resourceful. naturally.
engineering and environmental consultants

BARR

Memorandum DRAFT

To: David Bennett, City of Northfield
From: Joe Waln and Greg Williams
Subject: Summary of the Federal Emergency Management Agency Benefit Cost Analysis Tool Applied to Flood-prone Properties in Northfield, Minnesota
Date: May 4, 2023
Project: 23661042.00 Northfield Downtown Flood Study – Phase 2
c: Carleton College: Steve Pehn, Jay Stadler

1 Overview

Barr Engineering Co. (Barr) is assisting the City of Northfield (City) in evaluating options to reduce flood risk to some downtown properties and Carleton College adjacent to the Cannon River. As part of this evaluation, Barr used the Federal Emergency Management Agency's (FEMA's) Benefit Cost Analysis (BCA) tool to estimate the potential benefit realized by adding flood protection to each property evaluated. Projects with a benefit-cost ratio (BCR) greater than 1.0 may be eligible for certain federal funding sources (Reference [1]). Estimated benefits were compared to a range of engineer's opinions of probable costs (OPCs) developed for different flood mitigation options (see Section 4.1) outside of the BCA tool to calculate benefit-cost ratios (BCRs). This memorandum summarizes Barr's use of the BCA tool to estimate benefits and calculation of BCRs. Properties evaluated were the following:

Downtown Northfield properties:

- **205 Water Street South**
- **207 Water Street South**
- **301 Water Street South**
- 500 Water Street South
- 516 Water Street South
- 630 Water Street South
- **11 Bridge Square**
- **13 Bridge Square**

Carleton College locations:

- **Stadium**
- **West Gym**
- **West Practice Fields**
- Prentice House (107 Division Street North)
- Allen House (111 Division Street North)
- Wilson House (115 Division Street North)

The analysis described in this memorandum suggests that preferred flood mitigation options are cost effective for those properties listed above in bold (in some combination) while flood mitigation options for the remaining properties are not likely to be cost effective (see Section 4).

2 Summary of BCA Tool v.6.0

The FEMA BCA program was originally developed in the early 1990s to determine the cost effectiveness of proposed mitigation projects for FEMA flood risk mitigation grant programs (for eligibility and level of assistance). FEMA has updated to the program over time to update values in the software and to make it more efficient.

As of 2023, the current BCA tool (version 6.0) is available as a free Microsoft Excel add-on using Visual Basic programming for calculations. The program includes default values for some, but not all, required user inputs. FEMA has published the following primary documents to support use of the BCA tool:

- FEMA BCA Reference Guide (FEMA, June 2009)
- FEMA BCA Supplement to the Reference Guide (FEMA, June 2011)

Additional resources to support use of the BCA tool are available at: Resources to Support Benefit-Cost Analysis | FEMA.gov

Generally, the BCA tool considers pre- and post-mitigation flood elevation and recurrence data, property and structure details, and project cost to estimate a BCR. **Benefit** is equivalent to the estimated damages avoided due to the mitigation project with consideration for flood event recurrence interval and presented as a present value dollar amount. **Cost** is equivalent to the present value, in dollars, of the flood mitigation project with consideration for design, construction, operations and maintenance costs for a user-defined project lifespan.

Inputs to the Excel-based tool vary according to the benefit calculation method used and are divided into the following lists and described in the subsections of Section 3:

Modeled Damages Method:

- Project Configuration
- Cost Estimation
- Hazard Probability Parameters – Flood
- Building Information
- Standard Benefits – Building
- Standard Benefits – Contents
- Standard Benefits – Displacement
- Standard Benefits – Loss of Function/ Income
- Standard Benefits – Volunteer Costs
- Benefit-Cost Summary

Historical Damages Method:

- Project Configuration
- Cost Estimation
- Damage Analysis Parameters
- Historical Damages before Mitigation
- Expected Damages after Mitigation

3 BCA Tool Inputs

Inputs required to run the BCA Tool are generally described in the following subsections. Table 4 and Table 5 present the specific input values applicable to each property assessed using the "modeled damages" and "historical damages" options (see Section 3.1), respectively. Table 4 and Table 5 also categorize the type of input as one of the following:

- **User selected** – an input selected from a pre-populated menu built into the BCA tool.
- **User input** – a text or number of any value entered by the user. User inputs also include:
    - **Design input** – a user-entered value based on floodproofing mitigation design.
    - **Model input** – a user-entered value based on hydrologic and hydraulic modeling results.
- **Calculation** – a numeric value returned from the BCA tool based user selections and inputs.

Note that many of the BCA tool inputs summarized in the following sections are specific to the type of damage assessment used: modeled damages or historical damages. The project configuration (see Section 3.1) and cost estimation (see Section 3.2) inputs are similar for both damage assessments. Section 3.3 presents the BCA tool inputs specific to estimating benefits with the modeled damages method. Section 3.4 describes the BCA tool inputs relevant to estimating benefits using historical damages.

