

# FEMA Benefit-Cost Analysis Re-engineering (BCAR)

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*Wildfire Module*

*Methodology Report*

FEDERAL

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## Purpose

This report is provided for use by interested BCA users to review and understand the methodology behind the FEMA Wildfire Benefit-Cost Analysis (BCA) Module. The goal is to develop methodologies that keep the analysis process simple for the average user, while basing those methodologies on more accurate, well-defined scientific and engineering principles that accurately represent structure performance before and after mitigation. The intent of the Wildfire Module remains the same: to conduct a BCA for an individual structure or multiple identified structures utilizing project-specific and wildfire hazard data to estimate damages. This methodology report was reviewed by the FEMA BCAR Technical Advisory Group (TAG), and is part of a larger effort to re-engineer the FEMA BCA methods, modules, guidance and training, in order to improve the BCA process.

## Overview of the Wildfire Module

The following is a summary of the key equations and assumptions related to the Wildfire Module

The benefits of a hazard mitigation project are the future losses prevented or reduced by the project. The benefits counted in a BCA are the present value (in dollars) of the sum of the expected annual avoided damages over the project useful life. A BCA takes into account:

- Probabilities of various levels of natural-hazard events and damages
- Useful lifetime of the mitigation project
- Time value of money (the discount rate)

To calculate benefits, the Wildfire Module estimates the damages for both the before- and after-mitigation conditions based on the annual percentage chance (probability) that a wildfire will occur.

$$Benefits = \left( EAB \left[ \frac{1 - (1 + r)^{-T}}{r} \right] \right)$$

Where:

- EAB** Is the total expected annual benefit of the hazard mitigation project.
- T** Is the estimated amount of time (in years) that the mitigation action will be effective.
- r** Is the annual discount rate used to determine the “Net Present Value” of benefits. For FEMA-funded projects, the rate is set by the Office of Management and Budget (OMB).

The expected annual net benefit (EAB) is the difference between expected annual damages before ( $EAD_{\text{Before Mitigation}}$ ) and after ( $EAD_{\text{After Mitigation}}$ ) mitigation.

$$EAB = EAD_{\text{Before Mitigation}} - EAD_{\text{After Mitigation}}$$

Where:

- EAB** is the expected annual net benefit.
- $EAD_{\text{Before Mitigation}}$**  is the expected annual damages before mitigation.
- $EAD_{\text{After Mitigation}}$**  is the expected annual damages after mitigation.

To determine before-mitigation damages, the module assumes 100% loss of assets values inputted into the module. For after-mitigation damages, the module reduces losses by the percent reduction in damages, losses, and casualties inputted into the module by the analyst. The expected annual damages can be expressed as:

$$EAD_{\text{Before Mitigation}} = \left[ \sum (B + C + I + T + F + O) / BRI \right] + (D + Inj)$$

$$EAD_{After\ Mitigation} = \left[ \sum (B + C + I + T + F + O) / BRI \right] (1 - P) + (D + Inj)(1 - P)$$

Where:

- B** Building Value (cost to replace buildings within project area)
- C** Contents Value (default value is 50% of Building Value)
- I** Infrastructure Value of vulnerable infrastructure within project area
- T** Timber Value of marketable timber within project area
- F** Fire Suppression Costs for one typical fire
- O** Other
- D** Dollar value of annual deaths (see below)
- Inj** Dollar value of annual injuries (see below)
- BRI** Burn Recurrence Interval (see section titled Wildfire Hazard Data)
- P** Percent reduction in damages, losses, and casualties (project effectiveness, see section titled Effectiveness of Mitigation Measures)

The dollar value of annual deaths is based on an annual death rate (an estimated 8.4 deaths per 1,000,000 are due to wildland fire) and the number of residents in the project area. The dollar value of annual deaths can be expressed as:

$$D = (R) \left( \frac{Adr}{1,000,000} \right) (Svd)$$

Where:

- D** Dollar value of annual deaths
- R** Number of residents
- Adr** Annual death rate per 1,000,000
- Svd** Average statistical value of death

