## Wildfire

A wildfire occurs within the U.S. resulting in direct economic losses greater than $100 Million.

### Data Summary

In the following table, note that the low and high likelihoods do not correspond to the low and high impacts. In addition, low and high impacts are not necessarily correlated with each other between different impact categories.

| Category | Description | Metric | Low | Best | High |
|---|---|---|---|---|---|
| Health and Safety | Fatalities | Number of Fatalities | 0 | 5 | 25 |
| | Injuries and Illnesses | Number of Injuries or Illnesses | 0 | 63 | 187 |
| Economic | Direct Economic Loss | U.S. Dollars (2011) | $104 Million | $900 Million | $2.8 Billion |
| Social | Social Displacement | People Displaced from Home ≥ 2 Days | 770 | 110,000 | 640,000 |
| Psychological | Psychological Distress | Qualitative Bins | See text | | |
| Environmental | Environmental Impact | Qualitative Bins[1] | High[2] | | |
| LIKELIHOOD | Frequency of Events | Number of Events per Year | 0.2 | 0.8 | 3 |

### Event Background

Since 1970, wildfires have destroyed more than 10,000 homes and 20,000 other structures across the nation. Fire suppression has cost government agencies in excess of $20 billion and the insurance industry $6 billion in restitution.[3] Severe wildfire events have the potential to create great economic losses—from hundreds of millions of dollars to the three California wildfires in 1991, 1993, and 2003, each of which caused damages greater than $2 billion.[4]

Wildfires are a frequent event in the United States: some 1,570,000 wildfires were reported for the 20 year period 1990-2009, consuming a total of 94,000,000 acres[5] and 110 human lives.[6] Only a small proportion of these are large enough to overwhelm local fire-fighting capabilities.[7] Although the vast majority of large wildfires occur in sparsely populated regions of the United

[1] The United States Environmental Protection Agency (EPA) convened an ad hoc group of environmental experts representing the fields of environmental science, ecological risk, toxicology, and disaster field operations management to estimate environmental impacts for this event. The comments and rankings presented in this Risk Summary Sheet have not undergone review by the EPA and only represent the opinions of the group. Estimates pertain to the potential for adverse effects on living organisms associated with pollution of the environment; they are grouped into high, moderate, low, and de minimus (none) categories.

[2] Experts provided both first and second choice categories, allowing the experts to express uncertainty in their judgments as well as reflect the range of potential effects that might result depending on the specifics of the event. The first choice represents the 'Best' estimate.

[3] Zane et al. for National Center for Environmental Health. 2007. Wildfire-related deaths—Texas, March 12-20, 2006. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5630a1.htm.

[4] See Table 1.

[5] As compiled from National Interagency Fire Center, Total Wildland Fires and Acres (1960-2009), http://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html.

[6] As compiled from the SHELDUS database http://webra.cas.sc.edu/hvriapps/sheldus_setup/sheldus_login.aspx.

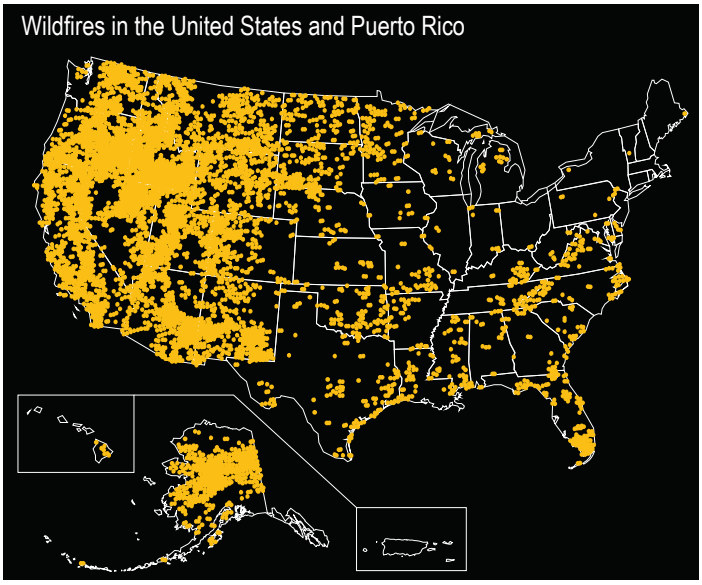
[7] Brush, Grass, and Forest Fires. Ahrens, Marty, 2010, National Fire Protection Association, pp 11, 15: http://www.nfpa.org/assets/files//PDF/OS.BrushGrassForest.pdf; analysis of SHELDUS database.

