STATE OF CALIFORNIA
AIR RESOURCES BOARD

MEETING OF THE RESEARCH SCREENING COMMITTEE

December 1, 2025
10:00 a.m.

California Air Resources Board
Research Division
Cal/EPA Building
1001 I Street
Sacramento, CA 95814
(916) 445-0753

California Air Resources Board

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Sacramento, CA 95814
(916) 445-0753

December 1, 2025
10:00 A.M

Agenda

California Air Resources Board

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Sacramento, CA 95814
(916) 445-0753

August 26, 2025
10:00 A.M.

Minutes

Research Screening Committee Members in Attendance via Teleconference:

Dr. Aly Tawfik
Dr. Sam Silva
Dr. Bryan Hubbell
Dr. Francesca Hopkins
Dr. Roya Bahreini

I. Approval of Minutes of Previous Meeting

April 7, 2025

II. Discussion of Research Proposals

1. "Improving Estimates of CO2 and CH4 Emissions Southern California Coastal Wetlands and BVOC Emission Estimates from all California Landscapes," University of California, Irvine, $800,000, Proposal No. 2891-317

A Research Screening Committee (RSC or Committee) member expressed that this was an important study and that the researchers brought a high level of expertise. They added that the proposal lacked integration between the two distinct tasks, one on wetland carbon cycle research and the second on biogenic volatile organic compound (BVOC) work. Another Committee member noted that details on wetland soil sampling were sparse, with no numbers or clear protocols provided, despite likely high spatial variability. The member also commented on the importance of getting the BVOC emission estimates correct, especially in Los Angeles, where errors in current projections and predictions of ozone could have significant impact. Both Committee members agreed that the principal investigators for the project tasks were highly qualified to address the uncertainties associated with each task.

Staff explained that the project was initially planned with the University of California, Irvine. Adding expertise from the University of California, Santa Cruz would provide access to an existing flux tower and make for a cost-effective collaboration. Staff further clarified that Task 1 would focus on selecting sites that address spatial limitations in existing data. California Air Resources Board (CARB) needs additional data to project future carbon storage in wetlands but does not yet have a definitive estimate. This project would explore what is feasible. Soil cores are a critical component for projection modeling. The Committee members were satisfied with these explanations.

Motion: Move to recommend CARB accept the proposal, subject to the inclusion of revisions based on comments from staff and the Committee.

The Committee approved the motion.

2. "Validating Vehicle Choice Surveys," University of California, Davis, $50,000, Proposal No. 2891-317

A Committee member praised the project for its value despite the small budget. However, they requested clarification regarding a reference to a third party, the role of stakeholders versus a Technical Advisory Committee (TAC), and why the work was not done in-house, given its straightforward nature. The member also highlighted that the contractor had not fully defined the research question at the proposal stage. CARB staff clarified that the budget was small because several tasks would be performed by CARB staff. The budget was primarily for a post-doc to perform the tasks not completed by CARB. However, partnering with the University of California, Davis (UCD) was essential for access to survey data. Staff noted there was not a third party performing an analysis, but data would be obtained from the Department of Motor Vehicles, which may have caused confusion during the review. Staff explained that the TAC would be overseen by UCD and would provide methodological and interpretive guidance, while CARB staff act as stakeholders. Research questions would be specified in the project's first task, which is to create a pre-analysis plan (PAP). To uphold the integrity of the research, the PAP would be completed before analysis begins. A public commenter supported the project, citing the importance of addressing disparities in participation in incentive programs.

Motion: Move to recommend that CARB accept the proposal, subject to the inclusion of revisions based on comments from staff and the Committee.

The Committee voted to approve the motion.

3. "Accelerated Evaluation of Ambient PM2.5 in Regions Affected by the 2024 NAAQS Update," University of California, Davis, $1,000,000, Proposal No. 2894-317

   The Committee expressed strong support for the project, noting that it will generate an important aerosol dataset using Advanced Chemical Speciation Monitors (ACSM). The Committee emphasized that the contract would also provide CARB with the technical expertise and documentation needed to independently operate this monitoring network in the future. The Committee was pleased to know that this contract was developed to address the regulatory challenges introduced by the U.S. EPA's revised annual Fine Particulate Matter (PM2.5) NAAQS, lowered from 12 $\mu g/m^3$ to 9 $\mu g/m^3$. They also acknowledged that the contractors (UCD and Georgia Institute of Technology) selected for this contract have extensive experience and are highly capable of performing the tasks successfully, as they have been involved in past CARB-sponsored research by running similar measurement sites at Fresno and Bakersfield with important results on seasonal variability in PM2.5 sources that are critical for emission control efforts. The Committee requested clarification on the scientific basis for selecting deployment sites. The contract manager explained that site selection was guided by recommendations from CARB's Air Quality Planning and Science Division and based on 2023 PM2.5 design values.

