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PERSPECTIVES

Assessing Wildfire Smoke Damage & Understanding Impacts of Wildfire Smoke on Air Quality

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HOW SOUTHERN CALIFORNIA WILDFIRES IMPACT AIR QUALITY, SMOKE DAMAGE, AND INSURANCE COVERAGE

The Southern California wildfires in January 2025 are expected to be one of the costliest natural disasters in United States (US) history, with economic losses currently ranging between $95 billion and $164 billion according to the University of California – Los Angeles (UCLA). Insured losses, according to UCLA, are estimated to be around $75 billion.[1]

Wildfires in Southern California are common. Santa Ana wind events often promote the rapid growth of wildfires even if they have no direct relationship to the origin of the fire. Santa Ana winds— characterized by warm, dry, and often strong winds blowing from the land to the ocean—are a common occurrence each year, primarily during the fall and winter months, and are often marked by increased fire danger.

The January 2025 wildfires in the Los Angeles area were no exception to this rule; powerful Santa Ana winds, critical-to-extreme fire weather conditions, and severe drought were all in place during early January across the region. This followed many months of below-normal precipitation, which was preceded by a rainy 2023-2024 winter season and an even rainier 2022-2023 rainy season. Ultimately, these heavy rain events associated with winter storms and atmospheric rivers were followed by an extended drier-than-normal period leading up to January 2025.

In this paper we discuss the threat of wildfires, especially as it concerns the state of California, the damage that wildfires and wildfire smoke can cause, how smoke damage is assessed and remediated, and the impacts to air quality during and following wildfire events. The following information may be of particular interest to insurance companies, lawyers, industry, and the public.

WILDFIRE PROPERTY DAMAGE & SMOKE DAMAGE

Wildfire Behavior, Smoke Dispersion, and Contributing Environmental Factors

Put simply, wildfires are the large-scale, uncontrolled burning of natural vegetation and other materials/fuels such as structures and building materials, electrical equipment and components, vehicles/engines/machinery, or chemicals. They produce intense heat and updrafts which disperse particulate matter (PM) into the air which can then travel great distances. These fires and the smoke they produce are influenced by three primary factors—the preceding and concurrent weather, the current phase of the fire, and the topography of the immediate and surrounding land. High winds, for instance, can affect the speed and intensity with which wildfires spread and determine where and how far away large and small particles (mainly solids like char and ash but also liquid and gas particles) within smoke settle. The concentration of particle matter can also depend on whether a fire has just begun or whether it is in its smoldering phase, wherein emissions increase due to incomplete combustion.

Naturally, during rainy seasons, vegetation growth is promoted and even enhanced. However, during droughts and dry periods, this vegetation dries, dies, or goes dormant, leaving ample fuel, if left unkept, for wildfire growth, such as the devastation which occurred in January 2025. Once these fires initiate, their spread can be difficult to control due to high wind gusts associated with the Santa Ana winds, especially in elevated and rough terrain. This was particularly the case for both the Palisades and Eaton Fires.

Wildfire Property Damage Insurance Claims

There have been significant increases in wildfire frequency and severity in recent years. In fact, the eight largest

[1] https://www.anderson.ucla.edu/about/centers/ucla-anderson-forecast/economic-impact-los-angeles-wildfires

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recorded wildfires in California have all occurred since 2017. In 2017 and 2018, California saw insured losses in excess of $10 billion, and in 2020 alone, insured losses were estimated between $5-9 billion. Though wildfires have always been a natural threat to the state, California now exists in a continuously heightened state of alert.

Presently, there are more than 2.3 million homes in California with a collective estimated value of $343 billion, placing the state at the top of the list of states with the greatest wildfire insurance risks, with runners-up including Idaho, Arizona, Oklahoma, Arkansas, Utah, Kentucky, Washington, Texas, Oregon, and Colorado.

Meteorology Services in the Event of Wildfires

When it comes to staying up-to-date and ahead of unfolding wildfire events, meteorologists are commonly called upon to perform a variety of specialized services including, but not limited to:

- Identifying wind speeds and directions to assist in understanding the spread of the fire and smoke.
- Identifying inversion and mixed layers for use in estimating smoke concentrations and other matter near the surface, assisting in air quality and other environmental and industrial hygiene investigations.
- Reviewing applicable weather warnings and forecasts in order to understand the forward notice given of wildfire-promoting weather.
- Identifying temperatures, humidity, and other factors which assist in understanding the state of the environment prior to ignition and during the event itself.
- Performing site-specific, in-depth meteorological investigations to assist in insurance claims and litigation.
- Authoring relevant reports for use by loss adjusters and attorneys.