States—a disproportionate share of the very largest wildfires by acres burned occur in Alaska[8]—it is at the "wildland/urban interface," where the wilderness meets new urban and suburban areas of high population densities, that the wildfires of greatest destructiveness in terms of human life and economic damage occur.[9] Overall, although wildfire frequency has decreased in the last 200 years, the severity of wildfires has increased, and the overall risk to life and property of wildfires in the U.S. is increasing.[10] In particular, the frequency and economic costs of the very largest wildfires considered here show a sharp increase around 1990.[11]

For even the most catastrophic wildfires in the United States, the numbers of dead and injured tend to be relatively small. No wildfire causing human deaths on a catastrophic scale in the United States has occurred since 1918, when a brush fire engulfed 38 towns across Minnesota, killing 450 people.[12] Since then, the largest death tolls have not numbered more than 30 from a single incident—for the majority of massive wildfires in recent decades, potentially affected populations receive sufficient advanced warning that no human deaths occur.

The health risk of wildfires is largely dependent on the population in the impacted area as well as the speed and intensity with which the fire moves through those areas.[13] Wildfires can increase eye and respiratory illnesses related to fire-induced air pollution. Wildfires can also result in direct and indirect deaths caused by direct contact with the wildfire or wildfire product (e.g., smoke or superheated air) or from indirect contact with a wildfire product (e.g., smoke that caused poor visibility resulting in a car crash).[14]

**Figure 1. Wildfires Greater than 250 Acres, 1980-2003[15]**




[8] National Interagency Fire Center, 1997-2009 Large Fires (100,000+ acres), http://www.nifc.gov/fireInfo/fireInfo_stats_lgFires.html.
[9] Fires in the wildland/urban interface, U.S. Fire Administration 2002, at http://www.usfa.dhs.gov/downloads/pdf/tfrs/v2i16.pdf; quoting Ainsworth et al, Natural History of Fire and Flood Cycles, University of California-Santa Barbara 1955, and 'History of fire', National Park Service.
[10] Wildfire hazards – a national threat. Fact sheet 2006-3015, U.S. Geological Survey, Department of the Interior, 2006; available at http://pubs.usgs.gov/fs/2006/3015/2006-3015.pdf.
[11] Analysis of SHELDUS database.
[12] National Interagency Fire Center, Historically significant wildland fires: http://www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html.
[13] U.S. Climate Change Science Program. 2008. Analyses of the effects of global change on human health and welfare and human systems: A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Gamble J.L. ed, Ebi et al authors, U.S. EPA.
[14] Zane et al. for National Center for Environmental Health. 2007. Wildfire-related deaths—Texas, March 12-20, 2006. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5630a1.htm.
[15] Wildfire Hazards – A National Threat. U.S. Geological Survey fact sheet 2006-3015, Feb 2006, available at http://pubs.usgs.gov/fs/2006/3015/2006-3015.pdf .

## Assumptions

The estimates provided above are based on historical examples of major wildfires in the United States. The dataset that was considered comprises all wildfires with reported total economic damage of $100 million or greater (in 2011 dollars) which occurred from 1990 to 2009.[16]

### *Fatalities and Injuries*

The SNRA project team used the following assumptions to estimate health and safety impacts caused by a wildfire event:

- In order to produce the summary figures in the "Data Summary," all "Low," "Best," and "High," estimates for human deaths and injuries are calculated from the dataset of catastrophic wildfires selected according to the economic cutoff of $100M minimum (see Table 1). The set chosen by this economic measure captured the range of the scenarios most catastrophic in numbers of dead and injured for all historical wildfires in the United States since 1990. To compute "Low", "Best", and "High" estimates for fatalities and injuries the historical low, average, and high values of the 1990-2009 dataset were used.
- The best-estimate frequency is the average frequency of occurrence of this set of wildfires in the selected twenty-year period. The low frequency is the inverse of the longest time interval between wildfires in this set (in days, measured from fire begin day); the high frequency is the greatest number of fires which occurred in one year (four, in 2006).

### *Economic Loss*

The SNRA project team used the following assumptions to estimate economic impacts caused by a wildfire event:

- Since total monetary losses appeared more representative of the geographic spread of wildfires and the relative difficulty of fighting them than the number of dead and injured, the former were used to select a set of national-level events having the capability to overwhelm local emergency response efforts.
- All "Low," "Best," and "High," estimates are calculated from historical data of property damage and crop damage, comprising all U.S. wildfires between 1990 and 2009 meeting a cutoff of $100 million dollars total cost adjusted to 2011 dollars (Table 1).[17] As the frequency and severity in economic impacts caused by large wildfires were seen to have sharply increased after 1990, the dataset was restricted to this date range to be more representative of present-day conditions.
- Estimates of total losses for wildfires can vary greatly between sources. One of the reasons for this is that different types of economic cost—the cost of suppressing the fire, private property damage, crop damage, costs incurred for environmental remediation, and the indirect business-interruption costs due to lost economic productivity, economic activity, and

[16] As compiled from the SHELDUS database, http://webra.cas.sc.edu/hvriapps/sheldus_setup/ sheldus_login.aspx. SHELDUS breaks down wildfire events into separate counties, and sometimes breaks down single wildfires in the same location into separate fires with overlapping date ranges, dividing casualty and damages between them to avoid double counting. Where this was obviously done (fires reported by counties in the same state having the same time range, or reported in the same city with overlapping or continuously adjacent time ranges) the separately reported portions of a single fire event were consolidated into single events.

All wildfires (after consolidation) above the $100 million threshold in 2011 dollars (a CPI multiplier of 1.0464 was used to convert the December 2009 values given in SHELDUS to May 2011) from 1970 follow after these endnotes. As noted in the "Assumptions" section, only the data points from 1990 on were used for analysis.

[17] Available at http://webra.cas.sc.edu/hvriapps/sheldus_setup/sheldus_login.aspx.

tax revenue—are accounted for or missing from cost tallies for different major wildfires, even within the same source. In general, for the type of wildfire considered here, which has a direct impact on human populations, the total damages enumerable as property and crop damage are substantially larger than the pure costs of suppressing the fire, and also tend to be substantially larger than the second-order indirect costs of lost economic activity and demand due to business interruption, injuries and fatalities, and loss of tax revenue base.[18] Hence the total reported property and crop damages used here for calculating economic loss estimates are believed to capture the dominant portion of the total economic losses from this type of wildfire.[19]

### *Social Displacement*

For the purposes of the SNRA, social displacement was defined as the number of people forced to leave home for a period of two days or longer. Note that there are limitations to this measure of social displacement, as the significant differences between temporary evacuations and permanent displacement due to property destruction are not captured.

To estimate social displacement for the SNRA, U.S. wildfire event data from the international disaster database EM-DAT[20] was used to approximate the number of people forced to leave home for two days or greater. EM-DAT's public interface reports estimates for "total number affected" by disaster events: these data are listed in Table 1 for the seven wildfire events in the main historical data set for which it was available.[21] The low, high, and average of the "total affected" data in Table 1 are used as the social displacement estimates for wildfires in the SNRA.

The "total affected" measure includes the number of people needing immediate assistance, which can include displacements and evacuations; the number of people needing immediate assistance for shelter; and the number of people injured. Because EM-DAT includes injuries in the "total affected" measure, there is potential for double-counting between the SNRA injury and displacement estimates for this event. However, displacement due to wildfires is typically significantly greater than the number of injuries, so using EM-DAT's "total affected" measure was judged to provide an estimate of social displacement of sufficient precision for the SNRA.

### *Psychological Distress*

Psychological impacts for the SNRA focus on *significant distress* and *prolonged distress*, which can encompass a variety of outcomes serious enough to impair daily role functioning and quality of life. An index for significant distress was created that reflected empirical findings that the scope and severity of an event is more important than the type of event. The equation for this

[18] Western Forestry Leadership Coalition 2010. The true cost of wildfire in the western U.S. At http://www.wflccenter.org/news_pdf/324_pdf.pdf. The SHELDUS database attempts to provide some consistency between reports by relying on two U.S. Government sources (the National Climactic Data Center and the U.S. Fire Administration (http://webra.cas.sc.edu/hvri/products/sheldusmetadata.aspx#6), and by including property and crop damage estimates only.

[19] Note that the damages to crops and private property considered here to be direct damages—since they represent the property and crops directly damaged or consumed by the wildfire—are usually referred to as 'indirect' costs in studies of the economic damages of wildfires. This is because 'direct' costs are by convention limited to the cost of fire suppression, and all damage caused by the wildfire is considered as 'indirect' or 'additional' costs (see for instance the reference above).