The dollar value of annual injuries is based on the annual death rate adjusted for injuries (an estimated 5.4 injuries occur for every death due to wildland fire) and the number of residents in the project area. The dollar value of annual injuries can be expressed as:

$$Inj = (R) \left( \frac{Adr}{1,000,000} \right) (5.4) (Svi)$$

Where:

- Inj** Dollar value of annual deaths
- R** Number of residents
- Adr** Annual death rate per 1,000,000
- 5.4** For every one death there are assumed to be 5.4 injuries
- Svi** Statistical value of major and minor injuries

## Overview of Problem Statements

Based on feedback from the URS BCAR Team and the FEMA BCAR TAG, the primary issue with the 2006 version of Wildfire Module on the FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) was a lack of sufficient guidance on key input values used in the module. The URS BCAR Team and the BCAR TAG identified the following problem statements as issues that needed additional guidance to be addressed in the Wildfire Module:

1. Wildfire Project List (BCAR Issue No. G-007)
2. Wildfire Hazard Data
3. Loss Estimation
4. Effectiveness of Mitigation Measures
5. Project Useful Lifetimes

Each of these problem statements and the methodologies adopted to address them are described in greater detail in the sections that follow.

### Problem Statement 1: Wildfire Project List

Wildfire projects may consist of one or more mitigation measures. Guidance on the 2006 FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) contained general descriptions of three project types. Methodology Update List Item Number G-007

required the BCAR effort to develop a list and examples of wildfire mitigation project types for the Wildfire Module.

## Methodology to Address Problem Statement 1

Based on the expert panel working session held in April 2008, the following project types were suggested for eligibility within FEMA's hazard mitigation grant programs.

- Untreated Wood Roof Replacements
  - Additional incorporation of fire-resistant building materials may be considered in conjunction with roof replacement, or if roof is already a non-untreated wood material.
- Vegetative fuel load management:
  - Create defensible space by removing surface vegetation within a reasonable distance from structures
    - 200 feet into a grassland area
    - 200 yards into the forest
  - Thinning / removal of surface fuel performed in conjunction with roof replacement and/or installation of fire-resistant building materials
  - Forest crown canopy thinning performed in conjunction with regular surface fuel thinning

These project types were found to be consistent with the acceptable projects outlined in FEMA's Wildfire Mitigation Policy for the Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) Program (Mitigation Policy MRR-2-08-1) issued on September 8, 2008. Therefore, the methodology employed to address Problem Statement 1 was to incorporate the following list of acceptable projects from FEMA's Wildfire Mitigation Policy into the Wildfire Module:

### 1. Defensible Space Activities

Defined by FEMA's Wildfire Mitigation Policy as the creation of perimeters around residential and non-residential structures through the removal or reduction of flammable vegetation including vertical clearance of tree branches. This includes performing the following activities around the structure(s) to be protected:

- a. Minimize volume of vegetation
- b. Replace flammable vegetation with less flammable species
- c. Clearing all combustibles (i.e. surface litter such as dry leaves, pine needles, dead and dying foliage and trees, and removal of propane tanks) in the safety zone around the structure

Supporting project documentation must include a description of requested defensible space activities around each property.

Note that defensible space around buildings and structures is required to receive funds for ignition-resistant construction projects.

The safety zone for defensible space may be determined by using the ICC Publication *International Wildland-Urban Interface Code*. Table 603.2 of the ICC publication lists a 30-foot safety zone for a moderate hazard. A second zone from 30 feet to at least 50 feet is recommended for a high hazard area. The most stringent requirement is based on an extreme hazard and recommends a minimum of 100 feet is required. If local codes are available, the applicant may use those codes in lieu of the ICC code Publication.

## **2. Structural Protection through Ignition-Resistant Construction Activities**

Defined by FEMA's Wildfire Mitigation Policy as the use of non-combustible materials and technologies on new and existing structures. Note that ignition-resistant construction projects will only be considered if one of the following conditions apply:

- o Documentation is provided to support that defensible space activities have previously been created and are currently being maintained (i.e. photographs and description of the defensible space); or
- o The project includes both defensible space and ignition-resistant materials for each property included in the mitigation. Supporting documentation must include a description of requested defensible space activities around each property.