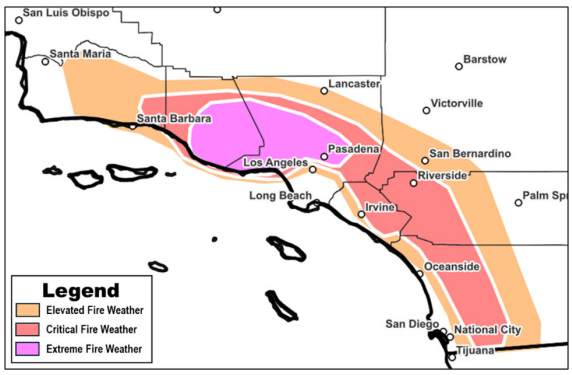

Figure 1 *- National Weather Service Storm Prediction Center forecast for wildfire weather conditions on January 8, 2025.*

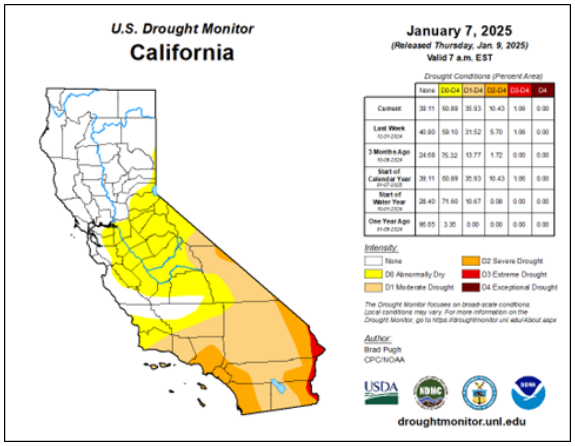

Figure 2 *- U.S. Drought Monitor conditions in California as of January 7, 2025.*

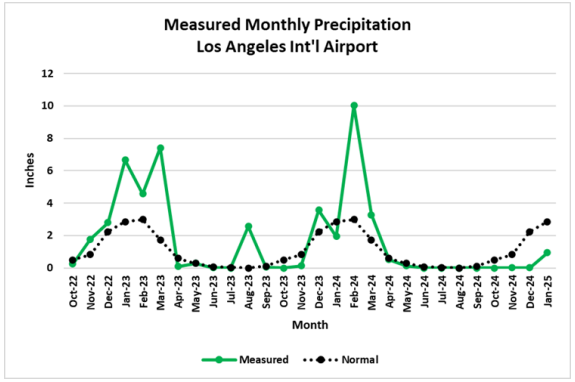

Figure 3 *- Monthly measured precipitation recorded at Los Angeles International Airport between October 2022 and January 2025.*

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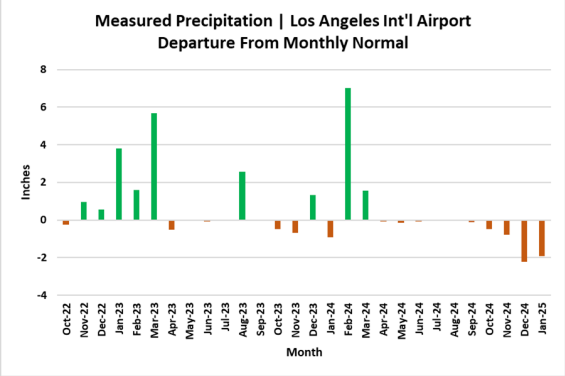

Figure 4 *- Monthly measured precipitation departure from normal monthly precipitation recorded at Los Angeles International Airport between October 2022 and January 2025.*

WILDFIRE SMOKE COMPOSITION, DAMAGE ASSESSMENT, AND REMEDIATION STRATEGIES

Smoke Damage Characteristics from Wildfire Events

Smoke generated by wildfires can take on characteristics based on a number of contributing factors. Generally made up of solid, liquid, and gas particles, smoke can comprise a host of various substances depending on fuel sources, including, but not limited to:

- Ash, char, and soot.
- Unburned or partially burned soil and vegetative particles.
- Fibers, such as asbestos.
- Heavy metals, such as lead.
- Polychlorinated Biphenyls (PCBs).
- Volatile Organic Compounds (VOCs), such as benzene or toluene.
- Semi Volatile Organic Compounds, such as Polycyclic Aromatic Hydrocarbons (PAH).
- Other gases, such as carbon monoxide, carbon dioxide, nitrogen oxides, etc.