   Motion: Move to recommend that CARB accept the proposal, subject to the inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the motion.

4. "Assessing Long-Term Health Impacts of Wildfire Smoke Exposure: Insights from an Established Birth Cohort Study," University of California, Davis, $700,000, Proposal No. 2896-317

   The Committee found this to be a valuable and timely study, highlighting in particular the strength of the proposed biospecimen and metals analysis, which would enhance the ability to characterize wildfire smoke impacts. The Committee also found the potential of the study to examine avoidance behaviors during smoke events added value to the study.

   A central concern was whether the study had sufficient statistical power to support all of the proposed analyses. While the proposal addressed this issue to some extent, the Committee recommended that discussion of statistical power be given greater emphasis in the proposal text and discussed explicitly in shaping the scope of the analyses. The Committee was especially focused on the expected statistical power for the disparities in health outcomes and the power needed to account for potential confounders. The Committee requested that a table with power calculations for all health endpoints be included. Additional specific comments include:

1. The need to account for the impacts of non-wildfire PM and total PM2.5 exposure.
2. Discuss limitations in data availability that may impact the statistical analysis including the use of confounders and impacts after 2021.
3. Clarify that NAAQS standards are not thresholds in the discussion on the use of standard levels (e.g., NAAQS) to evaluate effects, and include the importance of considering alternative thresholds.

Motion: Move to recommend that CARB accept the proposal, subject to the inclusion of revisions based on comments from staff and the Committee.

The Committee approved the motion.

5. "Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants," University of California, Berkeley, $600,000, Proposal No. 2897-317

   The Committee discussed the University of California, Berkeley (UCB) proposal to evaluate air cleaning technologies for indoor gas pollutants. CARB staff provided a brief overview of the study, which would compare 30 air cleaning devices in lab and field settings for their ability to remove Nitrogen Dioxide (NO2), hydrogen sulfide, and Volatile Organic Compounds (VOC). The Committee expressed concerns regarding the lack of technical details on sensor selection and calibration, as well as the potential influence of daily activities on pollutant concentrations. The Committee approved the proposal with the understanding that more specific information on sensors and testing procedures would be provided in the proposal to address these comments.

   Motion: Move to recommend that CARB accept the proposal, subject to the inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the motion.

III. Discussion of Draft Final Report

1. "Preterm Birth, Low Birth Weight, Childhood Autism, Parkinson's and Alzheimer Disease and Air Pollution – California Studies," University of California, Los Angeles, $998,612, Contract No. 21RD004

   Committee members provided the following recommendations:

   - Include language in the discussion of each section of the report to explain the uncertainties in the estimates of spatial and temporal trends from the Land Use Regression (LUR) models (e.g., spatial distribution of monitors, especially for air toxics), and how those uncertainties might carry over to the estimated associations of health outcomes.
   - Discuss differences in uncertainties of models for criteria pollutants and air toxics, including those due to differing spatiotemporal coverages of the monitors.
   - Clearly distinguish the presentation of observed/measured values relative to estimated outputs from LUR models.
   - Better integrate the discussion of findings and policy implications to produce a unified report, the introduction and conclusion sections that tie together the key outcomes in the report would help. Currently, the sections are drafted like standalone scientific papers.
   - Include a map of all available monitoring data for criteria and air toxics.

   Committee members also brought up the following concerns regarding the project:

   - The members expressed concerns about the availability of monitoring stations to establish robust air quality estimates. They also expressed concern about back-casting the pollution to time periods when monitoring data was more limited.
     - The members suggested inclusion of language about the uncertainties in the air pollution estimates and focusing on time periods when sufficient monitoring data is available.
   - Members pointed out changes in the diagnostics of Autism Spectrum Disorder since 1990 and the potential effects of these changes on the observed trends.

   Motion: Move to recommend that CARB accept the report, subject to the inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the motion.

IV. Other Business

1. Update on Research Planning

   Staff provided Committee members with an update on ongoing research efforts. This item did not require a vote.

Item No.: II.1
Date: December 1, 2025
Contract No.: 23RD006

Staff Evaluation of a Proposed Contract Augmentation

Title:	Using Integrated Observations and Modeling to Better Understand Current and Future Air Quality Impacts of Wildfires and Prescribed Burns
Contractor:	University of California, Davis
Subcontractor:	National Center for Atmospheric Research (NCAR)
Principal Investigators:	Michael Kleeman, Ph.D. Keith Bein, Ph.D. Sean Raffuse, Ph.D. Kelley Barsanti, Ph.D.
Budget:	$70,000
Contract Term:	36 Months

For further information, please contact Dr. Kerri Steenwerth at (279) 208-7842.