3.1 Project Configuration

The Project Configuration inputs ask the user to enter a project title and property location. The user must also select:

Property Structure Type – The user must select from a drop down menu. For this project, a structure type of "non-residential building" was selected for all properties with the exception of Prentice House, Allen House, and Wilson House located on the Carleton College campus which serve as student housing.

Hazard Type – The user must select from a drop down menu. For this project, a hazard type of "riverine flooding" was selected for all properties.

Mitigation Action Type – The user must select from a drop down menu. For this project, a mitigation action of "floodproofing measures" was selected.

Damage and Frequency Relationships – The user must select whether damage and frequency relationships are based on modeled damages, historical damages, or professional expected damages. For this this project, "modeled damages" was selected for the downtown Northfield properties and Carleton College residential properties. The option of "historical damages" was selected for a single analysis to include the stadium and west gym and a second analysis to include the west practice fields. The "historical damages" option was used for these properties/structures because recent

damages data is available (from the 2010 and 2016 flood events) and the affected structures (e.g., stadium) are not well-represented by the user-selectable, built-in inputs the BCA uses to calculate modeled damages.

3.2 Cost Estimation

The Cost Estimation inputs are dependent on mitigation action type selected in the Project Configuration inputs. For the mitigation action type of floodproofing measures user must enter the following information:

Project Useful Life – The user must enter the life of the project, in years. There is no default. A value must be entered to calculate a present value from annualized costs and benefits. For this analysis, a project life of 50 years was assumed for all floodproofing measures (for consistency with cost estimates).

Initial Project Cost – The user must enter the cost of the project. There is no default. For this project, we assume that this cost includes detailed design, permitting, and construction of the flood mitigation project.

Number of Maintenance Years – The user must enter the number of years the project will be maintained. The default value is set equal to the project useful life.

Annual Maintenance Costs – The user must enter annual maintenance costs. There is no default value.

The BCA tool calculates a total project costs, in present value, based on the above inputs. For this project, benefits calculated using the tool were compared to project costs outside of the tool to calculate Benefit-Cost (BC) ratios. Thus, the specific cost inputs to the tool are not relevant outside of the project life (which is relevant to the benefit calculations), and are therefore not presented in Table 4 and Table 5.

3.3 Benefit Calculation – Modeled Damages

Generally, the modeled damages approach to estimating benefits calculates the damage to a building based on modeled water surface elevations, building details, and a depth-damage curve. Damages estimated for pre- and post-mitigation conditions are compared to estimate a benefit. This method is useful when limited historical data is available but requires detailed inputs regarding each affected property (see Table 4). The following sections describe the BCA input parameters required to use the modeled damages assessment method.

3.3.1 Hazard Probability Parameters – Flood

Hazard probability parameters depend upon the hazard type selected in the Project Configuration inputs. For a hazard of riverine flooding the user must enter the following information:

Property Lowest Floor Elevation – The user must enter the lowest property floor. For this project, the basement floor elevation of each property was entered as the lowest floor. In most cases, this elevation is equivalent to the low opening from survey data.

Streambed Elevation at the Property – The user must enter a streambed elevation adjacent to the property. For this project, streambed elevations were based on HEC-RAS model cross sections at approximate property locations (or interpolated from available cross sections). Note that benefit estimates are not sensitive to this parameter in this analysis as the streambed is approximately 10 feet (or more) below the lowest floor of each evaluated property.

Elevation for the Top of Barrier/Floodproofing – The user must enter the top elevation of floodproofing measures. For this project, we assumed an elevation of 1 foot above the 100-year water surface elevation to provide protection during lower frequency (e.g., 500-year) events. In this case, a sensitivity analysis identified that benefit estimates are not sensitive to this parameter when it is greater than the 100-year water surface elevation.

Flood Recurrence Interval, Water Surface Elevation, and Discharge (Before Mitigation) – The user must enter the recurrent interval, water surface elevation, and discharge corresponding to four flood events. Default recurrence intervals include 10-. 50-. 100-, and 500-years but may be changed by the user. For this project, default recurrence intervals were used. Water surface elevations and discharges corresponding to these events were estimated using HEC-RAS model results (Reference [2]) and are summarized according to property location in Table 4. Discharge estimates are based on Barr's 2022 analysis (Reference [3]).

3.3.2 Building Information

The user must select the **Building Use** and **Building Type** from the options included in drop-drown menus built into the BCA tool. Table 4 lists the building uses and types selected for each analyzed property. The user must also answer "yes" or "no" to the following questions:

- Is the building located in a 100-year flood zone?
    - Downtown buildings are located within the 100-year flood zone. Carleton College structures evaluated with the "modeled damages" method are located outside the 100-year flood zone.
- Is the building engineered (to resist floods)?
    - Each building was assumed not to be engineered to resist floods based on available property data.