Wildfire smoke and the substances composing it are able to travel hundreds and even thousands of miles under the right conditions and can even cross continents. This means that smoke can affect air quality and quality of life in areas far from the actual fire.

The Importance of a Smoke Damage Assessment

Wildfire smoke is capable of impacting property to varying degrees, and thus assessments conducted by experts are necessary when determining the extent to which property has been impacted. Primary indicators tested for include combustion byproducts such as ash and char from vegetative sources (burned pollen, plant parts, phytoliths, and burned soil particles), and "unburned" soil and vegetation particles.

Assessments should include a visual inspection, qualitative residue assessments, and can include sampling with quantitative lab analyses and moisture and mold assessments, as necessary. Inspectors will typically want to examine:

- Exterior horizontal and vertical surfaces.
  - Windowsills.
  - Door thresholds.
  - Eaves.
  - Siding.
  - Roofs.
  - Vents and other openings to interior spaces.
- HVAC equipment and components.
  - Exterior and interior components.
  - Fresh air intake and supply ducts.
  - Filters.
  - Other vents, such as air to air exchanges and dryers.
- Interior horizontal and vertical surfaces.
  - Points of entry, such as windows, doors, and vents.
  - Attic insulation and substrates.
  - Basements or crawl spaces.
  - Garages.
  - Interior structure, cavities, and contents.

Smoke Damage Restoration Process

When investigators sample surfaces for evidence of smoke impact, three primary methods are utilized—micro-

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vacuum sampling, wipe sampling, and tape-lift sampling:

- **Micro-vac sampling** is typically 65% efficient. It is a good method for rough or porous surfaces but does not maintain particle integrity.
- **Wipe sampling** is typically 75% efficient on wet surfaces and 45% efficient on dry surfaces. It is not a great method for rough or porous surfaces and does not maintain particle integrity but is capable of sampling a large area.
- **Tape-lift sampling** is typically 95% efficient. It is good for both porous and non-porous surfaces and maintains particle integrity but sampling area is limited.

When wildfire smoke impact is suspected, and the wildfire has been contained, it is important to evaluate and mitigate as soon as possible as this can help limit particle dispersion. Equally important is verifying proper mitigation as soon as mitigation activities are complete. This helps to validate that the cleaning procedures utilized were effective.

Fortunately, the vast majority of materials, components, contents, and structural elements are able to be salvaged via restoration by appropriate experts following exposure from smoke. Examples of materials that are generally considered as salvageable following assessment by environmental investigators and remediation specialists include:

- Building finishes (if the smoke is pressurized some removal is recommended).
- HVAC equipment and rigid ducts (flex ducts are typically replaced).
- Intact closed-cell foam (other types of impacted insulation should be replaced).
- Layers beneath or obstructed by flooring, siding, and roof assemblies.

AIR QUALITY IMPACTS AND SMOKE DAMAGE FROM WILDFIRE POLLUTION

Wildfires are happening more often[2] and have become a serious issue in North America. Wildfires have the potential to release pollutants such as PM, VOCs, semi-VOCs, heavy metals, and regulated materials.[3,4] These pollutant emissions can significantly impact air quality and negatively impact public health. PM, PM_{10} (particulate matter with diameters that are 10 micrometers and small) and $PM_{2.5}$ (particulate matter with diameters that are 2.5 micrometers and smaller) emissions from the wildland fires (wildfires and prescribed fires) are a major part of wildfire smoke. These wildland fires account for 40% of the country's PM emissions.[5]

In recent years, increasing wildfire activity in the Western US and Canada has impacted air quality in the majority of the US. After the wildfires are extinguished or fully contained, lingering smoke can continue to affect air quality as the fires smolder. The US Environmental Protection Agency's (EPA's) *Exceptional Events Rule*[6] allows the states to exclude certain air quality data that result from exceptional events, such as wildfires from regulatory assessments and decisions. This has raised questions about the accuracy and reliability of air quality data and whether current standards effectively capture the impacts of wildfires. This has created significant challenges for the regulatory requirements under the Clean Air Act (CAA). As wildfires and wildfire smoke increasingly cause air pollution, understanding their impact on air quality and effects on public health has become crucial for policymakers.