I. Summary

A contract augmentation is requested to conduct model simulations assessing prescribed burn scenarios with various land management objectives. Prescribed burns are increasingly proposed as a policy strategy to mitigate wildfire risks in the western U.S. However, evidence of their effectiveness in reducing fire severity and smoke emissions remains limited. The recently California Air Resources Board (CARB) funded study will evaluate the air quality impacts of wildfires and prescribed burns on urban population centers downwind of fires by analyzing the measurement data and the modeling results to draw conclusions about the potential air quality benefits (and disbenefits) of prescribed burning activities compared to unplanned wildfires, and wildfires modified by pre-fire fuels treatment. In this contract augmentation, the investigators will perform additional modeling simulations, allowing consideration of an alternative set of prescribed burn scenarios. In these scenarios, fires would be relocated based on an alternative priority established by the California Department of Forestry and Fire Protection (CAL FIRE) (*e.g.,* fuel reduction in forested areas). The

results of these simulations will be compared with those of the wildfire-only (base) scenarios and the initially proposed prescribed burn scenarios. The results will quantify the probability of smoke exposure in populated areas and optimize the allocation of resources to protect human life and property simultaneously. By reducing fuel loads, prescribed burns also create fire-resilient landscapes where future fires burn with less intensity and are more easily managed. Prescribed burns in California contribute to regulatory and policy implications by serving as a tool to inform policy debates around wildfire prevention and air quality.

II. Technical Summary

Objective

This augmentation will conduct additional model simulations to evaluate and compare two prescribed burn scenarios designed to reduce wildfire risk in California. One scenario prioritizes fuel reduction in or near the Wildland-Urban Interface (WUI) to protect human life and property, while the other focuses on fuel reduction in more distant forested areas to achieve broader ecological and fire behavior goals.

Background

The Research Screening Committee (RSC) approved the original project in November 2023 to improve our understanding of the effects of planned and unplanned fires on communities. Climate change is expected to intensify drought and precipitation extremes, further heightening wildfire risks. Since ignition events cannot be fully prevented, managing fuel loads through prescribed burning has gained renewed focus. California has expanded support for prescribed and cultural burns through recent initiatives, including the 2020 Shared Stewardship Agreement and the Wildfire and Forest Resilience Task Force's Action Plan (Action Plan), which aims to treat one million acres annually starting in 2025. The Action Plan directs CARB to analyze the health impacts of prescribed fire smoke and compare them to those of wildfire smoke.

In areas with heavy forests and within the WUI, the overall emissions impact of prescribed burns relative to wildfires depends on the types of fuel consumed, the quantity and composition of emissions, and the spatial overlap of the burns. By removing fuel in a controlled, less intense manner, prescribed burns can dramatically reduce the risks of larger, more destructive wildfires, resulting in a net decrease in total smoke and pollutant emissions. Hence, the additional modeling studies aim to provide currently lacking information on the air quality impact estimates of prescribed burn scenarios in different landscapes with different management objectives.

Project Summary

In the original project, the University of California, Davis (UCD or Contractor) will conduct a comprehensive measurement-modeling approach to assess the air quality and public health implications of prescribed burning that relies on: i) a mobile measurement platform specifically designed for rapid deployment during fires; and ii) chemical transport models that include fire-specific refinements. Furthermore, the Contractor will apply the Multi-Scale Infrastructure for Chemistry and Aerosols version 0 (MUSICAv0) model, developed at NCAR, which is a multi-scale version of the Community Atmosphere Model with Chemistry (CAM-Chem) global model, with regional refinement down to ~6 km resolution. These measurement and modeling tools will be used to conduct the following four major research tasks:

1. Design a research plan /field deployment plan for characterizing wildfire smoke;
2. Design multiple scenario-based modeling frameworks for prescribed burning activities;
3. Perform data analysis of ambient observations and corroboration with scenario-based modeling; and
4. Prepare Draft Final Report. The final deliverables produced in the proposed research include a database of measured concentrations downwind of prescribed burns and wildfires, estimated emissions for historical fires, and predicted exposure fields downwind of prescribed burns and wildfires.

The proposed augmentation would allow the Contractor to perform additional model simulations for two prescribed burn scenarios:

- Reducing fuel loads in priority areas near the WUI to protect people and property; and
- Reducing fuel loads in forested areas farther from the WUI.