Projects must meet or exceed local codes and be in conformance with the following:

- o ICC Publication *International Wildland-Urban Interface Code*;
- o NFPA 1144: Standard for Reducing Structure Ignition Hazards from Wildland Fire;
- o NFPA 1141: Standard for Fire Protection Infrastructure for Land Development in Suburban and Rural Areas;
- o NFPA 703: Standard for Fire-Retardant Treated Wood and Fire-Retardant Coatings for Building Materials; and as appropriate,
- o NFPA 914: Code for Fire Protection of Historic Structures.

Eligible activities include:

- a. Installation of ignition-resistant roofing (roof coverings, roof sheathing, roof flashing, roof skylights, roof and attic vents, roof eaves and gutters) that conform to any of the following ignition-resistant construction standards: 1) construction materials that are fire-resistant in accordance with nationally-recognized testing standards, 2) construction materials that are non-combustible, and 3) construction materials constitute an assembly which has a minimum 1-hour fire-resistant rating.
- b. Installation of ignition resistant wall components (fascia, ceramic windows, window glazing, doors, window frames and insulation) that conform to any of the following ignition-resistant construction standards: 1)

construction materials that are fire-resistant in accordance with nationally-recognized testing standards, 2) construction materials that are non-combustible, and 3) construction materials constitute an assembly which has a minimum 1-hour fire-resistant rating.

- c. Protection of propane tanks or other external fuel sources
- d. Purchase and installation of external, structure-specific water hydration systems (external sprinklers) where a dedicated power source and dedicated cistern if no water source (e.g., lake, river, swimming pool) is available. To be considered, supporting documentation must include an operations and maintenance plan with assurances that a system (e.g. GIS) will be maintained to identify property addresses with wildfire sprinkler systems and made available to the appropriate fire department.

### **3. Hazardous Fuels Reduction Activities**

Defined as the removal of vegetative fuels adjacent to the at-risk structure that, if ignited, pose significant threat to human life and property, especially critical facilities. Eligible activities include community level vegetation management, vegetation removal, vegetation clearing or thinning, slash removal, vertical clearance of tree branches to reduce the threat to human life and structures. Such activities must be within 2 miles of structures to be protected, and may employ the following techniques:

- a. Chemical treatments, including herbicide applications with appropriate safeguards to ensure protection of the life, environment, and watersheds;
- b. Grazing or biomass conversion;
- c. Mechanical treatments such as disking, mulching, grinding, mowing, chopping and removal of such material; material left on site must meet appropriate depth practices;
- d. Biomass removal including clearing straw, dead or dry vegetation, thinning, removal of brush, pine straw or blown-down timber from wind throw, ice, or a combination thereof; and
- e. Other industry-accepted techniques at FEMA's discretion.

## **Problem Statement 2: Wildfire Hazard Data**

Several wildfire hazard data inputs (i.e., sample area size, acres burned and length of burn history) were used in the 2006 version of the Wildfire Module to determine the burn recurrence interval. However, the wildfire guidance on the 2006 FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) did not provide enough information on how to determine what is an appropriate sample area, nor does it define what is credible documentation for areas of "similar" fire hazard.

## **Methodology to Address Problem Statement 2**

Based on the expert panel discussion and further research, the methodology employed to address Problem Statement 2 was to use the "USGS / USDA LANDFIRE Simulated Historical Mean Fire Return Interval (MFRI)" data set to determine the Burn Recurrence Interval (BRI).

The Wildfire Module was developed to determine the BRI using the MFRI data, for the project area once the applicant enters the project area zip code. Refer to the Wildfire Risk Summary document in Appendix A for further details. The Wildfire Module also allows the user to override the default BRI using the MFRI data with a user-entered BRI value when accompanied by appropriate supporting documentation. Sources of appropriate supporting documentation for a user-entered BRI may include data from the following sources:

- o USDA Forest Service or other qualified agency
- o State and local fire hazard maps
- o Federal, State or local fire-fighting agency that fights wildfires
- o Forester or qualified timber company representative

### **Problem Statement 3: Loss Estimation**

Pre-mitigation damages in the Wildfire Module are determined based on a loss estimate of the total value of the assets and other costs (i.e., building value, contents value, infrastructure, timber value, fire suppression costs, other) as well as the value of deaths and injuries. The wildfire guidance on the 2006 FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) did not provide enough information on how to determine the value of the assets and other costs.