- Does the building have an active National Flood Insurance Program (NFIP) policy?
    - Each building was assumed not to have an active NFIP policy unless informed otherwise by the property owner.

Table 4 lists the answers to these questions for each analyzed property.

3.3.3 Standard Benefits – Building

A significant portion of project benefits include costs to repair or replace the physical structure (i.e., building replacement value, or BRV) that are avoided due to floodproofing. To estimate this benefit, the user must identify the following information:

Damage Curve – The BCA tool includes depth-damage curves that relate the depth of flooding to the percent of building replacement cost for each building use and building type. The default curves built into the BCA tool were used for this analysis.

Building first floor area – The first floor area was estimated from aerial photography and available property information (Reference [4]).

Building size (area) – The building size was estimated as the footprint multiplied by number of floors.

Building replacement value (BRV, per unit area) – The BCA tool uses a unit area building replacement value (BRV). The unit area BRV is based on the first floor area for buildings with non-residential damage curves and total area for residential structures with multi-story damage curves (such as those used in this analysis).

Total building replacement values provided by property owners were used in this analysis to calculate BRV, when available (see Table 4). Otherwise, building replacement values were taken from the building estimated market value (from county parcel data) for non-residential structures and from Zillow real-estate estimator for residential structures. From these values, a unit area BRV was calculated by dividing the total building value by the first floor area (for non-residential structures) or by the total area for residential structures with multi-story damage curves.

The calculated unit area BRVs were compared to the default value of $100/square foot built into the BCA tool, and the larger of the default or calculated values were used for the calculation of benefit.

Note: *the default unit area BRV of $100/square foot and unit area BRVs calculated from county tax data may underestimate the true building replacement costs and reduce the estimated benefit of flood protection*.

Demolition threshold – The user must select the percent damage above which the damage is assumed to be 100% of the replacement value. The BCA tool includes a default value of 50%; this value was used for all properties in this analysis.

The BCA tool uses the above information to estimate annual losses to building damages before and after the flood risk mitigation project. The difference in the before and after values is equal to the annual building benefit.

3.3.4 Standard Benefits – Contents

Project benefits also include costs avoided to replace damaged building contents. To estimate this benefit, the user must enter the building contents value.

Contents Value – The user may enter a dollar amount or use a default percentage of BRV based on building type. For this analysis, the default percentage was used unless the property owner provided a property-specific contents value (see Table 4).

From the contents value, the BCA tool uses estimates the annual losses due to contents damages before and after the flood risk mitigation project and calculates the annual contents benefit as the difference.

3.3.5 Standard Benefits – Displacement

Project benefits include displacement costs that may be avoided. User inputs for this benefit include:

Monthly cost of temporary space – For this project, default values were used. Default values vary according to building use (see Table 4).

One time displacement cost – For this project, default values were used. Default values vary according to building use (see Table 4).

Using default values, the displacement benefits are small, but still significant, relative to the building benefits and contents benefits.

3.3.6 Standard Benefits – Loss of Function/Loss of Income

Loss of function or income is a significant benefit for commercial structures (and other structure types), as flooding prevents the business from operating. User inputs for this benefit include:

Annual operating budget – No default values are included in the BCA tool for annual operating budget as it is highly variable for each property. For this project, we asked property owners to provide an approximate annual operating budget. If a property owner provided a range of values, the median of the range was used for that property (see Table 4). For properties where owner information was not provided, the annual operating budget was assigned a value of $1,000,000.

From the annual operating budget, the BCA tool estimates the loss of function/income before and after the flood risk mitigation project and calculates the associated benefit as the difference.

3.3.7 Standard Benefits – Volunteer Costs

The BCA tool has the option to include benefit costs related to volunteer flood fighting efforts. Those benefits were not considered in this analysis due to uncertainty in necessary assumptions regarding number of volunteers, duration of volunteer efforts, and volunteer housing costs.

3.4 Benefit Calculations – Historical Damages

The BCA tool provides users the option to estimate project benefits based on historical damages. The required inputs to this method are fewer than the modeled damages method (see Section 3.3). Generally, the historical damages approach calculates benefits based on user-entered past damages resulting from events of known (or estimated) return intervals scaled to present day dollars and compared to user-entered estimates of post-project damages for the same events. This method is especially useful when accurate records or estimates of past damages are available and/or the affected structures or properties are not well-aligned with inputs built into the BCA tool (e.g., damage-depth curves).

In this analysis, the historical damages method was used to estimate benefits for the following properties as two separate evaluations:

- Stadium and west gym
- West practice fields

Table 5 and the following sections summarize the inputs to the historical damages evaluations.

3.4.1 Damage Analysis Parameters – Damage Frequency Assessment

The user must enter the **year the analysis was conducted** (2023), the **year the property was built**, and the **analysis duration** (in years). The BCA tool includes a default option for the analysis duration equal to the difference between the year of analysis and the year the property was built. The year of analysis is relevant to the extrapolation of damages and benefits to present dollars. The year the property was built and duration of analysis do not affect the damage and benefit calculations based on the other inputs entered in this analysis. Table 5 presents the inputs used.

3.4.2 Historical Damages Before Mitigation

The historical damages method relies on user-entered damages from past events. The user is asked to enter the following information for one or more events:

Damage Year – the year the damage was incurred; this information is used to extrapolate past damages to present day dollars.

Recurrence Interval – the estimated recurrence interval (in years) of the historical event associated with the damages. The 2010 and 2016 events were used to evaluate benefits for the stadium, west gym, and pump/oil house. These events are similar in magnitude to the estimated 100 year event (References [2] and [3]) and were assigned recurrence intervals of 101 years and 100 years, respectively, for this analysis. A three year recurrence interval was assumed to evaluate benefits for the west practice fields based on input from Carleton College staff.

Damages – the dollar amount of the damages associated with the historical event. The BCA tool has inputs for several categories of "optional damages" in addition to the main damages field. All categories of damages are treated similarly in the BCA tool. In this analysis, the total damages were entered under the main damages field and no data was entered in the "optional damages" fields. The user must also select if the damages are presented in current dollars or not; for this analysis, damages were entered as dollar values based on the year of occurrence (i.e., not current dollars).

Volunteer Costs – the user may enter the number of volunteers and the number of days. No volunteer costs were entered in this analysis. The BCA tool includes depth-damage curves that relate the depth of flooding to the percent of building replacement cost for each building use and building type. The default curves built into the BCA tool were used for this analysis.

The BCA tool calculates an inflated total damages reflecting the dollars in the year of analysis and annualized damages based on the above inputs. Table 5 presents the specific inputs used in this analysis.

3.4.3 Expected Damages After Mitigation

The BCA tool estimates benefits based on the difference in damages before and after mitigation. The user must enter expected damages corresponding to events of estimated return intervals similar to the inputs described in Section 3.4.2. For the purposes of this analysis, flood mitigation was assumed to reduce damages by 90 percent. Thus, expected damages after mitigation were entered as 10% of the historical damages (adjusted to 2023 dollars). Table 5 presents the specific inputs used in this analysis.

4 Benefit-Cost Summary

The BCA tool is designed to calculate a benefit-cost ratio (BCR) for potential flood risk mitigation projects. Herein, the BCA tool was used to evaluate potential floodproofing of eight non-residential properties in downtown Northfield, MN and several facilities on the Carleton College campus. Benefits of flood protection were estimated based on an assumed flood protection elevation (see Section 3.3) or expected damages after mitigation (see Section 3.4). Project costs were estimated outside of the BCA tool and compared to BCA tool-calculated benefits. Flood mitigation options with an annualized cost less than the annualized benefit calculated by the BCA tool will result in a BCR greater than 1.0. The Annualized benefit of flood protection for each property is summarized in Table 1.

Table 1 Annualized Benefit for Downtown Northfield and Carleton College Properties

Area	Property	Benefit Evaluation Method	Annual Mitigation Benefit	Total Mitigation Benefit[1]
Area 1	205 Water Street South	Modeled Damages	$ 132,598	$ 3,411,715
	207 Water Street South	Modeled Damages	$ 250,918	$ 6,456,061
	301 Water Street South	Modeled Damages	$ 2,320	$ 59,693
Area 2	11 Bridge Square	Modeled Damages	$ 17,077	$ 439,387
	13 Bridge Square	Modeled Damages	$ 2,999	$ 77,164
Area 3	500 Water Street South	Modeled Damages	$ 43	$ 1,106
	516 Water Street South	Modeled Damages	$ 41	$ 1,055
	630 Water Street South	Modeled Damages	$ 72	$ 1,853
Student Houses	107 Division St N (Prentice House)	Modeled Damages	$ 12,481	$ 321,133
	111 Division St N (Allen House)	Modeled Damages	$ 14,579	$ 375,114
	115 Division St N (Wilson House)	Modeled Damages	$ 17,073	$ 439,284
Carleton College	Stadium and West Gym	Historical Damages	$ 46,732	$ 1,202,392
	West Practice Fields	Historical Damages	$ 37,667	$ 969,173
		Total	$ 534,601	$ 13,755,156

(1) Total Mitigation Benefit assumes 50-year project life and 3% discount rate; discount rate is an estimate of the decreased value of dollars over time (a higher discount rate equates to a lower benefit over the project life).