The WUI-focused scenario uses a spatial optimization model that identifies high-impact fuel treatment sites based on vegetation type, density, and moisture levels. Outcomes would include reduced fire intensity and spread, as well as fewer structures lost during wildfires. The second prescribed burn scenario would be conducted to model long-term, strategic burns aimed at reducing fuel loads, restoring forest health, and preventing high-intensity wildfires. Simulations guide when and where to burn by considering fuel conditions, distance to communities, and weather. Results would aim to demonstrate that managed fires can safely reduce fuels, target high-risk areas for crown fires, and improve forest structure by thinning ladder fuels.

Model outcomes would be used to determine if these treatments shift fires from severe crown events to low-intensity surface fires, are cost-effective over time, and promote resilient, fire-adapted ecosystems. Findings could potentially guide long-term fire management and investment strategies. Both scenarios would be developed with the University of California, Berkeley (UCB) and CAL FIRE experts. Prescribed burns reduce fuel buildup to protect against large, destructive wildfires, but they also generate smoke that can directly impact nearby communities. This trade-off involves weighing the potential long-term benefits of reduced smoke from future wildfires against the immediate, short-term exposure to smoke from the prescribed fire itself. These model outcomes are designed to help agencies assess population exposure to prescribed burn smoke near cities, and consider how weather, burn characteristics, and population density interact to determine risk.

III. Staff Comments

An earlier version of the full proposal was reviewed by staff from CARB's Air Quality Planning & Science Division (AQPSD), Monitoring and Laboratory Division, and Research Division. The current version has incorporated staff comments to improve its clarity. The reviewers generally recognized the quality of the proposed research effort and the practical importance of the results. The reviewers stated that the assembled team has extensive experience and resources to apply to the project, and the results will be well worth the investment of these resources.

Dr. Kleeman (UCD) will serve as the Principal Investigator (PI), coordinating and synthesizing the efforts of other task leaders. Dr. Raffuse (UCD) will lead the development of prescribed burn and wildfire emissions using the BlueSky modeling framework. Dr. Barsanti (NCAR) will lead the development of prescribed burn scenarios and interpret comparisons of air quality under prescribed burn vs. wildfire scenarios. She will collaborate with the team to analyze the public health implications of exposure predictions and write reports and peer-reviewed papers that document project results.

IV. Staff Recommendation

The staff recommends the RSC recommend that CARB approve this contract augmentation for a total amount not to exceed $70,000, subject to the inclusion of any changes and additions specified by the Committee.

Item No.:	III.1
Date:	December 1, 2025
Contract No.:	21RD006

Staff Evaluation of a Draft Final Report

Title:	High Spatiotemporal Resolution PM2.5 Speciation Exposure Modeling in California
Contractor:	University of California, Riverside
Principal Investigator:	Jun Wu, Ph.D.
Budget:	$301,214
Contract Term:	48 Months

For further information, please contact Dr. Jason Schroeder at 1(279)-298-7609.

I. Summary

Fine particulate matter (PM2.5) remains a major public health concern, yet most monitoring and regulatory frameworks focus on total mass rather than chemical composition. This project developed a deep-forest spatiotemporal model to estimate daily 1-km concentrations of five key PM2.5 components—sulfate, nitrate, elemental carbon, organic carbon, and dust—across the western United States (2002–2019) and extended the record for California to 2000–2020. The model combined satellite aerosol optical depth, Community Multiscale Air Quality Model (CMAQ) simulations, meteorology, and land-use data and showed strong agreement with ground observations (R^2 = 0.66–0.89). Results indicate major declines in sulfate and nitrate (~50 percent), smaller reductions in organic and elemental carbon, and little change in dust, with persistent hotspots in the Los Angeles Basin and San Joaquin Valley. Disparity analyses revealed higher exposures to nitrate and organic carbon in disadvantaged communities. These findings confirm the success of past emission controls while emphasizing emerging challenges from agricultural sources, dust, and wildfire smoke, providing a foundation for equitable and targeted air-quality management in California.

II. Technical Summary

Objective

This project aimed to develop a high-resolution, long-term modeling framework to estimate daily concentrations of the major chemical components of PM2.5 - sulfate, nitrate, elemental carbon, organic carbon, and mineral dust – across the Western United States and California. The objective was to fill a data gap in understanding component-specific PM2.5 exposures, evaluate the effectiveness of emission-control programs, and identify persistent pollution disparities affecting vulnerable communities.