[20] EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université Catholique de Louvain located in Brussels, Belgium (http://www.emdat.be/frequently-asked-questions), and is supported by the Office of U.S. Foreign Disaster Assistance (OFDA) of USAID (http://transition.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/). See Criteria and Definition, http://www.emdat.be/criteria-and-definition, EMDAT Data Entry Procedures, at http://www.emdat.be/source-entry, and EMDAT Glossary, at http://www.emdat.be/glossary/ for details of criteria, thresholds, and methodology for the EM-DAT database.

[21] In addition to these, the Old Topanga fire had an EM-DAT Total Affected count of 130. This was excluded from the SNRA data set as being either a clear undercount (a fire causing $2 B of damages would be expected to destroy hundreds or thousands of homes) or a count of injuries rather than homeless.

index uses the fatalities, injuries, and displacement associated with an event as primary inputs; a factor elicited from subject matter experts weights the index for differing psychological impact based on the type of event, but as a secondary input.[22] The numerical outputs of this index formula were used to assign events to bins of a risk matrix for a semi-quantitative analysis of psychological risk in the SNRA.

### *Environmental Impact*

The United States Environmental Protection Agency (EPA) convened an ad hoc group of environmental experts representing the fields of environmental science, ecological risk, toxicology, and disaster field operations management to estimate environmental impacts for this event. Estimates are based on the following assumptions:

- Experts were elicited to provide estimates in the environmental impact category based on assumptions. Actual environmental/ecological harm that occurs as a result of the events described in a given scenario may vary considerably, and will depend on numerous variables (e.g., chemical or biological agent, contamination extent, persistence, toxicity—both chronic and acute toxicity—and infectivity).
- EPA defined environmental consequence (impact)[23] as the potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use; or the depletion of natural resources.
- The EPA experts identified the best estimate for environmental impacts as "High." Experts made this estimate given the assumption that the wildfire threatens an "urban U.S. setting," as the fire could envelop oil, chemical, or other hazardous storage tanks and cause widespread release of such materials. However, many wildfires would have low longer-term effects on eco-systems and, in fact, provide longer-term benefits including re-seeding of certain plants and assisting the growth of forested areas. Thus, this scenario could quite conceivably be scored as "Low" or "De Minimus (None)" if the wildfire does not occur in an urban U.S. setting.[24]

## Potential Mitigating Factors

The primary drivers of increased impacts associated with wildfires appear to be the high proportion of new home construction in high-risk regions adjacent to or intermixed with wildlands,[25] long-term changes in forest management practices,[26] and early effects of climate

[22] The Significant Distress Index is calculated from these inputs using a formula proposed by subject matter experts consulted for the SNRA project: $N_{SD} = C_{EF} \times (5\,Fat + Inj + \frac{1}{2}\,D)$, where $N_{SD}$ represents the number of persons significantly distressed, $C_{EF}$ is the expert assessed Event Familiarity Factor, *Fat* is the number of fatalities, *Inj* is the number of injuries and/or illnesses, and *D* is the number of persons displaced (Social Displacement). In words, this formula suggests that there are 5 significantly distressed persons for each life lost; 1 for each person injured; and 1 for each 2 people displaced. This formula was constructed to reflect the empirical finding that the most severe stressor of a disaster is losing a loved one, followed by injury, followed by displacement. Uncertainty was captured by applying the index formula to the low, best, and high estimates of these three human impact metrics.

The Event Familiarity Factor is intended to capture the extent to which the event entails an ongoing threat with uncertainty regarding long term effects, is unfamiliar, or that people dread, exacerbating psychological impacts. This factor, ranging from 1.0 for familiar events to 1.3 for unfamiliar events, was provided by subject matter experts for each national-level event included in the SNRA: wildfires were given a $C_{EF}$ of 1.0.

The numerical estimates calculated from this formula are reported in Appendix G. The semi-quantitative risk matrix is discussed in the Findings (Psychological Distress Risk).

[23] The 2011 SNRA referred to impacts as 'consequences' because of prior usage in quantitative risk assessment (Kaplan and Garrick [1981, March], On the quantitative definition of risk: *Risk Analysis* 1(1) 11-32). Except where it will cause confusion, 'impact' is used synonymously in this document because of pre-existing connotations of the word 'consequence' within FEMA.

[24] The best and second best estimates were switched by the SNRA project team in October 2011, subsequent to the reporting of the SNRA results to FEMA, in response to stakeholder feedback focusing on the longer-term environmental effects associated with the experts' "Low" judgment.

