Flood Damages

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Overview

- What is Damage Modeling?
- Structural Damage Calculation Overview
- Consideration in a Structure Damage Calculation
- Software and Damage Comparisons
- Other Damages to consider
- Other Project Benefits

Who is in our Audience?

- Engineers or Community Managers?
- Federal, State, Local, Consultants?
- Experienced Damage Modeling?
- Why are you in this session?

What is Damage Modeling & When its used

What do we mean by Damage Modeling

- Economic evaluation of impacts due to flooding

Purposes of Damage Modeling

- Evaluating flood improvement options
- Improving operations of water control facilities
- Assessing impacts of an actual or theoretical flood event
- Mitigation / Buyout evaluations
- Flood response and evacuation planning

Cost and Benefit Categories

Lifecycle

- Land Rights
- Remediation
- Construction Costs
- Operation
- Maintenance

Resiliency

- Property Damage Reduction
- Reduction of causalities & Injuries
- Reduced Displacement Costs
- Reduced Transportation Costs
- Reduce Utility Vulnerability

Environmental

- Improve Ecosystems
- Reduce Utility Use
- Noise Levels
- Climate Change
- Air Quality
- Water Quality
- Urban Heat Island effects

Social / Community Development

- Volunteer Engagement
- Mental Health
- Physical Health
- Recreation
- Cultural Value
- Greater Housing Affordability
- Reduce Suffering

Economic Revitalization

- Property Values
- Reduced Impacts to Businesses
- Local Jobs from Construction
- Indirect Job Creations Post Construction
- Tourism

Damage Calculation Overview

Flood Elevation verse Probability

Storm	Probability	Elev
100-yr	0.01	624.63
50-yr	0.02	624.04
25-yr	0.04	623.24
10-yr	0.1	622.34
5-yr	0.2	621.59
2-yr	0.5	620.41

Data Needed:

- Water surface probability

Damage Calculation Overview

Flood Elevation verse Probability

Storm	Probability	Elev	First Floor = 624 ft	Depth
100-yr	0.01	624.63		0.63
50-yr	0.02	624.04		0.04
25-yr	0.04	623.24		-0.76
10-yr	0.1	622.34		-1.66
5-yr	0.2	621.59		-2.41
2-yr	0.5	620.41		-3.59

Data Needed:

- Water surface probability
- Structure Survey Data
  - First Floor
  - Low Water Entry
  - Min Flood Elev.

Damage Calculation Overview

Flood Elevation verse Probability

Storm	Probability	Elev	First Floor = 624 ft	Depth
100-yr	0.01	624.63		0.63
50-yr	0.02	624.04		0.04
25-yr	0.04	623.24		-0.76
10-yr	0.1	622.34		-1.66
5-yr	0.2	621.59		-2.41
2-yr	0.5	620.41		-3.59

Depth	Damage
-2	0%
-1	2.50%
0	13.40%
1	23.30%
2	32.10%
3	40.10%
4	47.10%
5	53.20%
6	58.60%

Data Needed:

- Water surface probability
- Structure Survey Data
  - First Floor
  - Low Water Entry
  - Min Flood Elev.
- Structure Type
- Damage Curve Data

Damage Calculation Overview

Flood Elevation verse Probability

Storm	Probability	Elev
100-yr	0.01	624.63
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First Floor = 624 ft

Depth
0.63
0.04
-0.76
-1.66
-2.41
-3.59

Depth	Damage
-2	0%
-1	2.50%
0	13.40%
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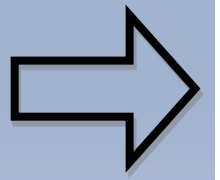


Depth verse Damage

Depth	Damages
0.63	$297,076
0.04	$227,338
-0.76	$0
-1.66	$0
-2.41	$0
-3.59	$0

Data Needed:

- Water surface probability
- Structure Survey Data
  - First Floor
  - Low Water Entry
  - Min Flood Elev.
- Structure Type
- Damage Curve Data
- Structure Value

Lifecycle Costs – Useful Life

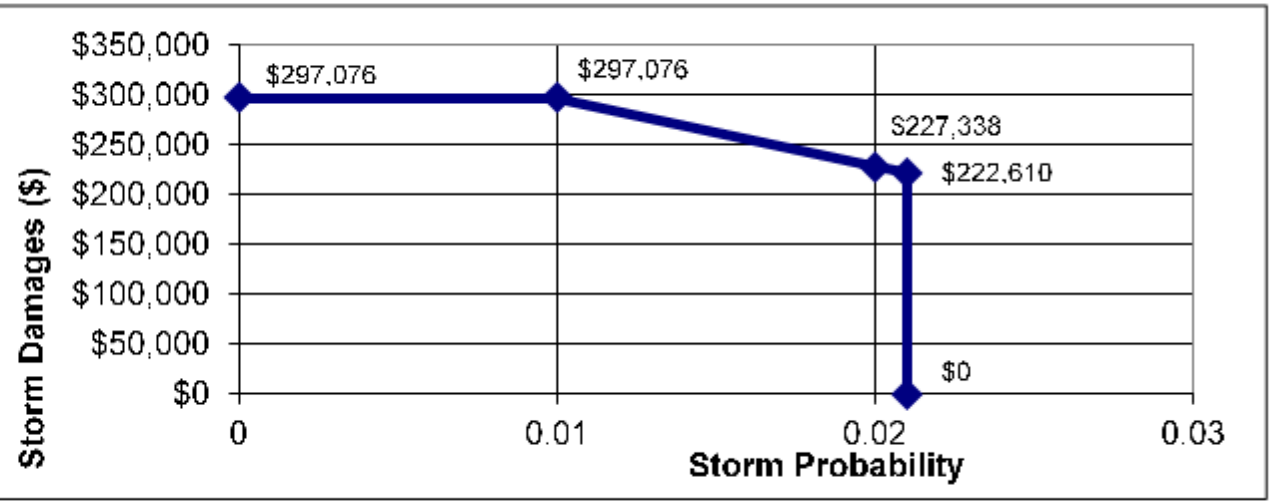
- Source:
- FEMA BCA Reference Guide
- Appendix D

