyed then that estimate contains error associated with a statistical sample.

The estimate of damages to structures and contents is affected by errors in measurement of the elevations of the first floor and start of damages. These elevations may be obtained with increasing levels of error through field surveys, aerial surveys and topographic maps. The arrangement of contents within a structure can affect the extent of damages. For this study first floor and ground elevations were obtained from surveys conducted by the county.

Hydrologic variables that can affect damages to structures and contents are velocity, sediment, duration and frequency. Flood warning systems can reduce damages provided that there is adequate warning time.

### Stage Damage Uncertainty

Stage damage uncertainty in first floor and start of damage elevations are combined with uncertainty in damages to building and contents to determine the stage damage curve with uncertainty. It is assumed that errors in first floor elevations are normally distributed with standard deviation .01 feet. A standard deviation of 0.03 was found in previous Corps studies and is discussed on Page E-30, EC 1105-2-205.

Uncertainty in first floor elevations is combined with uncertainty in building and contents damages to determine the stage damage curve with uncertainty. Standard depth damage relationships are used to represent the average, or most likely, building and contents damage. For the IWR curves representing residential structures, standard deviations for these averages are provided. For other structures, standard deviations are developed by multiplying the average by a coefficient of variation. A coefficient value of 0.2 was used to estimate standard deviations. This estimate of the coefficient of variation is within the range discussed in Corps guidance. The range depended on stage and varied from 2.29 at zero damage to 0.16 at 23 feet above zero damage. The mean and standard deviation are used as parameters of a normal distribution. Analytically, the problem is to develop the overall risk and uncertainty associated with the stage damage curve from the risk and uncertainty associated with first floor elevations and depth damage relationships. The parameters of these joint probability distributions are difficult to obtain analytically. The HEC-FDA computer program approximates the stage damage uncertainty numerically with a Monte Carlo simulation. This method involves developing a risk based flood damage model where the various parameters are the probability distributions discussed above. At each flood stage these distributions are sampled and the resulting value of damages recorded. Multiple iterations allow the estimation of the distribution of damages at any stage. By rerunning the model with multiple stages, a complete stage damage curve with uncertainty can be developed.

Each simulation determines damages for various flood frequencies. For each iteration of the simulation, the model chooses from the various parts of each of the probability distributions based on their relative frequencies and calculates the resulting damage. A complete simulation for a specific flood requires multiple iterations of the model to derive an accurate distribution of damages for that flood event. As the number of iterations increases, the simulation generated distribution approaches the "true"

distribution. The number of simulations required to achieve the desired level of accuracy is influenced by a number of factors. The number of iterations increases with: 1) the variance and skew of the variable of interest; 2) reductions in the probability contributory variables; and 3) the number of contributing variables.

## FLOOD DAMAGES

### Recurring Losses

Recurring flood losses are those potential damages that are estimated to occur at various flood stages. The 100-year flood could cause an estimated \$13,016,000 in damages to residential and public structures. Recurring losses by event are presented in Table 1. Also shown in the table is an estimate of the number of structures damaged at each event and of those the number receiving damages to the first floor.

Table 1 Damages by Event Huntington Cameron Run Fairfax County, Va				
Event		Number of Structures with Damage	Number of Structures with FF Damage	Damage (\$000)
Probability	Recurrence Interval (years)			
0.5	2	0	0	0.0
0.2	5	1	0	5.9
0.1	10	11	0	292.8
0.04	25	132	2	4,455.9
0.02	50	160	68	8,318.2
0.01	100	176	152	13,016.0
0.004	250	182	180	16,657.6
0.002	500	182	182	20,418.0

## Annual Losses

Expected annual damages are determined by developing a probability distribution for expected annual damages. The HEC-FDA program uses Monte Carlo simulation to generate the probability distribution. The program combines uncertainty in the stage frequency function with uncertainty stage damage function for each simulation. After thousands of simulations the program calculates the mean of the expected annual damage distribution. The effectiveness of a flood reduction plan is measured by the extent to which it reduces annual losses. Annual losses for Huntington are expected to be \$542,300.

## IMPROVEMENT PLANS

Improvement plans are of two types, structural and nonstructural. Structural plans evaluated here are the construction of levees and dredging. Plan 1 is a combination of levee and dredging. Plan 1a provides for a levee height to the 100-year profile. Plan 1b provides for a levee height to 50-year profile plus 3 feet downstream and 4 feet upstream. Plan 1c provides for the 100-year profile plus 3 feet downstream and 4 feet at the upstream end. Dredging would reduce water surface profiles upstream of Huntington. Plan 2 is the same as Plan 1 with no dredging. Plans are evaluated with and without pumps to handle interior drainage during storm events.

Nonstructural alternatives were evaluated in an earlier phase of this study but were not carried forward for further evaluation to insufficient damage reduction. These alternatives included raising first floors, filling basements, adding utility rooms and evacuating the flood plain.