The BCA tool reference material notes that properties and flood protection measures evaluated using the BCA tool may be combined in various ways to achieve the user's goals (Reference [1]). With this consideration, this analysis yields the following broad conclusions:

1. Cost-effective (i.e., BCR > 1) flood mitigation projects likely are not available for any combination of the following Area 3 properties due to minimal benefits:
    - 500 Water Street South
    - 516 Water Street South
    - 630 Water Street South
2. Construction of a permanent floodwall to protect the properties in Area 1 is likely to achieve a BCR >1 if the project cost is less than approximately $7.1M to protect the following properties:
    - 205 Water Street South
    - 207 Water Street South
    - 301 Water Street South

3. Dry floodproofing of the properties in Area 3 (11 Bridge Square and 13 Bridge Square) is likely to achieve a BCR >1 if the project cost is less than approximately $520,000.
4. A combination of dry floodproofing, permanent floodwall, and interior pumping/drainage improvements designed to protect the stadium, west gym, and pump/oil house is likely to achieve a BCR >1 if the total project cost is less than approximately $4.8M.
5. Construction of a low berm to protect the west practice fields is likely to achieve a BCR >1 if the project costs is less than approximately $970,000.

4.1 Benefit Cost Ratio (BCR) of Preferred Alternatives

Northfield city staff and Carleton College staff met with Barr staff to discuss feasible flood mitigation options including a range of temporary and permanent alternatives (Reference [5]). Table 2 summarizes the preferred flood mitigation options resulting from discussion and preliminary evaluations of feasibility, costs, and relative benefit.

Table 2 Preferred Mitigation alternatives for Downtown Northfield and Carleton College Properties

Area	Affected Properties	Alternative ID	Preferred Flood Mitigation Description	Estimated Cost[1]
Downtown Area 1	205 Water St S 207 Water St S 301 Water St S	Alt 1-2	Permanent **floodwall** at an elevation of 904 to 906 feet set back from river	$1.56M **$1.99M** $2.86M
Downtown Area 2	11 Bridge Sq 13 Bridge Sq	Alt 2-2	**Dry floodproofing** of affected structures	$719K **$853K** $1.12M
Downtown Area 3	500 Water St S 516 Water St S 630 Water St S	Alt 3-1	Continue to use **emergency measures** such as sandbags and pumps to protect individual properties during a flood.	Not evaluated
Carleton College	107 Division St N 111 Division St N 115 Division St N	Alt CC1-1	Continue to use **emergency measures** such as sandbags and pumps to protect individual properties during a flood.	Not evaluated
	Stadium	Alt CC2-4	**Dry floodproofing** the stadium structure, construct **floodwalls** to limit inundation of the track and field	$1.32M **$1.73M** $2.54M
	West Gym	Alt CC3-2	**Temporary closure** offset from the basement entry points to allow for egress during flood events and prevent floodwaters from pressing up against the building.	$207K **$238K** $327K

Area	Affected Properties	Alternative ID	Preferred Flood Mitigation Description	Estimated Cost[1]
	Pump/oil house	Alt CC4-4	**Sump pump** in the floor of the Pump House to automatically dewater the building if water is present.	Not evaluated
	West practice fields	Alt CC5-2	**Low berm** along perimeter of the fields adjacent to the river that prevents flooding from 10-year event.	$333K **$348K** $383K

(1) Low, medium, and high opinions of probably cost (OPCs) are presented for each preferred alternative in 2022 dollars based on a 50 year project life and include operations and maintenance cost at an assumed 3% discount rate.

Table 2 presents the engineer's opinion on probable costs (OPCs) including as low, medium, and high values plus estimated operations and maintenance costs over a 50 year project life. Table 3 compares the OPCs to the estimated project benefits from the BCA tool to calculate BCRs for each preferred alternative or combinations of preferred alternatives (excluding alternatives including only emergency response measures). Calculated BCRs presented in Table 3 indicate that the preferred mitigation alternatives are cost-effective (i.e., BCR >1) for the full range of OPCs for alternatives 1-2 and CC5-2, as well as when all preferred alternatives are considered together.

Table 3 Estimated Benefit Cost Ratios (BCRs) for Preferred Mitigation Alternatives

Area	Affected Properties	Preferred Alternative	Estimated Benefit (BCA Tool)	Estimated Cost[1] (OPC)	BCR[2]
Downtown Area 1	205 Water St S 207 Water St S 301 Water St S	Alt 1-2	$9.93M	$1.56M **$1.99M** $2.86M	6.35 **4.98** 3.47
Downtown Area 2	11 Bridge Sq 13 Bridge Sq	Alt 2-2	$517K	$719K **$853K** $1.12M	0.72 **0.61** 0.46
Carleton College	Stadium West Gym	Alt CC2-4 Alt CC3-2	$1.20M	$1.53M **$1.97M** $2.87M	0.79 **0.69** 0.42

Area	Affected Properties	Preferred Alternative	Estimated Benefit (BCA Tool)	Estimated Cost[1] (OPC)	BCR[2]
Carleton College	West practice fields	Alt CC5-2	$969K	$333K **$348K** $383K	2.91 **2.78** 2.53
		Total	$12.62M	$4.14M **$5.16M** $7.23M	3.04 **2.44** 1.74

(1) Low, medium, and high opinions of probable cost (OPCs) are presented for each preferred alternative in 2023 dollars based on a 50-year project life and include operations and maintenance costs at an assumed 3% discount rate.
(2) BCRs are calculated based on low, medium, and high OPCs.