Project Type	Useful Life (years)		Comment
	Standard Value	Acceptable Limits (documentation required)	
Acquisition/Relocation			
All Structures	100	100	
Elevation			
Residential Building	30	30–50	
Non-Residential Building	25	25–50	
Public Building	50	50–100	
Historic Buildings	50	50–100	
Structural/Non-Structural Building Project			
Residential Building Retrofit	30	30	
Non-Residential Building Retrofit	25	25–50	
Public Building Retrofit	50	50–100	
Historic Building Retrofit	50	50–100	
Roof Diaphragm Retrofit	30	30	Roof hardening and roof clips
Tornado Safe Room – Residential	30	30	
Tornado Safe Room – Community	30	30–50	Retrofit or small community safe room ≤ 16 people (30 yr), New (50 yr)
Non-Structural Building Elements	30	30	Ceilings, electrical cabinets, generators, parapet walls, or chimneys
Non-Structural Major Equipment	15	15–30	Elevators, HVAC, sprinklers
Non-Structural Minor Equipment	5	5–20	Generic contents, racks, shelves
Infrastructure Projects			
Major Infrastructure (minor localized flood reduction projects)	50	35–100	
Concrete Infrastructure, Flood Walls, Roads, Bridges, Major Drainage System	50	35–50	
Culverts (concrete, PVC, CMP, HDPE, etc.)	30	25–50	Culvert with end treatment (i.e., wing walls, end sections, head walls, etc.)
	10	5–20	Culvert without end treatment (i.e., wing walls, end sections, head walls, etc.)
Pump Stations, Substations, Wastewater Systems, or Equipment Such as Generators	50	50	Structures
	5	5–30	Equipment
Hurricane Storm Shutters	15	15–30	Depends on type of storm shutter
Utility Mitigation Projects	50	50–100	Major (power lines, cable, hardening gas, water, sewer lines, etc.)
	5	5–30	Minor (backflow values, downspout disconnect, etc.)

Average Annual Damage (AAD) and Capitalized Costs Calculation

Calculation of Average Annual Damage

Storm Frequency	Storm Probability	Total Damage	Delta 1/RI	Average Damages in Interval	AAD in Interval
Infinite	0	$297,076			
			0.01	$297,076	$2,971
100	0.01	$297,076			
			0.01	$262,207	$2,622
50	0.02	$227,338			
			0.001	$224,974	$225
47.6	0.021	$222,610			
			0	$111,305	$0
47.6	0.021	$0			
			Average Annual Damages		**$5,818**