Background

While PM2.5 mass concentrations are routinely monitored and regulated, the chemical composition of PM2.5 varies widely by source, atmospheric behavior, and health impact. Historically, most air quality management and epidemiological studies have treated PM2.5 as a single pollutant, limiting insight into which emission sources and components drive exposure risks and health inequities. To support more targeted and equitable air quality management, this project integrated satellite, modeling, and ground-based data to generate long-term, spatially detailed records of PM2.5 components. These data provide a scientific foundation for evaluating regulatory progress, understanding climate-air quality interactions, and supporting CalEnviroScreen and other environmental justice (EJ) applications.

Project Summary

Researchers developed and applied a two-stage spatiotemporal deep-forest modeling framework to estimate daily 1-km PM2.5 component concentrations from 2002-2019 across the western United States, extending the record for California to 2000 to 2020. The framework first generated gap-free total PM2.5 fields using Multi-angle Implementation of Atmospheric Correction (MAIAC) satellite aerosol optical depth and ancillary predictors, then used these estimates along with CMAQ –speciated simulations, Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis data, meteorological variables, land-use characteristics, and wildfire indicators to predict component concentrations. Model evaluation against ground monitors demonstrated high predictive accuracy (cross-validation R^2 = 0.66–0.89). Results revealed major, policy-driven reductions in sulfate and nitrate (~50 percent statewide decline), modest decreases in organic carbon and elemental carbon, and minimal changes in dust. Persistent exposure hotspots were identified in the Los Angeles Basin and San Joaquin Valley, driven primarily by organic carbon and nitrate. Analysis of health and demographic indicators using CalEnviroScreen showed that disadvantaged communities experienced systematically higher exposures to nitrate and organic carbon, underscoring ongoing environmental inequities.

Decomposition analysis attributed most long-term trends to emission controls rather than meteorological variability, while highlighting the growing role of wildfire smoke – especially in Northern California and the Sierra Nevada – as an episodic driver of PM2.5 extremes. Overall, the findings demonstrate the effectiveness of California's fuel-sulfur, oxides of nitrogen (NO_X), and diesel control programs while revealing persistent challenges linked to agricultural emissions, dust resuspension, and increasing wildfire frequency. The results confirm the success of past emission-control programs but indicate the need for next-generation strategies targeting nitrate and organic carbon precursors, dust mitigation, and wildfire smoke management.

III. Staff Comments

The draft final report was reviewed by CARB staff in RD, including the Emissions and Remote Sensing Branch. Previous draft reports were submitted and reviewed, and the project team was responsive to all CARB staff comments throughout the review process. The project met its modeling and analysis objectives, producing a robust, high-resolution dataset of PM2.5 chemical components across California and the western U.S. The methods were scientifically rigorous and consistent with current best practices in satellite data integration and machine learning. The final report clearly documents model performance, uncertainty, and validation procedures, and provides valuable insights into emission-control effectiveness, wildfire impacts, and persistent air-quality disparities relevant to CARB's regulatory and EJ programs.

IV. Staff Recommendation

Staff recommends the RSC recommend that CARB approve this report, subject to inclusion of any changes and additions specified by the Committee.

Item No.:	III.2
Date:	December 1, 2025
Contract No.:	21RD010

Staff Evaluation of a Draft Final Report

Title:	Understanding the Sources and Formation Regimes of Present-day PM2.5 to Mitigate Particulate Pollution in California
Contractor:	University of California, Riverside
Principal Investigators:	Don Collins, Ph.D Roya Bahreini, Ph.D. Cesunica Ivey, Ph.D.
Budget:	$500,000
Contract Term:	48 months

For further information, please contact Dr. Morteza Amini at (279) 842-9160.

I. Summary

This research contract aims to address a critical problem faced by CARB in developing effective and cost-efficient strategies to achieve attainment of the PM2.5 National Ambient Air Quality Standards (NAAQS). The drivers behind PM2.5 exceedances in California are complex and not yet fully understood. To address this, the study combined retrospective analysis of multidecadal historical PM2.5 data with four intensive field campaigns to understand both long-term and present-day drivers of particulate pollution. The multidecadal PM2.5 analysis used generalized additive models (GAM) to identify the meteorological and chemical factors most strongly associated with ambient PM2.5 concentrations in Riverside, Bakersfield, and San Jose. Field campaigns conducted in Riverside, Wilmington, and Bakersfield provided a comprehensive assessment of fine particulate matter composition, sources, formation pathways, and sensitivities to precursor emissions. Furthermore, two complementary approaches – Positive Matrix Factorization (PMF) and GAM – were used to analyze the campaign data. The integrated analysis across all sites underscored several patterns. First, organics were the dominant particulate matter (PM) component statewide, and their secondary production was modulated by both photochemical and aqueous-

phase pathways. