Proposed Wildfire Methodology for Risk and Resilience Assessments

Jenyl L. Meszaros and C. David Binning, P.E.

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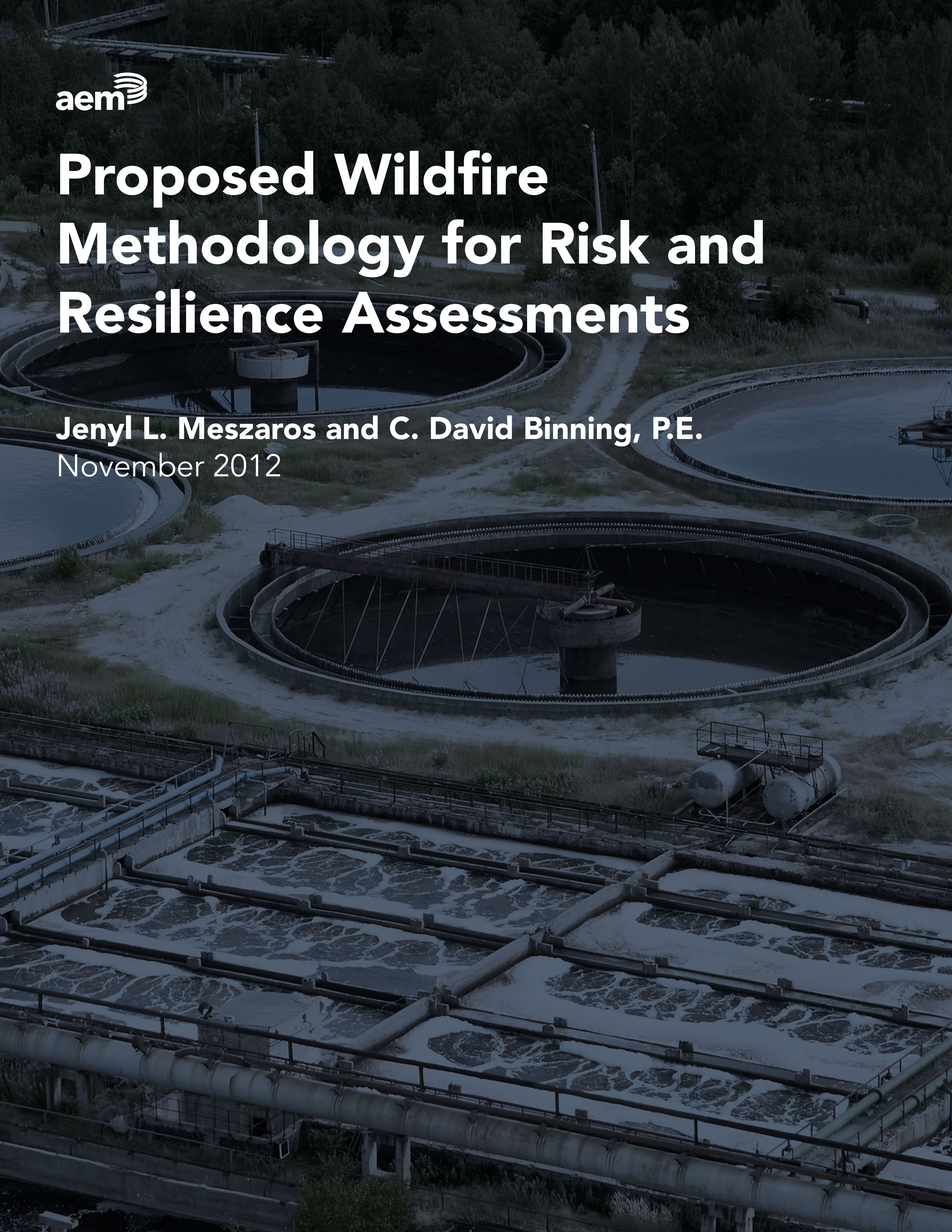

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Introduction

Natural hazards (threat) are a constant concern for water sector security and risk managers. The publication of the ANSI/AWWA J100-10 Standard for risk and resilience using the RAMCAP approach, provided recommended methodologies for assessing a number of these threats as they pertain specifically to the water sector. The Standard provides approaches to determine a utility's risk for hurricanes, tornadoes, floods, and earthquakes in its non-mandatory appendices. The standard also recommends that a utility assess its risk to ice storms and wildfires, but provides no guidance. This paper provides a recommended methodology that is both duplicable and easy to use for a J100 assessment team to determine the risk that facility has to the effects of a wildfire.