Interest Rate:	**2.25%**
Term	**50 years**
Capitalized:	**$173,577**

Multiplier = $\frac{(1+r)^t - 1}{r(1+r)^t}$

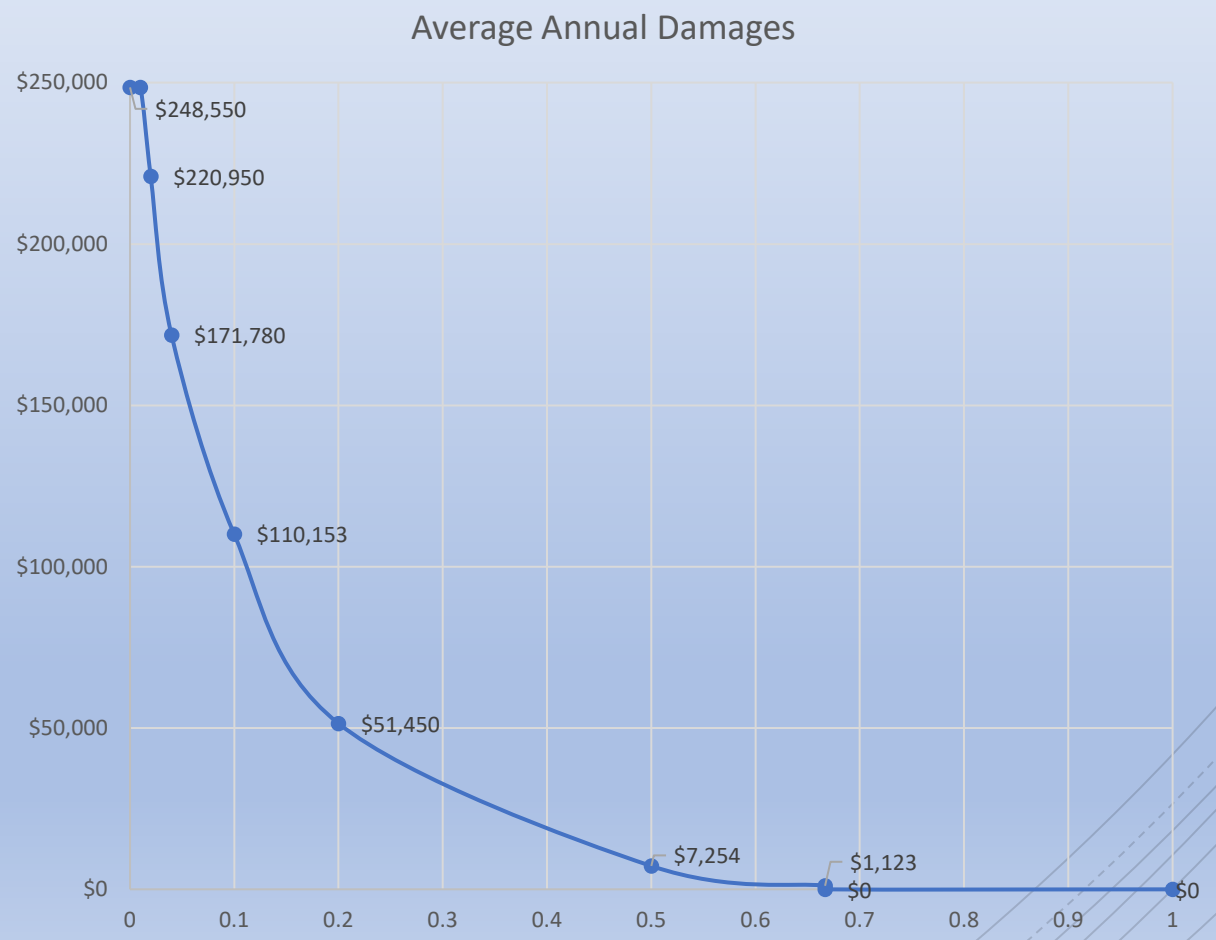
Why Small Flood Events Matter

Frequency	Probability	Damage
inf	0.00	$248,550
100	0.01	$248,550
50	0.02	$220,950
25	0.04	$171,780
10	0.1	$110,153
5	0.2	$51,450
2	0.5	$7,254
1.5	0.667	$1,123
1	1.0	n/a

Range	Prob	Inc. AAD
100 - Inf.	0.01	$2,485.50
50 - 100	0.01	$2,347.50
25 - 50	0.02	$3,927.30
10 - 25	0.06	$8,457.98
5 - 10	0.1	$8,080.12
2 - 5	0.3	$8,805.60
1.5 - 2	0.167	$698.08
1 – 1.5	0.333	$0
SUM	1.00	$34,415.9

ADD w/o Small Events = $16,832
vs.
ADD w/ Small Events = $34,415

Capitalized w/o Small Events = $502,435
vs.
Capitalized w/ Small Events = $1,027,287



Damage Model Inputs

Hazard Data

- H&H Modeling Water Surface Elevations
- FEMA's Risk MAP depth grids
- Probabilistic flood scenarios

Inventory

- General Building Stock (HAZUS)
- Assessor Building Data
- Survey Data (First Floor Elevations)
- Baseline inventory dataset including vulnerability

Damage and Fragility Functions

- Damage = Value of Damage ($)
- Fragility = Likelihood (% damage)

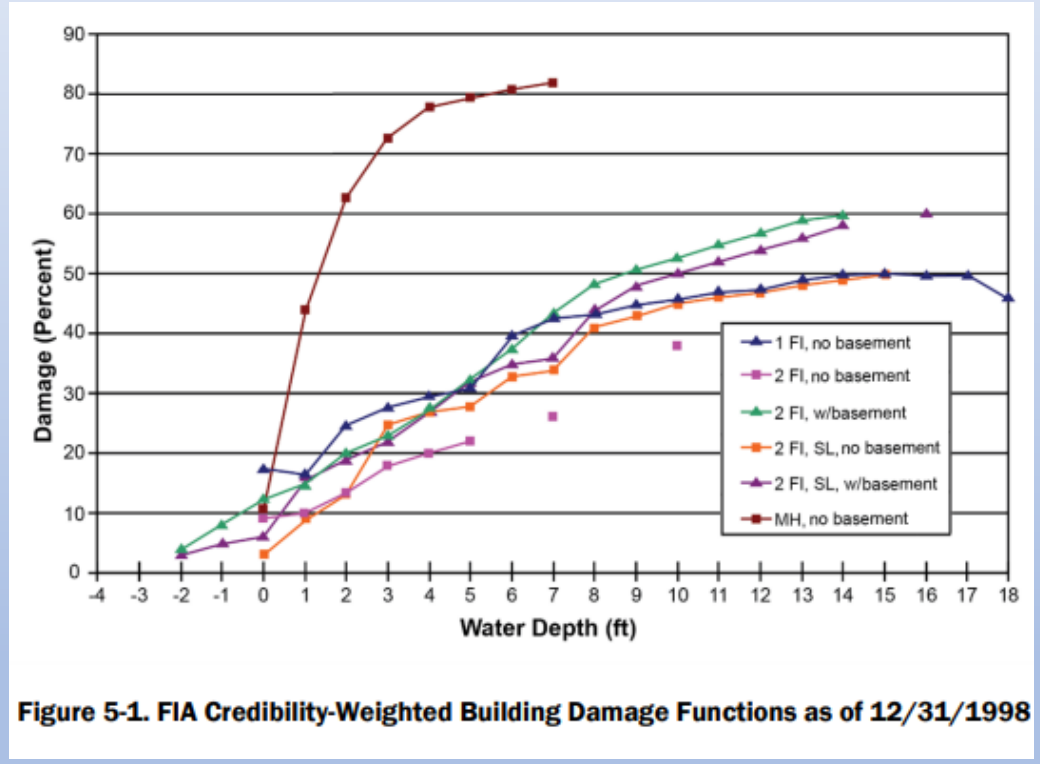
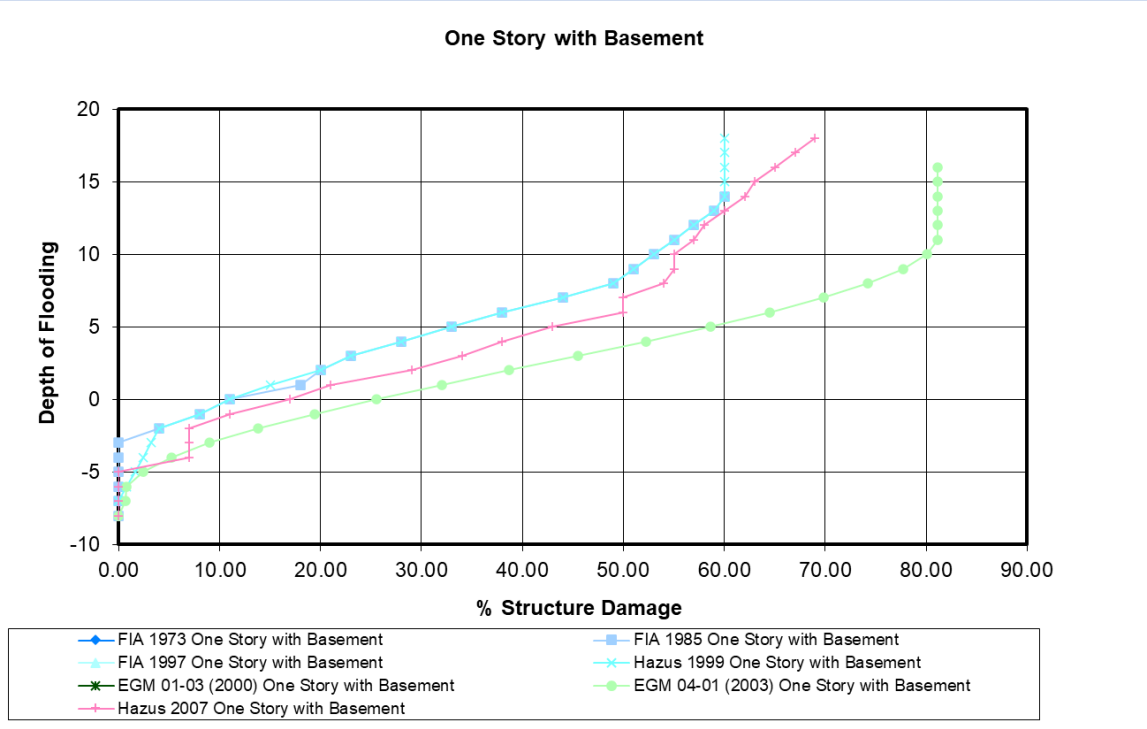
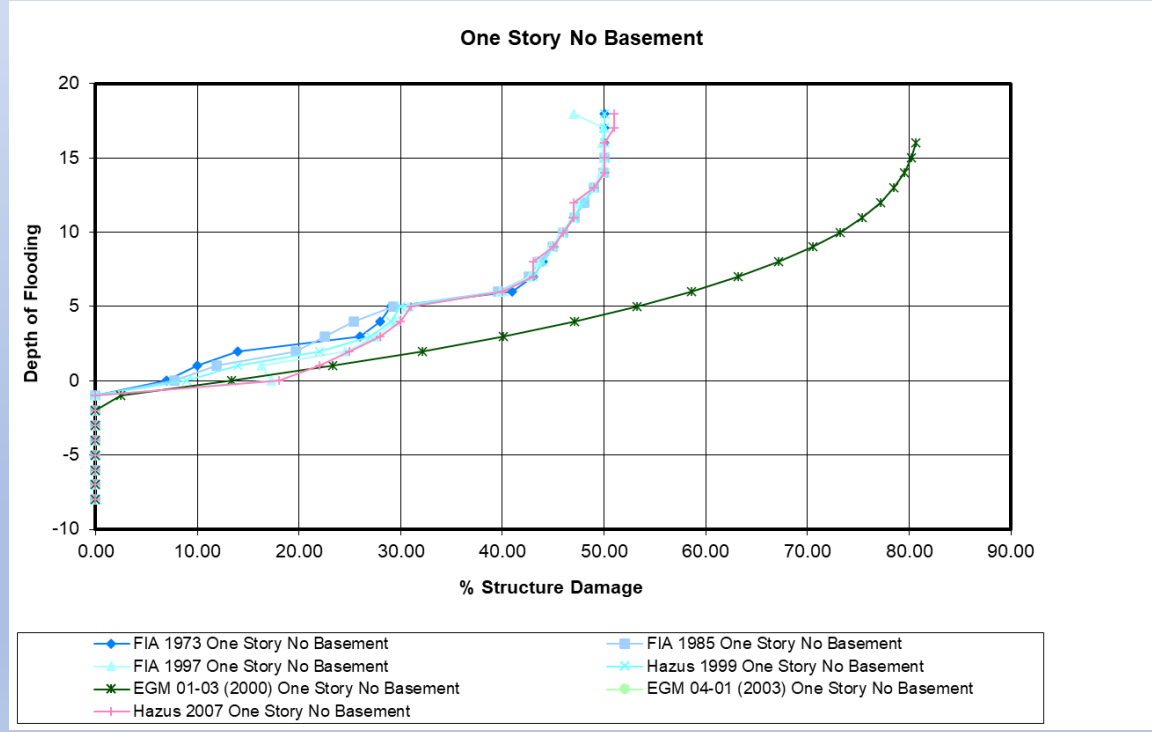


Figure 5-1. FIA Credibility-Weighted Building Damage Functions as of 12/31/1998

Damage Curve Comparison





Damages Software

FEMA: HAZUS-MH	Multiple Events
FEMA: BCA	Single Structure
USACE: HEC-FDA	Multiple Events
USACE: HEC-FIA	Single Event
IDNR Damages	Multiple Events

FEMA: HAZUS-MH

Advantages

- Has Direct Damages to
  - Transportation - Bridges Scour, Traffic
  - Utilities equipment - Water, electric, Sewer, Gas, Comm.
  - Vehicles -Inundation
  - Essential facilities
- Considers Induced Damages, Debris, Fire, HazMat
- Considers Social loses of Casualties, Family Relocation, Rentals, Wage and Business Income
- Can Start with minimal/census Data
- Can handle multiple Reaches

Limitations

- HEAVY ArcGIS use with Spatial Analyst and a DEM
- Gridded water depths required
- Structure values based on $/sqft (level 1 from R.S. Means)Substantial training would be required
- **AAD requires 5 return periods** - 10, 25, 50, 100, 500 events. Excludes lower return frequencies.
- No initial damages frequency determined
- Can have long compute times

FEMA: BCA

Advantages

- Considers Displacement
- Considers Demolition Threshold at 50% damaged
- Can modify frequency of events
- Gives BCR per Structure
- Can handle multiple reaches
- Has Direct Damages to:
  - Transportation - Bridges Scour, Traffic
  - Utilities equipment - Water, electric, Sewer, Gas, Comm.
  - Vehicles -Inundation
  - Critical facilities analysis

Limitations

- Single Structure Analysis
- No initial damages frequency determined
- Structure values based on $/sqft
- Enter water surface manually for each structure
- Can only enter 5 flood events

USACE: HEC-FDA

Advantages

- Considers Uncertainty in H&H with Monte Carlo Sim.
- Up to 8 events
- Handles Multiple Reaches
- Utilizes an existing and future scenario
- Stand alone program
- Can be utilize for Vehicle inundation

Limitations

- Requires Uncertainty data – excessive effort
- Future scenario less than ideal for multiple alternatives
- Individual structure data not easily accessible
- Not intuitive for new users

USACE: HEC-FIA

Advantages

- Can Compute Agricultural damages
- Includes Vehicle Damages
- Estimates Loss of Life
- Indirect Damages (loss of income)
- Good for emergency planning
- Uses Monte Carlo to add uncertainty

Limitations

- Single run events
- Utilizes Point Shapefiles
- Grid water surface required
- Not well suited for a steady flow analysis

IDNR Damages

Advantages

- Unlimited flood events can be evaluated
- More accurate calculation -> Evaluates frequency when damages begins
- Immediate computation time
- Greater Data Output options
- Can utilize for Vehicle inundation
- Standalone Program

Limitations

- Is a Single Reach Profile based damage assessment.
- Only can evaluate damages based on flood depth
- Internally Developed by OWR in contract with USGS.

Comparison of Software

Program	System	Event Inputs	Non Structural	Hydraulic Input	Recommend
FEMA Hazus	GIS	Multiple (5)	Yes	Grid (2D)	2D Multi event
FEMA BCA	Stand alone	Multiple (5)	Yes	Manual	Buyouts
USACE FDA	Stand alone	Multiple (8)	No	Profile (1D)	Uncertainty
USACE FIA	GIS	Single (1)	No	Grid (2D)	2D Single Event
IDNR Damages	Stand alone	Multiple (Any)	No	Profile (1D)	1D Multi Event

Average Annual Damage (AAD) and Capitalized Costs Calculation

Calculation of Average Annual Damage

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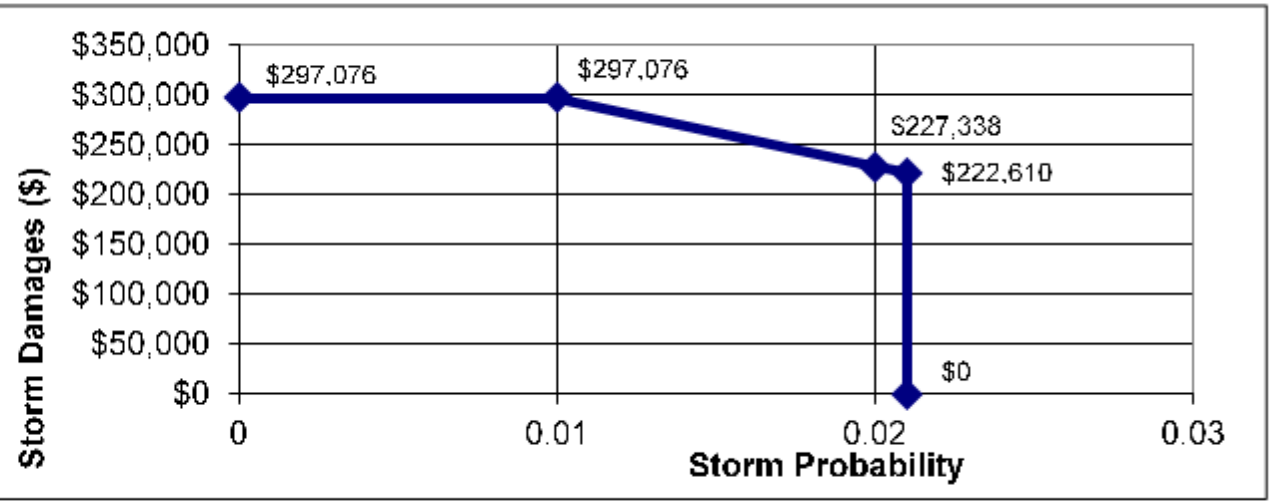