### **Methodologies to Address Problem Statement 3**

The following methodologies were employed to address Problem Statement 3 to improve the guidance on how to determine the various loss estimate inputs in the Wildfire Module:

1. **Building replacement value** should be the total building replacement value of the structures located in the area protected by the mitigation measure. The methodology for determining the total building replacement value should be consistent with how building replacement value is determined in the other BCA modules.
2. **Contents replacement value** should be determined as a standard percentage of the building replacement value, consistent with the methodology developed for the other BCA modules.

3. **Infrastructure value** should be the value of infrastructure within the proposed project area that can be potentially damaged or destroyed by wildfire. The narrative summary in the BCA module should include the reasoning used to determine the amount of infrastructure at risk before mitigation and be documented in a letter or other communications from a credible agency such as a power company, telecommunications company, or water authority.
4. **Timber value** should be the value of marketable lumber within the proposed project area that can be potentially damaged or destroyed by wildfire. The narrative summary in the BCA module should include the reasoning used to determine the amount of timber at risk before mitigation and be documented in a letter or other communications from a credible agency/organization such as the US Department of Agriculture, the county or state forester or private company with timber rights in the project area.
5. **Fire suppression costs** should be the average cost to fight one typical fire in the project area. These costs must be documented in a letter or other communications from a credible agency/organization such as the county or state forester.
6. **Other costs** that may be included in the analysis should include at-risk cultural resources. Documentation should include a narrative of what assets are being protected and how a value has been assigned; documentation must come from a credible source.

#### **Problem Statement 4: Effectiveness of Mitigation Measures**

The effectiveness of a mitigation measure refers to the percent reduction in damages, losses, and casualties. A 100% effective project would represent 100% reduction in damages or zero risk of burning. The wildfire guidance on the 2006 FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) did not provide enough information on how to determine the effectiveness of mitigation measures. There were no standard values or other guidance on effectiveness of proposed mitigation measures. The *Guidance for Wildland/Urban Interface Fire Mitigation Projects* on the 2006 BCA Toolkit CD provided ranges for various types of mitigation measures, but was not definitive. In addition, no guidance was provided on how to determine effectiveness for projects that include a combination of mitigation measures (i.e., vegetation management and defensible space).

#### **Methodologies to Address Problem Statement 4**

The methodology employed to address Problem Statement 4 to improve the guidance on the effectiveness of mitigation measures is summarized in Table 1 below and programmed into the Wildfire Module software.

**Table 1. Estimated Effectiveness of Wildfire Mitigation Projects**

<b>Mitigation Project Type(s)</b>	<b>Estimated Project Effectiveness</b>
Defensible Space only	10%
Hazardous Fuels Reduction only	10%
Ignition-Resistant Materials only	0% (not permitted by FEMA Wildfire Policy without documentation of Defensible Space already in place)
Defensible Space + Hazardous Fuels Reduction	20%
Defensible Space + Ignition-Resistant Materials	20%
Defensible Space + Hazardous Fuels Reduction + Ignition-Resistant Materials	30%
Ignition-Resistant Materials + Hazardous Fuels Reduction	10% (Ignition-Resistant Materials not permitted by FEMA Wildfire Policy without Defensible Space)
Other	To be input by user (supporting documentation required; limited to a maximum value of 45%)

The methodology employed to address Problem Statement 4 was based on the following information:

- 1) An understanding of project effectiveness of active and passive mitigation measures that protect against various natural and human-caused hazards. Active measures require human intervention – such as fire suppression - for full

effectiveness; while passive measures do not. Past experience has shown that very few projects are 100% effective at reducing all future damages (except for acquisition and demolition or existing structures), and that passive mitigation measures are generally more effective than active measures at reducing damages.