## ECONOMIC BENEFIT ESTIMATION

Economic benefit is measured as a reduction in inundation damages, reduction in emergency cost associated with flood fighting, and reduction in the cost of temporary housing. Inundation reduction refers to physical damages to buildings and contents including furnishings, equipment, materials and products. Inundation reduction benefit is shown in Table 2. Total annual inundation reduction benefit for Huntington is estimated to vary directly with the extent of protection provided as expected. Annual benefits for the plan without interior drainage pumps are less due to the ponding of rainfall that with the project in place cannot outlet into the river.

Table 2  
 Expected Value and Probabilistic Values  
 of EAD and EAD Reduced  
 Huntington  
 Cameron Run  
 Fairfax County, Va

Plan	Expected Annual Damage (\$'000)			Probability Damaged Reduced Exceeds Indicated Values		
	Without Plan	With Plan	Damage Reduced	0.75	0.50	0.25
Plan 1a	542.3	192.5	349.8	204.9	329.0	471.6
Plan 1b	542.3	112.9	429.4	238.6	398.4	585.7
Plan 1c	542.3	0.0	542.3	253.2	461.4	746.1
Plan 2a	542.3	224.5	317.8	193.2	302.1	423.4
Plan 2b	542.3	117.7	424.6	237.4	394.9	578.8
Plan 2c	542.3	1.9	540.4	257.3	466.9	747.0
Plan 1a without pumps	542.3	245.3	297	67.7	229.7	457.1
Plan 1b without pumps	542.3	128.6	413.7	168.0	348.8	592.9
Plan 1c without pumps	542.3	55.4	486.9	232.8	422.8	674.6
Plan 2a without pumps	542.3	251.8	290.5	61.1	223.1	450.6
Plan 2b without pumps	542.3	129.4	412.9	167.3	348.1	592.1
Plan 2c without pumps	542.3	55.4	486.9	232.8	422.8	674.6

## PLAN COSTS

The anticipated cost of each improvement plan is displayed in Table 3.

Table 3 Project Cost Huntington Cameron Run Fairfax County, Va \$000							
Plan	First Cost	Interest During Construction	Investment Cost	Annual Investment Cost	O&M	Induced Damages	Total Annual Project Cost
Plan 1a	19,600.0	893.8	20,493.8	1,058.2	587.6	1.0	1,646.8
Plan 1b	20,800.0	948.5	21,748.5	1,123.0	587.6	1.2	1,711.8
Plan 1c	22,000.0	1,003.2	23,003.2	1,187.8	587.6	1.5	1,776.9
Plan 2a	14,800.0	674.9	15,474.9	799.0	150.0	2.0	951.0
Plan 2b	16,000.0	729.6	16,729.6	863.8	150.0	2.4	1,016.2
Plan 2c	19,980.0	911.1	20,891.1	1,078.7	150.0	2.6	1,231.3
Plan 1a without pumps	15,400.0	702.3	16,102.3	831.4	512.6	1.0	1,345.0
Plan 1b without pumps	16,600.0	757.0	17,357.0	896.2	512.6	1.2	1,410.0
Plan 1c without pumps	17,900.0	816.3	18,716.3	966.4	512.6	1.5	1,480.5
Plan 2a without pumps	10,600.0	483.4	11,083.4	572.3	75.0	2.0	649.3
Plan 2b without pumps	11,800.0	538.1	12,338.1	637.1	75.0	2.4	714.5
Plan 2c without pumps	13,100.0	597.4	13,697.4	707.3	75.0	2.6	784.9

Interest during construction shown in the third column is an economic cost that stops when the project is operational and begins to accrue benefits. It represents the opportunity cost of funds tied up in the project before the project yields benefits. Induced damages shown in Column 7 are the result of higher water surface profiles upstream of the project area. These costs are minor but were estimated anyway. The annual cost of each alternative shown in Column 8 will be compared with the annual benefit of each alternative to assess the economic justification of each alternative.

## PLAN JUSTIFICATION

A plan must have a benefit cost ratio greater than one, or net benefit greater than zero, to be justified. Table 4 and Table 5 display the benefit and cost of each alternative. All plans are estimated to have net benefits less than zero and the benefit-cost ratios less than one to one. Although none of the alternatives are economically justified, as levees increase in height the additional damages prevented are less than the additional costs.