Interest Rate:	**2.25%**
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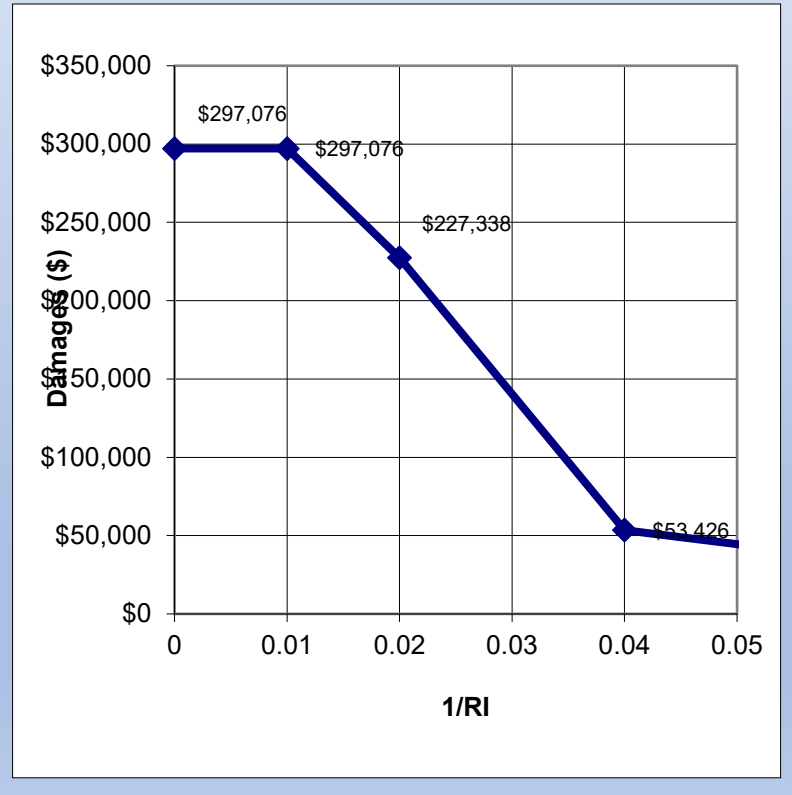
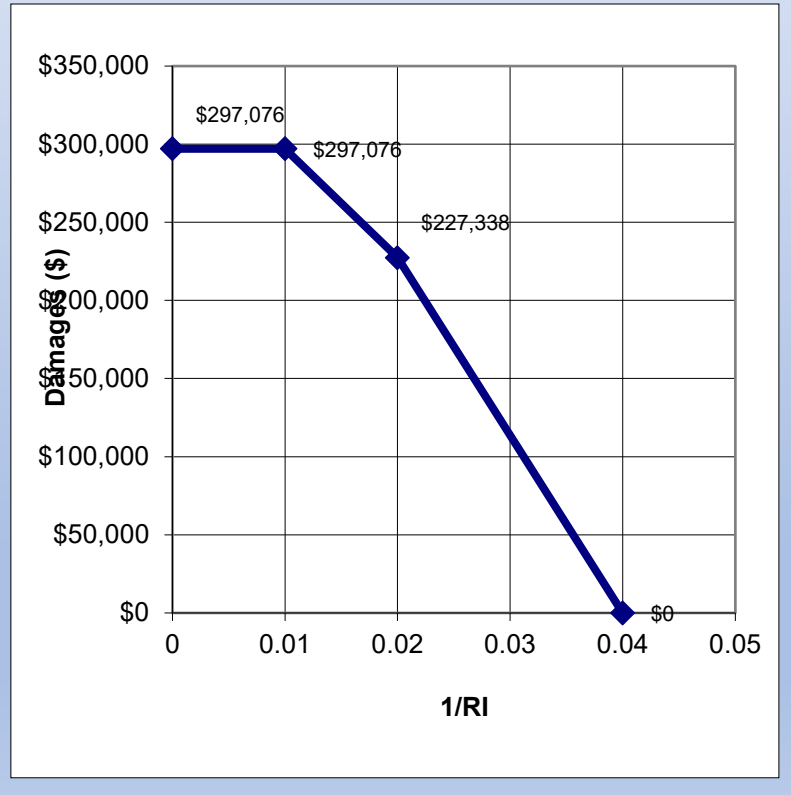
Comparison of Computations