[25] Fires in the wildland/urban interface, U.S. Fire Administration 2002, at http://www.usfa.dhs.gov/downloads/pdf/tfrs/v2i16.pdf; quoting Wildland Fire Preparedness/Education Partnership, Firewise Colorado, February 2001.

change.[27] These three trends most converge in California, where the data show that two-thirds of the most catastrophic (by cost) wildfires of the last twenty years have occurred.[28]

## Additional Relevant Information

The frequency of catastrophic fires, such as those listed in Table 1, depends upon the threshold used to select which fires will be on the list. The economic cutoff of $100M resulted in a set of major wildfires which have occurred with an average historical frequency of slightly less than once per year in the 1990-2009 time period (0.8 per year to be precise). Wildfires causing 500 million dollars or greater in damages occur about one every other year (0.45/year); the most catastrophic wildfires, causing $2 billion or more in damages, occur about one every four years (0.25/year).

**Table 1. U.S. wildfires causing ≥ $100 million in direct economic damages, 1970-2009[29]**

| Begin | End | Location | State | Name (if any) | Fatal | Injured | Total damage (2011 dollars) | EM-DAT Tot.Aff |
|---|---|---|---|---|---|---|---|---|
| 9/25/70 | 9/29/70 | LA/San Diego | CA | Laguna Fire | 9 | 770 | $1,288,741,000 | |
| 8/8/77 | 8/8/77 | Monterey | CA | | 0 | 0 | $1,182,055,000 | |
| 10/20/91 | 10/20/91 | Oakland | CA | Oakland Hills Fire | 25 | 150 | $2,803,063,000 | |
| 10/26/93 | 10/31/93 | Sacramento | CA | | 0 | 89 | $514,587,000 | |
| 10/27/93 | 11/4/93 | Los Angeles | CA | Old Topanga Fire | 6 | 187 | $2,221,587,000 | |
| 5/31/98 | 7/30/98 | Central Florida | FL | | 0 | 150 | $261,731,000 | |
| 7/1/98 | 7/10/98 | Central Florida | FL | | 0 | 65 | $523,462,000 | 40,124 |
| 8/2/98 | 8/30/98 | Chelan | WA | | 0 | 0 | $123,978,000 | |
| 5/4/00 | 5/31/00 | Los Alamos | NM | Cerro Grande | 0 | 0 | $1,966,720,000 | 25,400 |
| 9/29/00 | 9/30/00 | Tehama | CA | | 0 | 0 | $717,197,000 | |
| 6/17/03 | 7/15/03 | Pima | AZ | Rodeo-Chediski Fire | 0 | 0 | $161,404,000 | 1,269 |
| 10/25/03 | 11/5/03 | San Diego | CA | Cedar Fire | 22 | 157 | $2,572,317,000 | 27,104 |
| 3/12/06 | 3/18/06 | Carson | TX | | 12 | 8 | $107,289,000 | |
| 4/11/06 | 4/13/06 | Wheeler | TX | | 0 | 2 | $103,553,000 | |
| 6/24/07 | 6/30/07 | Alpine | CA | Alpine Fire | 0 | 3 | $544,127,000 | 768 |
| 10/21/07 | 10/31/07 | San Diego County | CA | | 10 | 132 | $748,175,000 | 640,064 |
| 11/15/08 | 11/19/08 | Sacramento | CA | | 0 | 0 | $156,960,000 | 55,000 |

[26] Fires in the wildland/urban interface, U.S. Fire Administration 2002, http://www.usfa.dhs.gov/downloads/pdf/tfrs/v2i16.pdf; Westerling et al 2006, Warming and earlier spring increase western U.S. forest wildfire activity, *Science* 313(5789) pp 940-943, http://www.sciencemag.org/content/313/5789/940.full.pdf.

[27] National Academy of Sciences, America's Climate Choices, 2011, p 19, at http://dels.nas.edu/Report/Americas-Climate-Choices/12781; Global Climate Change Impacts in the United States, U.S. Global Change Research Group, p 82, at http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf; Ryan et al, The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States, U.S. Department of Agriculture Synthesis and Assessment Product 4.3 (2008), sections 3.1-3.2, at http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf; Westerling et al 2006, Warming and earlier spring increase western U.S. forest wildfire activity, *Science* 313(5789) pp 940-943, at http://www.sciencemag.org/content/313/5789/940.full.pdf.

[28] For wildfires above $100 M reported total cost.

[29] Dataset used for analysis excluded the two fire events before 1990.