BACKGROUND

Wildfires are common in parts of the country, especially west of the Rocky Mountains. Industry consensus has determined that in many cases the immediate effect of these fires to the water sector is minimal as the typical wildfire is a fast moving conflagration that sweeps across the system with little direct damage. The lack of trees on the plant site deny the fire a burn-path and the types of structures on a facility's property tend to be only superficially damaged by these types of fires. On the other hand, the long-term effects from these fires can be very serious for the utility owner/operator. Contamination of the watershed can cause intake clogging, treatment problems and finished water quality issues.

One distinguishing feature of the RAMCAP approach to a risk assessment is the definition of risk as the product of consequences, vulnerability, and threat likelihood (R = C x V x T). To understand the risk that a water-sector asset has for a given threat, the consequences of a successful attack, vulnerability to the attack, and likelihood of the attack occurring must be understood. To evaluate the risk from the threat of wildfires to the water sector, parameters based on demonstrated outcomes are needed. The return period of wildfires provides an indicator of the threat likelihood. The incremental cost increase to operate in the aftermath of a wildfire forms the basis for the consequences. Finally the vulnerability system's assets to wildfire impacts determines whether and to what degree the asset will be affected by defined types of consequences. The product of these values forms the risk for this threat.

The approach advocated here to analyze the risk to wildfires, uses two separate categories: minor wildfires and major wildfires. Minor wildfires are those characterized as consuming an area between 0.01 and 10 km^2, while major wildfires will be those consuming an area of greater than 10 km^2 (Malamud et al.). This is similar to the graduated scales of hurricanes and earthquakes and will require two separate sets of calculations.

THREAT LIKELIHOOD

The likelihood of a wildfire occurring is based on historical data. The US Forest Service uses Bailey's ecoregion divisions as an accurate depiction of the ecoregions in the US. These ecoregions are based on certain climate, vegetation, and soil characteristics common to the areas. Figure 1 depicts Bailey's ecoregions. The regions with a prefix of "M" are noted as mountainous regions.

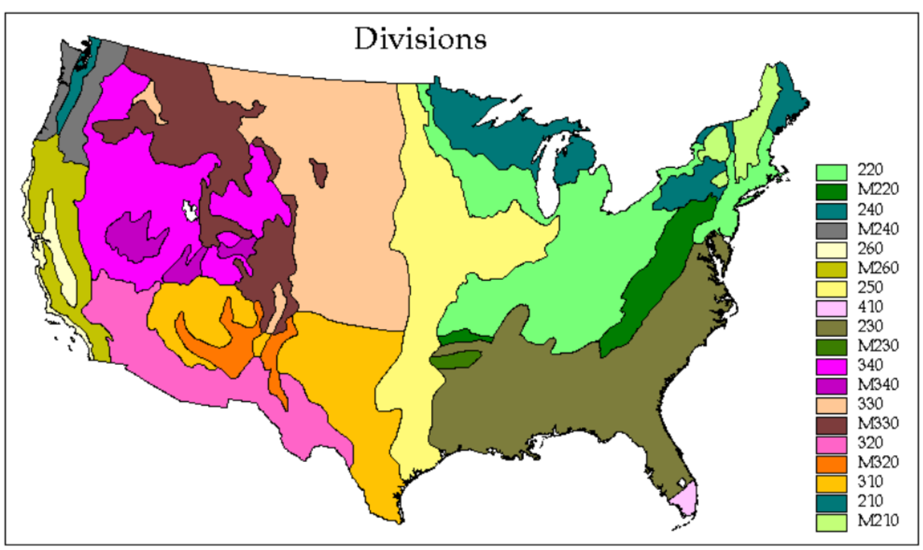

Figure 1. US Ecoregions (USFS)

In 2005, Bruce Malamud, James D. A. Millington, and George L. W. Perry characterized wildfires in the US based on these ecoregions. One of the factors that they were able to determine was the number of major and minor wildfires that occur in each region per year. Table 1 shows each of these regions, their areas, and occurrences.

Ecoregion Division Name	Ecoregion Division Code	Ecoregion Division Area, sq. km	Minor WF Occurrences per year	Major WF Occurrences per year
Hot Continental	220	969,955	0.19	34
Hot Continental Mountains	M220	192,955	0.30	55
Marine	240	38,591	0.79	23
Marine Mountains	M240	138,300	2.47	100
Mediterranean	160	88,319	0.22	2
Mediterranean Mountains	M260	241,388	0.51	13
Prairie	250	772,597	0.28	9
Savanna	410	20202	0	0
Subtropical	230	1,064,749	0.12	33
Subtropical Mountains	M230	22,792	0.24	32
Temperate Desert	340	689,458	0.85	13
Temperate Desert Mountains	M340	112,924	1.66	27
Temperate Steepe	330	1,099,973	0.89	22
Temperate Steepe Mountains	M330	585,081	1.18	36
Tropical/Subtropical Desert	320	441,811	0.29	8
Tropical/Subtropical Steepe	310	654,341	0.40	20
Tropical/Subtropical Steepe Mountains	M310	130,018	0.41	18
Warm Continental	210	381,507	1.70	203
Warm Continental Mountains	M210	112,924	13.64	1,672

Table 1. Characterizing wildfire regimes in the United States. (Malamud et al.)