- 2) Information shared by participants in the April 2008 expert panel working session indicated that the two measures that are typically the most effective at reducing WUI fire damages are ignition-resistant roofing materials and vegetation management around buildings.
- 3) Telephone discussions with California Fire official Dave Sapsis indicated that vegetation management can help protect against a WUI fire approaching a building; while ignition-resistant building materials can help reduce the chance of ignition once the fire reaches a building.
- 4) Discussions with officials of the State of California's Office of Emergency Services (OES).
- 5) Eligible wildlife mitigation activities discussed in FEMA's Wildfire Mitigation Policy for the Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) Program (Mitigation Policy MRR-2-08-1) issued September 8, 2008.

## **Problem Statement 5: Project Useful Lifetimes**

*Description:* Project useful life is the estimated amount of time (in years) that a mitigation project will remain effective. The wildfire guidance on the 2006 FEMA Mitigation BCA Toolkit CD (Version 3.0, July 2006) did not provide enough information on how to determine the project useful life. There were no standard values or other guidance on project useful life specifically for wildfire mitigation measures other than vegetation management. The *Guidance for Wildland/Urban Interface Fire Mitigation Projects* provided ranges for various types of measures but was not definitive.

## **Methodologies to Address Problem Statement 5**

Based on the expert panel working session held in April 2008, the following methodologies were employed to address Problem Statement 5 and provide improved guidance on acceptable project useful life values.

### **1. Defensible Space Activities**

- a. Grass – 3 months to 1 year (removing/mowing)
  - Depends on geographic location and precipitation (dying grass is the hazard)
- b. Brush – 2 years to 4 years (removing/reducing/thinning)
  - Depends on drought conditions
- c. Surface Fuels /Forest Crown Canopy – 3 years to 20 years (reduce/thin)
  - Assumes a 3-year surface fuel maintenance/treatment program

- Once forest crown is thinned, the surface fuel treatment must be maintained every 3 years; however, re-logging is not necessary on that frequency. Forest crown canopy treatment (logging) is recommended on a 20-year cycle.
2. **Ignition-Resistant Construction Activities:** to be documented by subapplicant using recommendations from manufacturers of ignition-resistant roof or building materials. These may be based on warranties.
  3. **Hazardous Fuel Reduction Activities**
    - a. Grass – 3 months to 1 year (removing/mowing)
      - Depends on geographic location and precipitation (dying grass is the hazard)
    - b. Brush – 2 years to 4 years (removing/reducing/thinning)
      - Depends on drought conditions
    - c. Surface Fuels /Forest Crown Canopy – 3 years to 20 years (reduce/thin)
      - Assumes a 3-year surface fuel maintenance/treatment program
      - Once forest crown is thinned, the surface fuel treatment must be maintained every 3 years; however, re-logging is not necessary on that frequency. Forest crown canopy treatment (logging) is recommended on a 20-year cycle.

## Appendix A: Wildfire Risk Summary

### Wildland Fire Return Interval: Proposed Recommendations

#### 1. Wildfire Burn Recurrence Interval

Based on the expert panel discussion and further research, we recommend that the preferred data set used to calculate the Burn Recurrence Interval (BRI) be the "USGS / USDA LANDFIRE Simulated Historical Mean Fire Return Interval (MFRI)" data set.

It was determined that the "Wildland Fire Risk to Flammable Structures (WFRFS)" national data set derived by Menakis et al. at the USDA Forest Service may do a better job of calculating the overall risk of structures burning in an area due to the inclusion of population density. However, the BCA module requires a fire return interval for cost calculations, and this required data is not part of the WFRFS data set. We believe that the MFRI data, when used in conjunction with the population data supplied during the grant application process, should allow for a consistent, relative risk to be calculated for each grant application in the same standardized manner as for the other BCA components.

#### 2. LANDFIRE Background

LANDFIRE, also known as the Landscape Fire and Resource Management Planning Tools Project, is a vegetation, fire, and fuel characteristics mapping project managed by both the USDA Forest Service and DOI and represents the first nationwide mapping effort of its kind.