Unlike industrial emissions, which are controlled and predictable through technology and regulatory permits, wildfires are influenced by complex factors such as climate change, severe dust storms, forest management practices, and natural variability. During and after the wildfire events, the air quality can experience temporary spikes leading to unsafe levels of $PM_{2.5}$ and ozone. For example, during

[2] National Interagency Coordination Center, Wildland Fire Summary and Statistics Annual Report 2024
[3] Frequently Asked Questions: Wildfire Emissions | California Air Resources Board
[4] Wildfires Increase Concentrations of Hazardous Air Pollutants in Downwind Communities - PMC
[5] https://www.epa.gov/sciencematters/danger-wildland-fire-smoke-public-health
[6] https://www.epa.gov/sites/default/files/2018-10/documents/exceptional_events_rule_revisions_2060-as02_final.pdf

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the 2018 wildfires in Portland, Oregon, the air quality index (AQI) reached unhealthy levels above 151.[7] The AQI is a tool used to communicate how clean or polluted the air is in a specific area. The AQI provides a numerical value and a color code to indicate the level of air pollution and its potential health effects. The AQI (Figure 5) helps people understand the quality of air they breathe and take appropriate actions to protect their health.

Wildfire Impacts and the Roles of Key Stakeholders in Smoke Damage

There are three major stakeholders as it concerns understanding/researching, preparing for, managing, and preventing the many impacts of wildfires and wildfire smoke, and each has a crucial role to play. Their work and contributions help determine the degree to which public health, safety, and general welfare are impacted when wildfires occur. They include:

- Regulatory agencies (EPA/state agencies).
- Industry.
- Public.

EPA's Response to Wildfire Smoke Damage and Air Quality Standards

The EPA has been leading the way on establishing air quality standards under the CAA. The EPA's mission, especially with the CAA, is to protect public health and the environment by ensuring that the air quality across the US meets the National Ambient Air Quality Standards (NAAQS).[9] When wildfires occur, they often cause short term spikes in $PM_{2.5}$ and ozone levels, making it hard for some areas to meet the NAAQS standards. Wildfire smoke can also travel long distances, affecting air quality in regions far from the fires and impacting public health. Under the CAA, the EPA's job is to enforce standards that keep the air clean and safe to breath, even when natural events cause temporary declines in air quality. However, the CAA also recognizes that it may not be appropriate to use the monitoring data influenced by "exceptional" events (e.g. wildfires) that are collected by the ambient air quality monitoring network when making certain regulatory determinations.[6]

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

***Figure 5** - AQI, color codes, and their meanings.[8]*

[7] https://www.upbeacon.com/article/2018/08/air-quality-worsens
[8] https://www.airnow.gov/aqi/aqi-basics/
[9] NAAQS Table | US EPA

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Industry Perspectives on Wildfire Impacts

Industry stakeholders argue that wildfires are natural events that are made worse by climate trends and forest mismanagement, not by individual industrial operations. They believe the CAA should differentiate between human-caused emissions and those from natural events. Penalizing industries for air quality issues caused by wildfires would be unfair. Various industries are actively investing in energy efficiency, recycling, and cleaner technologies to enhance sustainability and reduce environmental impact. These efforts not only demonstrate the industry's efforts toward reducing climate change but also help mitigate wildfire risks indirectly.

Public Health Concerns from Wildfire Smoke and Air Quality Impacts

The public and public health advocates emphasize that wildfires significantly increase air pollution, especially when the NAAQS are exceeded. This directly impacts public health, well-being, and quality of life. Wildfire smoke can cause respiratory problems, cardiovascular issues, and other health complications, particularly among vulnerable populations such as the elderly and children.[10] Therefore, the public has a crucial role in providing feedback to the EPA and the states on regulations and policies related to air quality and wildfires. The public should actively participate, voice their concerns, and influence decision making.