The threat likelihood is the probability that a wildfire will occur within the facility's watershed in a timeframe of one year. The entire watershed is considered the affected area due to water quality (WQ) issues that will occur at the treatment plant due to the fire occurring elsewhere in the watershed. Threat likelihood for a wildfire is therefore given as:

$$T = \frac{A_w}{A_e} * \frac{1}{t_e}$$

Where,

T = threat likelihood
A_w = Area of the watershed that the facility obtains its source water from and the facility's assets are located on, in km_2
A_E = Area of the ecoregion (found in Table 1), in km^2
t_E = Time between fires (found in Table 1), in years.

This calculation will be completed twice, once for minor wildfires and the other for major wildfires, with t_E being the only difference between the two. Please see the end of this document for an example calculation.

VULNERABILITY

For use in a J-100-10 assessment, the vulnerability of a water utility to wildfires is broken down into several categories. These include power loss, asset loss, water quality/treatment issues, and system pressure losses. To capture the significance of each of these consequences, a group of six questions was created. These questions evaluate the vulnerability of the asset to each area of interest, and then a final vulnerability value is derived based on the answers to those questions. There are three potential answers to each of the questions as shown in Table 2:

Value	Meaning
0	There is no impact to the asset
0.5	There is some impact to the asset
1	There is total impact to the asset

Table 2. Value scale for wildfire impact questions.

The questions used to determine the vulnerability of an asset are:

(1) Will the asset lose power? If the asset was in the path of a wildfire it could be susceptible to a commercial power loss. This power loss would render the asset ineffective until power is restored. Suggested guidelines for answering this question include:

- 0: if the asset has no threat of losing commercial power because it uses no electricity or has sufficient back-up generation on-site to last until power is restored.
- 0.5: if the asset could/will lose commercial power and there is some back-up generation on-site to last a short amount of time, but would not be sufficient if commercial power is not restored quickly.
- 1: if the asset will lose commercial power and there is no back-up generation on-site. The asset will remain inoperable until commercial power is restored.

(2) Will access to the asset be lost? Although a facility may be able to easily repair an asset that is damaged by a wildfire, gaining access to that asset may be limited or blocked due to the fire or other damage. For example, a field pump needs to be repaired, but the roads surrounding it are closed due to the wildfire. Suggested guidelines for weighting this question include:

- 0.0: there are multiple routes to the asset that would not be affected by a wildfire.
- 0.5: there are multiple routes to the asset, but they may be affected by the fires, rendering them impassable
- 1.0: there is only 1 route to the asset and it could be closed due to a wildfire.

(3) Will the asset need to be replaced? This question measures the vulnerability to the fire itself. Due to the location or materials that a water facility owns, many assets may not be vulnerable to immediate fire damage. Suggested guidelines for weighting this question include:

- 0: The asset is buried (underground piping), comprised entirely of materials that do not burn, or has been completely safeguarded against a fire through other protection measures.
- 0.5: The asset would incur some damage from the fire, but would not need complete replacement.
- 1: The asset would need to be replaced due to extensive damage from the fire.

(4) Will the source water be lost? Suggested guidelines for weighting this question include:

- 0.0: if there is no significant change in the quality or quantity of the source water in the first year following the fire.
- 0.5: if either the quantity or quality of the source water requires a significant increase in treatment time resulting in the inability of the plant to meet its peak demand.
- 1.0: if either the quantity or quality of the source water will not permit the plant to meet its rated average summer day production.

(5) Will the system demand to fight the fires cause you to lose system pressure? Firefighters may place unusually high, multiple demands on the system for an extended period of time to fight a wildfire within the service area. This question ascertains whether the system pressure will drop to dangerously low levels due to this extra use by the firefighters. Suggested guidelines for weighting this question include:

- 0.0: if the system is generally able to meet anticipated increased fire flow demands without endangering other users on the system
- 0.5: if the additional demand will adversely impact some of the service area but not all
- 1: if the additional water used will cause system pressures to drop below state minimum pressure standards (typically 20 psi).

(6) Will the wildfire result in significantly increased operating cost for this asset? Wildfires create a host of issues for a water treatment facility for many years after the fire until the burned area recovers. The long term treatment effects of a wildfire could cause the facility to increase the need for chemicals, increase treatment time, or decrease the capacity of the plant. Suggested guidelines for weighting this question include:

- 0.0: if there is anticipated to be only minor additional long term operating costs as a result of the fire.
- 0.5: if there is anticipated to be some additional treatment costs, but none that would severely impact the treatment process or output of the facility.
- 1.0: if a significant increase in treatment cost is anticipated with daily treatment capacity limited or the facility can no longer operate.