No Minimum Damages



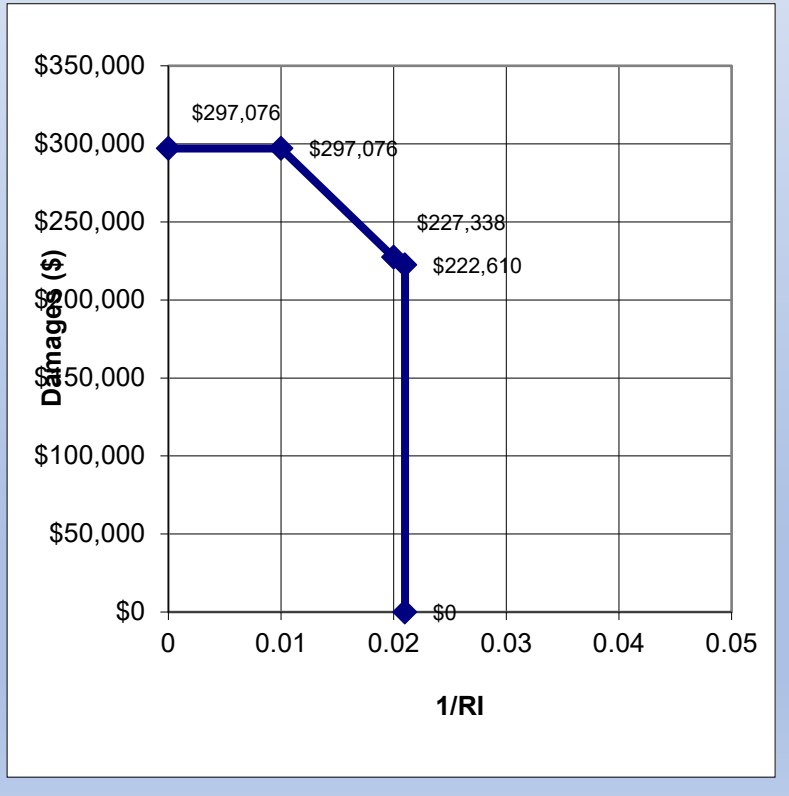
AAD = $10,003

Min damage set at provided frequency

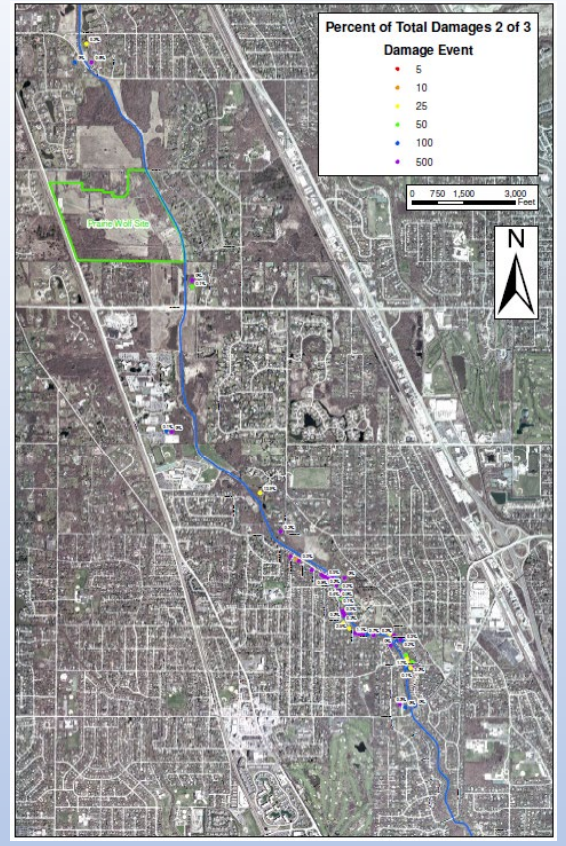


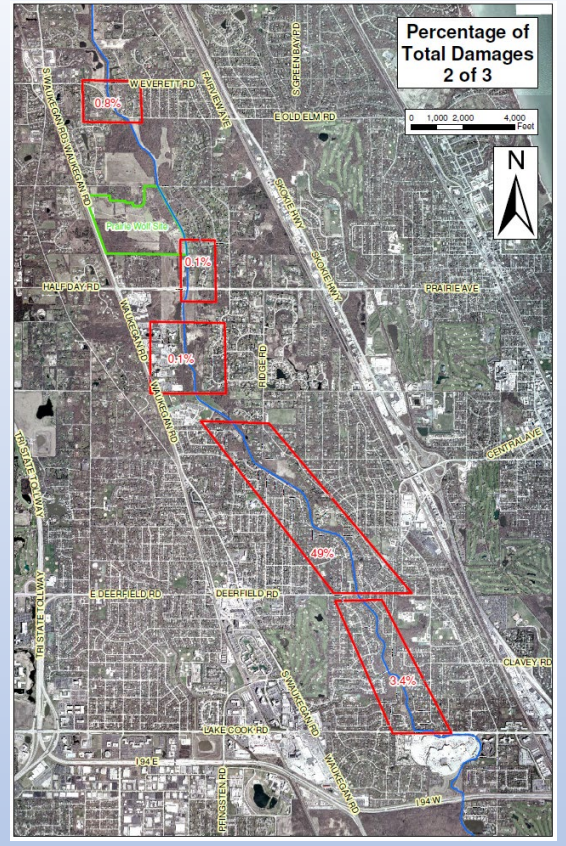
AAD = $7,866

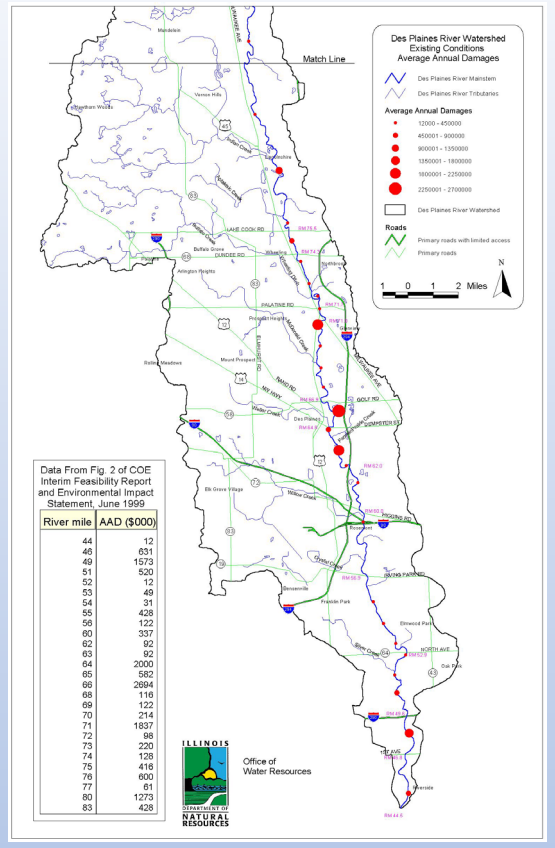
Min damage set at computed frequency



AAD = $5,818







Damage Output types - GIS

Non-Structural Benefits

From BCA Reference Guide

Building Type		Displacement Costs	
HAZUS-MH MR3 Label	Occupancy Class	[A] Rental Cost (2008)	[B] Disruption Costs (2008)
		$/ft²/month	$/ft²
Residential			
RES1	Single Family Dwelling	0.73	0.88
RES2	Mobile Home	0.51	0.88
RES3	Multi Family Dwelling (All Types, includes duplex to 50+ units)	0.65	0.88
RES4	Temporary Lodging	2.19	0.88
RES5	Institutional Lodging	0.44	0.88
RES6	Nursing Home	0.80	0.88
Commercial			
COM1	Retail Trade	1.25	1.17
COM2	Wholesale Trade	0.52	1.02
COM3	Personal and Repair Services	1.46	1.02
COM4	Professional/Technical/Business	1.46	1.02
COM5	Banks	1.82	1.02
COM6	Hospital	1.46	1.46
COM7	Medical Office/ Clinic	1.46	1.46
COM8	Entertainment and Recreation	1.82	0.00
COM9	Theaters	1.82	0.00
COM10	Parking	0.36	0.00
Industrial			
IND1	Heavy	0.21	0.00
IND2	Light	0.29	1.02
IND3	Food/Drugs/Chemicals	0.29	1.02
IND4	Metals/Mineral Processing	0.21	1.02
IND5	High Technology	0.36	1.02
IND6	Construction	0.15	1.02
Agricultural			
AGR1	Agriculture	0.73	0.73
Religious/Non-Profit			
REL1	Church/Membership Organization	1.09	1.02
Government			
GOV1	General Services	1.46	1.02
GOV2	Emergency Response	1.46	1.02
Education			
EDU1	Schools/Libraries	1.09	1.02
EDU2	College/Universities	1.46	1.02