LANDFIRE data products are designed to facilitate national- and regional-level strategic planning and reporting of wildland fire and resource management activities and can be adjusted by users for more local applications. LANDFIRE meets agency and partner needs for data to support large landscape fire management planning and prioritization, community and firefighter safety, effective resource allocation, and collaboration between agencies and the public. LANDFIRE methods are repeatable and consistently applied across the nation, and products will be updated and maintained into the future.

LANDFIRE's data products assist in:

- Identification of areas across the nation at risk associated with accumulation of hazardous fuel
- Prioritization of national hazardous fuel reduction projects
- Improved coordination between agencies with regard to fire and other land resource management

The Simulated Historical Mean Fire Return Interval (MFRI) was published in 2006 by the US Forest Service, and quantifies the average number of years between fires under the presumed historical fire regime.

The MFRI was derived from vegetation and disturbance dynamics simulations using the LANDSUM landscape succession and disturbance dynamics model.

LANDSUM simulates fire dynamics based on:

- vegetation dynamics
- topography
- spatial context
- dynamic wind direction and speed
- frequency of extremely dry years
- landscape-level fire size characteristics

MFRI is calculated from the simulation length divided by the number of fires that were measured on each pixel. The simulations were 10,000 years in duration to observe the most complete representation of the fire regime characteristics within spatially complex landscapes, given computational limitations.

Simulated historical mean fire return intervals were classified into 22 categories of varying temporal length (shown below) to preserve finer detail for more frequently burned areas and less detail for rarely burned areas.

Category	Return Interval (Years)	Category	Return Interval (Years)
1	0-5	12	61-70
2	6-10	13	71-80
3	11-15	14	81-90
4	16-20	15	91-100
5	21-25	16	101-125
6	26-30	17	126-150
7	31-35	18	151-200

8	36-40	19	201-300
9	41-45	20	301-500
10	46-50	21	501-1000
11	51-60	22	>1000

Additional data layer values were included to represent Water (111), Snow / Ice (112), Barren (131), and Sparsely Vegetated (132). Vegetated areas that never burned during the simulations were included in the category "Indeterminate Fire Regime Characteristics" (133); these vegetation types either had no defined fire behavior or had extremely low probabilities of fire ignition.

Values 111, 112, 131, 132, and 133 were reclassified to Category 22 (>1000 year return interval), as the probability of them burning was deemed to be extremely low.

### 3. Scale of Study / Data Aggregation

With regard to the scale of the analysis, several suggestions were made during and following the panel discussion. The suggestions and their foreseen pros and cons have been aggregated as follows:

- a) Zipcode
  - i. Pro – publically known for all areas
  - ii. Con – may change over time
- b) County
  - i. Pro – publically known for all areas
  - ii. Pro – will not change over time
  - iii. Con – doesn't follow any geographic boundaries
- c) Watershed (HUC 4 level)
  - i. Pro – will not change over time
  - ii. Pro – follows geographic boundaries
  - iii. Pro – look-up table between zipcode and watershed and/or county and watershed is do-able
  - iv. Pro – watershed scale would be favorable to authors of data, as it will allow the aggregation of risk values
- d) Township/Range
  - i. Con – publically not known for all areas
- e) Lat/Long
  - i. Pro – required for all permit applications
  - ii. Con – not easy to transpose Lat/Long info into aggregated risk value (would need a very large look-up table for every lat/long risk value combination)

- f) Census tract / block
  - i. Con – publically not known for all areas, would need a look-up table
  - ii. Con – doesn't follow any geographic boundaries
  - iii. Con – variable in size depending on population density
- g) Tax rate area
  - i. Con – publically not known for all areas
  - ii. Con – doesn't follow any geographic boundaries
  - iii. Con – variable in size depending on state zoning

It is our recommendation to use zip codes as the proposed scale of study and data aggregation for the Wildfire Module. Lookup tables between zip codes and watersheds (or counties and watershed if zip code is not found) will be relatively easy to produce if needed for future updates to the Wildfire Module.

### **Summary**

In summary, we propose that the LANDIFRE data (MFRI) be used to calculate burn recurrence intervals (BRI), and aggregate the BRIs based on zip code. Lookup tables by zip code will relate the area of interest to the BRI. This will help FEMA determine the suitability of the proposed actions as outlined by the grant application.