Once these questions are evaluated, the average of the values determines the overall vulnerability of the asset to wildfires.

CONSEQUENCES

The consequences to the facility owner from a wildfire are an accumulation of many factors the sum of the individual losses. The potential financial consequences include:

Cost of asset replacement. This is the dollar value of the asset if it would need to be completely replaced.

Lost income due to the time required to replace the asset. This is the dollar value of income lost (time * MGD lost * $/MGD) because the asset is unusable due to needed repairs/replacement. This includes the time to order, access, and repair/replace the asset.

Lost income due to power loss. This is the dollar value of income lost (time * MGD lost * $/MGD) because the asset is unusable due to a loss of commercial and any on-site back-up power.

Cost of additional treatment needed over the next year. This value describes the additional cost of chemicals, filters, etc. that would be needed through the year of operation after the wildfire to continue to provide water at current quality standards.

Lost income due to lower productivity from additional treatment. If the wildfire is severe enough to require significant amounts of additional treatment time, the treatment capacity of the plant could be decreased. This could cause water shortages to the served area. The lost income due to this decreased capacity and ability to serve customers is accounted for in this value.

Loss of human life. As used in this and all other J-100-10 consequence analyses include the loss of life of water system people and any loss of life directly caused by the loss of water service.

Serious injuries. As used in this and all other J-100-10 consequence analyses include the serious injury of water system people and any serious injury directly caused by the loss of water service.

TOTAL RISK

The total risk (R) of an asset that is affected by a wildfire is the product of the consequences (C_{Mi}), vulnerability (V_{Mi}), and threat likelihood (T_{Mi}) for minor wildfires plus the product of the consequences (C_{Ma}), vulnerability (V_{Ma}), and threat likelihood (T_{Ma}) for major wildfires. The equation depicting this is:

$$R = (C_{Mi} * V_{Mi} * T_{Mi}) + (C_{Ma} * V_{Ma} * T_{Ma})$$

EXAMPLE

Asset: Field Pump
Location: Denver, CO
Ecoregion: M330- Temperate Steepe Mountain

<u>Minor Wildfire:</u>

Threat Likelihood

T_{Mi} = (90,000/585,081)* 1/1.18
T_{Mi} = 0.13036

Vulnerability

Will the asset lose power?	1.0
Will you lose access to the asset?	0.5
Will you need to replace the asset?	0.5
Will you lose the Source Water?	0.0
Will the system demand to fight the fires cause you to lose system pressure?	0.5
Will you require additional water treatment through this asset?	0.0

V= 0.416

Consequences

Cost of asset replacement, if applicable	$650,000
Lost income due to time to replace asset, if app.	$5,000
Lost income due to power loss, if app.	$10,000
Number of Lives Lost	0
Stat value of a life	$6,200,000
Number of Serious Injuries	0
Stat value of serious injury	$651,000
WQ Issues	
Cost of additional treatment needed over the next year, if app.	$0
Lost income due to lower productivity from additional treatment, if app. C	$0

C= $665,000

Risk = $665,000 * 0.416 * 0.13036

R = $36,063

Major Wildfire:

Threat Likelihood
T_{Mi} = (90,000/585,081)* 1/36
T_{Mi} = 0.00427

Vulnerability

Will the asset lose power?	1.0
Will you lose access to the asset?	0.5
Will you need to replace the asset?	0.5
Will you lose the Source Water?	0.0
Will the system demand to fight the fires cause you to lose system pressure?	0.5
Will you require additional water treatment through this asset?	0.0

V= 0.416

Consequences

Cost of asset replacement, if applicable	$650,000
Lost income due to time to replace asset, if app.	$5,000
Lost income due to power loss, if app.	$12,000
Number of Lives Lost	0
Stat value of a life	$6,200,000
Number of Serious Injuries	0
Stat value of serious injury	$651,000
WQ Issues	
Cost of additional treatment needed over the next year, if app.	$0
Lost income due to lower productivity from additional treatment, if app. C	$0

C= $667,000

Risk = $667,000 * 0.416 * 0.00427

R = $1,185

Total Risk = $36,063 + $1,185 = $37,248

SOURCES

Malamud, Bruce, James D.A. Millington, and George L.W. Perry. "Characterizing wildfire regimes in the Unites States." National Academy of Sciences. 102.13 (2005): 4694-4699. Print. <http://www.pnas.org/content/102/13/4694.full.pdf>.

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