5 References

[1] Federal Emergency Management Agency, "Final BCA Reference Guide," Washington DC, June 2009.

[2] Barr Engineering Co., "DRAFT - Cannon River Hydraulic Model Updates," Minneapolis, January 10, 2023.

[3] Barr Engineering Co., "Cannon River Flood-Frequency Analysis Update," Minneapolis, December 6, 2022.

[4] Rice County, "Rice County Property Values and Taxes," Rice County, 2022. [Online]. Available: https://www.ricecountymn.gov/249/Property-values-and-taxes. [Accessed October 2022].

[5] Barr Engineering Co., "Carleton College Flood Mitigation Alternatives," Minneapolis, March 15, 2023.

[6] Federal Emergency Management Agency, "Supplement to the Benefit-Cost Analysis Reference Guide," Washington DC, June 2011.

Table 4. Summary of BCA Tool Inputs and Calculated Benefits - Modeled Damages Option

BCA Parameter/Input (by BCA Tool Heading)	Input Parameter Source/Type	Property Address: 205 Water Street South	207 Water Street South	301 Water Street South	11 Bridge Square	13 Bridge Square	500 Water Street South	516 Water Street South	630 Water Street South	107 Division Street N	111 Division Street N	115 Division Street N
Project Configuration												
Property Structure Type	User Selected	building	building	building	building	building	building	building	building	building	building	building
Hazard Type	User Selected	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding	Riverine Flooding
Mitigation Action Type	User Selected	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing	Floodproofing
Property title	User input	Professional Building (Auditory Services; SMSQ)	Larsons Printing	Basils Pizza	Carlson Capital Management	Tune, Cottage Tea Room	Professional Building (Law, Hair, nutrition)	Just Food Coop	Strip mall	Prentice House	Allen House	Wilson House
Damage based on:	User Selected	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages	Modeled Damages
Cost Estimation												
Project Life (years)	Design input	50	50	50	50	50	50	50	50	50	50	50
Initial cost	Design input	Mitigation alternative project costs estimated outside of BCA tool										
Maintenance years	Design input											
Annual maint cost	Design input											
Total mitigation cost	Calculation											
Hazard Parameters												
100 year WSEL minus low floor		5.77	6	0.86	3.39	1.2	-2.07	-2.13	-2.49	2.36	2.22	3.08
Is 100 year + 3 ft > 500 year?		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Lowest Floor Elevation	User input	897.42	897.42	902.65	900.18	902.37	910.16	910.16	911.17	899	899	898
Streambed Elevation	User input	887.92	887.99	888.44	889.1	889.1	893.6	896.45	865.17	887.5	887.5	887
Floodproof top (100yr WSEL + 3 ft)	Design input	906.19	906.42	906.51	906.57	906.57	911.09	911.03	911.68	904.36	904.22	904.08
10 yr WSEL (ft)	Model Result	900.11	900.23	900.26	900.34	900.34	905.86	905.84	906.31	898.74	898.65	898.56
50 yr WSEL (ft)	Model Result	901.09	901.24	901.31	900.36	900.36	906.57	906.56	907.08	900.62	900.49	900.37
100 yr WSEL (ft)	Model Result	903.19	903.42	903.51	903.57	903.57	908.09	908.03	908.68	901.36	901.22	901.08
500 yr WSEL (ft)	Model Result	905.43	905.76	905.9	905.94	905.94	909.4	909.3	910.14	903.03	902.84	902.66
10 yr Flow (cfs)	Model Result	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200
50 yr Flow (cfs)	Model Result	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000
100 yr Flow (cfs)	Model Result	16200	16200	16200	16200	16200	16200	16200	16200	16200	16200	16200
500 yr Flow (cfs)	Model Result	21600	21600	21600	21600	21600	21600	21600	21600	21600	21600	21600
Building Information												
Building Use	User Selected	Commercial - Professional/ Technical	Commercial - Retail Trade	Commercial - Retail Trade	Commercial - Professional/ Technical	Commercial - Retail Trade	Commercial - Professional/ Technical	Commercial - Retail Trade	Commercial - Retail Trade	Residential	Residential	Residential
Building Type	User Selected	Office One Story	Clothing	Non-fast Food	Office One Story	Electronics	Office One Story	Grocery	Clothing	stories	stories	stories
Basement (for residential)	User Selected									Yes	Yes	Yes
Located outside Floodplain (Y/N)	User input	No	No	No	No	No	No	No	No	NA	NA	NA
Is the Building Engineered (Y/N)	User input	Yes	No	No	No	No	No	No	No	NA	NA	NA
Active NFIP Policy (Y/N)	User input	No	Yes	No	No	No	No	No	No	Yes	Yes	Yes
Standard Benefits - Building												
Damage Curve	User Selected	Office - One Story	Retail - Clothing	Retail - Non-fast Food	Office - One Story	Retail - Electronics	Office - One Story	Grocery	Retail - Clothing	FEMA FIA 2 story w/ basement	FEMA FIA 2 story w/ basement	FEMA FIA 2 story w/ basement
First floor Area	User input	7300	4042	1747	1628	2320	6450	12000	42523	--	--	--
Building Size	User input	14600	8084	3494	4884	6960	6450	12000	42523	1750	2944	1596
Building Replacement Value (site specific)	User input	$ 391,300	$ 1,471,000	$ 151,500	$ 385,400	$ 266,200	$ 235,400	$ 444,800	$ 1,566,100	$ 245,000	$ 301,000	$ 203,000
Unit Area BRV (total area, site specific) (/ft2)	Calculation	$ 27	$ 182	$ 43	$ 79	$ 38	$ 36	$ 37	$ 37			
Unit Area BRV (site specific) (/ft2)	Calculation	$ 54	$ 364	$ 87	$ 237	$ 115	$ 36	$ 37	$ 37	$ 140	$ 102	$ 127
Unit Area BRV (default) (/ft2)	User input	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100
Max Unit Area Replacement Value (/ft2)	User input	$ 100	$ 364	$ 100	$ 237	$ 115	$ 100	$ 100	$ 100	$ 140	$ 102	$ 127
Building Replacement Value (default)	Calculation	$ 730,000	$ 404,200	$ 174,700	$ 162,800	$ 232,000	$ 645,000	$ 1,200,000	$ 4,252,300	$ 175,000	$ 294,400	$ 159,600
Unit Area BRV default floor area (/ft2)	User input	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100