Table 4  
 Expected Value and Probabilistic Values  
 Net Benefits  
 Huntington  
 Cameron Run  
 Fairfax County, Va

Plan	Expected Annual NED Benefit and NED Cost (\$'000)			0.75	0.50	0.25
	Benefit	Cost	Net Benefit			
Plan 1a	349.8	1,646.8	-1,297.0	-1,441.9	-1,317.8	-1,175.2
Plan 1b	429.4	1,711.8	-1,282.4	-1,473.2	-1,313.4	-1,126.1
Plan 1c	542.3	1,776.9	-1,234.6	-1,523.7	-1,315.5	-1,030.8
Plan 2a	317.8	951.0	-633.2	-757.8	-648.9	-527.6
Plan 2b	424.6	1,016.2	-591.6	-778.8	-621.3	-437.4
Plan 2c	540.4	1,231.3	-690.9	-974.0	-764.4	-484.3
Plan 1a without pumps	297	1,345.0	-1,048.0	-1,277.3	-1,115.3	-887.9
Plan 1b without pumps	413.7	1,410.0	-996.3	-1,242.0	-1,061.2	-817.1
Plan 1c without pumps	486.9	1,480.5	-993.6	-1,247.7	-1,057.7	-805.9
Plan 2a without pumps	290.5	649.3	-358.8	-588.2	-426.2	-198.7
Plan 2b without pumps	412.9	714.5	-301.6	-547.2	-366.4	-122.4
Plan 2c without pumps	486.9	784.9	-298.0	-552.1	-362.1	-110.3

The first half of the following tables show the expected damage reduced, expected benefit-cost ratios, and expected net benefits; and the second half of the table shows the cumulative probability distributions for these estimates.

Table 5  
 Expected Value and Probabilistic Values  
 Benefit/Cost Ratios  
 Huntington  
 Cameron Run  
 Fairfax County, Va

Plan	Expected Benefit/Cost Ratio			
		0.75	0.50	0.25
Plan 1a	0.2	0.1	0.2	0.3
Plan 1b	0.3	0.1	0.2	0.3
Plan 1c	0.3	0.1	0.3	0.4
Plan 2a	0.3	0.2	0.3	0.4
Plan 2b	0.4	0.2	0.4	0.6
Plan 2c	0.4	0.2	0.4	0.6
Plan 1a without pumps	0.2	0.1	0.2	0.3
Plan 1b without pumps	0.3	0.1	0.2	0.4
Plan 1c without pumps	0.3	0.2	0.3	0.5
Plan 2a without pumps	0.4	0.1	0.3	0.7
Plan 2b without pumps	0.6	0.2	0.5	0.8
Plan 2c without pumps	0.6	0.3	0.5	0.9

## PROJECT PERFORMANCE

Table 6 indicates the probability of project failure in any given year and the cumulative probability of failure over ten, twenty and fifty year periods. Failure occurs when water levels reach elevations where significant damages are incurred. In any given year the probability of either Alternative 1c or Alternative 2c being overtopped is very low. The cumulative failure probabilities for these two alternatives over the 50-year period of analysis are also very low.

Table 6  
Annual Performance and  
Equivalent Long-term Risk  
Huntington  
Cameron Run  
Fairfax County, Va

Plan	Annual Performance (Expected Annual Probability of Design Being Exceeded)	Equivalent Long-term Risk (Probability of Exceedance Over the Indicated Time Period)		
		10 Years	25 Years	50 Years
Without Project	0.0800	0.57	0.88	0.98
Plan 1a	0.0120	0.11	0.26	0.45
Plan 1b	0.0060	0.06	0.14	0.26
Plan 1c	0.0000	0.00	0.01	0.01
Plan 2a	0.0130	0.13	0.29	0.49
Plan 2b	0.0060	0.06	0.15	0.27
Plan 2c	0.0000	0.00	0.00	0.01

Table 7 displays the probabilities that the alternative plans will contain the various events from the 10 % (return interval 10 years) to the 0.2 % (return interval 500 years). Alternative 1a would have about a 54 % chance of containing the 1 % event (return interval 100 years); Alternative 1b would have about an 80 % chance of containing this event; and Alternative 1c would have about a 99 % chance of containing this event. The a, b, c options for Plan 2 have similar probabilities of containing the 1 % flood.

Table 7  
 Conditional Probability of  
 Design Non-exceedance  
 Huntington  
 Cameron Run  
 Fairfax County, Va

Plan	Conditional Probability of Design Containing Indicated Event					
	10%	4%	2%	1%	0.40%	0.20%
Without Project	0.69	0.18	0.06	0.02	0.01	0.00
Plan 1a	1.00	0.98	0.81	0.54	0.27	0.15
Plan 1b	1.00	1.00	0.95	0.80	0.52	0.35
Plan 1c	1.00	1.00	1.00	0.99	0.98	0.98
Plan 2a	1.00	0.96	0.77	0.49	0.24	0.14
Plan 2b	1.00	1.00	0.95	0.79	0.51	0.34
Plan 2c	1.00	1.00	1.00	0.99	0.98	0.97

#### RECOMMENDED PLAN

The recommended plan is Alternative 2c that provides a levee height to the 100-Year profile plus 3 feet in the downstream section and plus 4 feet in the upstream section. This plan is expected to prevent nearly all the annual flooding damage at an investment or first cost of \$20,891,100. This plan has a 99 % chance of containing the flooding event with a 1 % chance of occurrence (100 year recurrence interval).