Source: HAZUS-MH MR3 Flood Technical Manual, Table 14.10. The 2006 HAZUS values were inflated using the CPI for 2007 and 2008 from the Bureau of Labor Statistics (bls.gov) Historical CPI Data

More from BCA Reference Guide

Transportation

- FEMA Standard Values for Loss of Service for roads:
  - Loss of road/bridge service: $38.15/vehicle/hour
  - Mileage: Use current Federal Mileage Rate

Utility

- FEMA Standard Values for Loss of Service for utilities:
  - Loss of electric power: $126/person/day
  - Loss of potable water: $88/person/day
  - Loss of wastewater: $41/person/day

Transportation Time

Cost/Benefit Category	Recommended Monetized Value(s)	Reference and Notes
Value of Travel Time	See nested table below	*Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (Revision 2 – corrected)* http://www.dot.gov/office-policy/transportation-policy/guidance-value-time

Recommended Hourly Values of Travel Time Savings (2013 U.S. $ per person-hour)

Category	Surface Modes* (except High-Speed Rail)	Air and High-Speed Rail Travel
Local Travel		
Personal	$12.42	
Business	$25.23	
All Purposes **	$12.98	
Intercity Travel		
Personal	$17.39	$33.05
Business	$24.44	$60.74
All Purposes **	$18.90	$44.24

Truck Drivers	$25.75
Bus Drivers	$26.69
Transit Rail Operators	$45.77
Locomotive Engineers	$38.14
Airline Pilots and Engineers	$83.32

* Surface figures apply to all combinations of in-vehicle and other transit time. Walk access, waiting, and transfer time in personal travel should be valued at $24.85 per hour for personal travel when actions affect only those elements of travel time.

** These are weighted averages, using distributions of travel by trip purpose on various modes. Distribution for local travel by surface modes: 95.4% personal, 4.6% business. Distribution for intercity travel by conventional surface modes: 78.6% personal, 21.4% business. Distribution for intercity travel by air or high-speed rail: 59.6% personal, 40.4% business. Surface figures derived using annual person-miles of travel (PMT) data from the 2001 National Household Travel Survey. http://nhts.ornl.gov/. Air figures use person-trip data.

Source: Tiger Benefit Cost Analysis Resource Guide (www.transportation.gov)

Environmental - Emissions

Recommended Monetized Value(s)	Reference and Notes

Emission Type	$ / short ton ($2013)	$ / metric ton ($2013)
Carbon dioxide (CO_2)	(varies)*	(varies)*
Volatile Organic Compounds (VOCs)	$1,813	$1,999
Nitrogen oxides (NOx)	$7,147	$7,877
Particulate matter (PM)	$326,935	$360,383
Sulfur dioxide (SOx)	$42,240	$46,561

* See **"Social Cost of Carbon (3%)"** values below.

1 Gallon of Gas burned =
17.7 pounds of CO2

Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks (August 2012), page 922, Table VIII-16, "Economic Values Used for Benefits Computations (2010 dollars)"
http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf

The Resource Guide converts these values into 2013 dollars.

NOTE:
Emissions units are frequently reported as "tons" throughout documents such as the CAFE rulemaking referenced above. There is a distinction between short tons, long tons, and metric tons, however. Carbon dioxide emissions (as reported in the SCC guidance and elsewhere) are typically reported in metric tons, whereas emissions for VOCs, NOx, PMs, and SOx are measured in short tons. The English "long ton" is not used in these tabulations. A short ton is 2000 lbs., while a metric ton is approximately 2,205 lbs., and a long ton is 2,240 lbs.

Source: Tiger Benefit Cost Analysis Resource Guide (www.transportation.gov)

Injuries

Cost/Benefit Category	Recommended Monetized Value(s)	Reference and Notes
Value of Injuries	See table below	*Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses (2014)* http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life **NOTE:** Accident data (particularly those provided through law enforcement records) are typically reported as a single number (e.g. "X number of crashes in Year Y") and/or on the KABCO scale of crash severity. Applicants should convert these values to the AIS scale before applying the recommended monetized values. See **Part II Section 3 ("Converting Available Accident Data into AIS Data")**.

AIS Level	Severity	Fraction of VSL	Unit value ($2013)
AIS 1	Minor	0.003	$ 27,600
AIS 2	Moderate	0.047	$ 432,400
AIS 3	Serious	0.105	$ 966,000
AIS 4	Severe	0.266	$ 2,447,200
AIS 5	Critical	0.593	$ 5,455,600
AIS 6	Unsurvivable	1.000	$ 9,200,000

Source: Tiger Benefit Cost Analysis Resource Guide (www.transportation.gov)

Holistic view for resiliency project

Resilience Benefits

Environmental Benefits

Social Benefits

Economic Benefits

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Illinois Association for
Floodplain and Stormwater Management

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IAFSM – Annual Conference
3/14/2023

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DEPARTMENT OF
NATURAL
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