HOW WILDFIRE RISK ASSESSMENTS CAN HELP

Obtaining a proper understanding of wildfire risk is important for quantifying insurance carrier exposure risk. This can be complicated, as there are many variable factors such as drought conditions, vegetation growth, and even urban expansion and development. Following wildfire events, understanding the wide variety of weather conditions at loss locations can prove vital, from wind speeds and directions to stability conditions promoting the trapping of smoke and pollutants near the ground. Meteorologists have long proven to be an excellent resource in wildfire risk and post-event analysis.

Because wildfires and wildfire smoke significantly impact property, air quality, and public health, it is important for all stakeholders to work together to develop strategies that balance the immediate need for public safety, property and infrastructural safety, and air quality protection. Some of these initiatives could include the following:

Initiative	Description
Improved Forest Management	Implement controlled burns and selective thinning to reduce fuel loads.
Technology Investment	Invest in advanced detection, monitoring, and rapid response systems, including advanced firefighting equipment.
Data and Research Enhancement	Enhance air quality research to refine models and inform regulatory standards and risk assessments. Collaborate with regulatory agencies, academic institutions, and industry.
Industry Incentives	Encourage adoption of cleaner, lower-emission technologies, and flexible operational plans to protect health and minimize environmental impact during poor air quality periods.
Public Health Initiatives	Establish clean air shelters, increase healthcare support, and educate the public during wildfires.
Multi-Sector Partnerships	Develop and implement comprehensive wildfire management and climate mitigation strategies with stakeholders. Support and expand the workforce for mitigation, planning, and post-fire recovery.
Transparent Reporting	Ensure stakeholders are informed and engaged through continuous dialogue, policy refinement, and sharing best practices.

***Figure 6** - Initiatives that can help all stakeholders address the need for public safety, property and infrastructural safety, and air quality protection.*

This effort should be seen not just as working to combat and mitigate the effects of wildfires, but also as an opportunity for collaboration among regulatory agencies, industry, and the public. A balanced and collaborative path forward keeps each stakeholder engaged and mutually accountable, while at the same time focusing on the common goal of cleaner air, safer communities, prosperity, and a more sustainable future.

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Daniel Schreiber is a Senior Vice President in J.S. Held's Forensic Meteorology service line. He is a Certified

[10] https://www.epa.gov/wildfire-smoke-course/health-effects-attributed-wildfire-smoke

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Consulting Meteorologist with over 10 years of experience in military, aviation, and severe weather operations. Mr. Schreiber has provided consulting and expert services for both plaintiff and defense law firms, as well as insurance adjusters, appraisers, umpires, and policyholders throughout North America. He has been consulted and/or retained as an expert in over 850 matters and has testified in both depositions and during trials in state and federal courts. He regularly plays an integral role in multi-million-dollar insurance disputes and injury/wrongful death lawsuits from coast to coast. Before joining J.S. Held, Dan was a highly successful meteorology business owner.

Dan can be reached at daniel.schreiber@jsheld.com or +1 830 453 0255.

AJ Karna is a Senior Director in J.S. Held's Energy & Power – Energy & Environmental Advisory service line and specializes in air quality permitting and compliance. With over 13 years of consulting experience, he excels in environmental air permitting, compliance, and EPCRA projects, including Tier II and Toxic Release Inventory Reporting. AJ has led teams, mentored staff, and managed complex projects to ensure regulatory compliance and environmental stewardship. He has provided expert consultation on permit applications, negotiated with regulatory agencies, and designed studies to support compliance. AJ has also taught and coached clients and colleagues on air permitting and compliance and has presented at industry conferences. He supports various industries, including power plants and refineries, and actively participates in air permit application meetings, offering valuable insights and negotiating favorable terms.

AJ can be reached at aj.karna@jsheld.com or +1 314 816 0246.

Bill Zoeller oversees the Industrial Hygiene & the Built Environment Service Line within J.S. Held's Environmental, Health & Safety practice. Bill is a graduate of the University of Wisconsin La Crosse with a degree in Microbiology and BioMedical Science. He has over two decades of industrial hygiene experience with project design and assessment of remediation from catastrophic events such as water, fire, and biological impacts to properties, as well as regulated materials assessments and pollution claims. Bill has a wide range of project experience from residential to large, complex multi-million-dollar projects in manufacturing, healthcare, educational, food manufacturing, and multi-family properties.

Bill can be reached at wzoeller@jsheld.com or +1 920 442 4195.

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