Table 4. Summary of BCA Tool Inputs and Calculated Benefits - Modeled Damages Option

BCA Parameter/Input (by BCA Tool Heading)	Input Parameter Source/Type	Property Address										
		205 Water Street South	207 Water Street South	301 Water Street South	11 Bridge Square	13 Bridge Square	500 Water Street South	516 Water Street South	630 Water Street South	107 Division Street N	111 Division Street N	115 Division Street N
Unit Area BRV default total area (/ft2)	Calculation	$ 200	$ 200	$ 200	$ 300	$ 300	$ 100	$ 100	$ 100			
Max Unit Area Replacement Value (/ft2)	User input	$ 200	$ 364	$ 200	$ 300	$ 300	$ 100	$ 100	$ 100	$ 140	$ 102	$ 127
Demo Threshold	User input	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Annual loss before Mitigation	Calculation	$ 36,687	$ 88,900	$ 810	$ 5,005	$ 1,047	$ 424	$ 705	$ 865	$ 7,646	$ 8,961	$ 10,181
Annual loss after Mitigation	Calculation	$ 1,532	$ 3,088	$ 367	$ 810	$ 560	$ 387	$ 665	$ 793	$ 514	$ 630	$ 425
Annual building loss benefit	Calculation	$ 35,155	$ 85,812	$ 443	$ 4,195	$ 487	$ 37	$ 41	$ 72	$ 7,132	$ 8,331	$ 9,756
Standard Benefits - Contents												
Contents Value	User input	$ 87,600	$ 590,000	$ 45,422	$ 53,956	$ 215,622	$ 90,300	$ 1,272,000	$ 1,530,828	$ 30,197	$ 59,698	$ 19,177
Contents Value (% of BRV)	User input	12%	40%	26%	14%	81%	14%	106%	36%	17%	20%	12%
Annual contents losses before mitigation	Calculation	$ 8,129	$ 63,560	$ 240	$ 1,011	$ 995	$ 60	$ 705	$ 286	$ 5,606	$ 6,563	$ 7,530
Annual contents losses after mitigation	Calculation	$ 184	$ 1,239	$ 95	$ 113	$ 454	$ 54	$ 705	$ 286	$ 257	$ 315	$ 213
Exptect annual contents benefit	Calculation	$ 7,945	$ 62,321	$ 145	$ 898	$ 541	$ 6	$ -	$ -	$ 5,349	$ 6,248	$ 7,317
Standard Benefits - Displacement												
Monthly cost of temp space	User input	1.36	1.16	1.16	1.36	1.16	1.36	1.16	1.16	NA	NA	NA
One time displacement costs	User input	0.95	1.09	1.09	0.95	1.09	0.95	1.09	1.09	NA	NA	NA
Annual displacement loss before mitigation	Calculation	$ 26,269	$ 15,877	$ 494	$ 1,819	$ 993	$ 162	$ 295	$ 352	NA	NA	NA
Annual displacement loss after mitigation	Calculation	$ 1,285	$ 752	$ 325	$ 430	$ 648	$ 162	$ 295	$ 352	NA	NA	NA
Annual displacement benefit	Calculation	$ 24,984	$ 15,125	$ 169	$ 1,389	$ 345	$ -	$ -	$ -	NA	NA	NA
Standard Benefits - Loss of Income												
Annual operating budget	User input	$ 1,000,000	$ 1,300,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	NA	NA	NA
Loss of function	Calculation	$ 2,740	$ 3,562	$ 2,740	$ 2,740	$ 2,740	$ 2,740	$ 2,740	$ 2,740	NA	NA	NA
Annual loss of function before mitigation	Calculation	$ 64,514	$ 87,661	$ 1,563	$ 10,595	$ 1,626	$ -	$ -	$ -	NA	NA	NA
Annual loss of function after mitigation	Calculation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	NA	NA	NA
Annual loss of function benefit	Calculation	$ 64,514	$ 87,661	$ 1,563	$ 10,595	$ 1,626	$ -	$ -	$ -	NA	NA	NA
Standard Benefits - Volunteers												
Volunteers required	User input	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Number of days volunteer lodging	User input	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Per person lodging cost	User input	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Expect annual volunteer benefit	Calculation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC Summary												
Annaul standard mitigation benefit	Calculation	$ 132,598	$ 250,919	$ 2,320	$ 17,077	$ 2,999	$ 43	$ 41	$ 72	$ 12,481	$ 14,579	$ 17,073
Standard mitigation benefit (3% rate)	Calculation	$ 3,411,715	$ 6,456,087	$ 59,693	$ 439,387	$ 77,164	$ 1,106	$ 1,055	$ 1,853	$ 321,133	$ 375,114	$ 439,284
Total mitigation project benefits (3% rate)	Calculation	$ 3,411,715	$ 6,456,087	$ 59,693	$ 439,387	$ 77,164	$ 1,106	$ 1,055	$ 1,853	$ 321,133	$ 375,114	$ 439,284

Notes:

NA = not applicable based on building use or other user-selected parameter

Values from property owner survey

Values from BAC Tool defaults

Values based on parcel data

Assumption

Based on Zillow

Table 5. Summary of BCA Tool Inputs and Calculated Benefits - Historical Damages Option

BCA Parameter/Input (by BCA Tool Heading)	Input Parameter Source/Type	215 Division Street N		440 Water Street N
Project Configuration				
Property Structure Type	User Selected	Non-residential building		Other
Hazard Type	User Selected	Riverine Flooding		Riverine Flooding
Mitigation Action Type	User Selected	Floodproofing		Floodproofing
Property title	User input	Stadium, West Gym		Practice Fields
Damage based on:	User Selected	Historical Damages		Historical Damages
Cost Estimation				
Project Life (years)	Design input	50		50
Initial cost	Design input	Mitigation alternative costs estimated outside of BCA Tool		
Maintenance years	Design input			
Annual maint cost	Design input			
Total mitigation cost	Calculation			
Hazard Parameters				
Damage Analysis Parameters -Damage Frequency Assessment				
Year Analysis was Conducted	User input	2023		2023
Year Property was Built	User input	1927		1980
Anlaysis Duration (years)	Calculation	97		44
Historical Damages Before Mitigation (multiple events)				
Damage Year	User input	2010	2016	2016
Recurrance Interval (years)	User input	100	10	3
Damages ($)	User input	$ 3,558,496	$ 465,000	$ 100,000
Optional Damages ($)	User input	$ -	$ -	$ -
Volunter Costs ($)	User input	$ -	$ -	$ -
Total Damages ($)	Calculation	$ 3,558,496	$ 465,000	$ 100,000
Current Dollars (yes/no)	User input	No	No	No
Inflated Damages ($)	Calculation	$ 5,246,940	$ 583,565	$ 125,498
Expecgted Damages After Mitigation (multiple events)				
Recurrance Interval (years)	User input	101	100	3
Damages ($)	User input	$ 524,694	$ 58,357	$ 12,550
Optional Damages ($)	User input	$ -	$ -	$ -
Number of Volunteers	User input	$ -	$ -	$ -
Number of Days	User input	$ -	$ -	$ -
Total Damages ($)	Calculation	$ 524,694	$ 58,357	$ 12,550
BC Summary				
Annaul standard mitigation benefit	Calculation	$ 46,732		$ 37,667
Standard mitigation benefit (3% rate)	Calculation	$ 1,202,392		$ 969,173
Total mitigation project benefits (3% rate)	Calculation	$ 1,202,392		$ 969,173

Notes:

Values provided by Carleton College

Values from BAC Tool defaults

Assumption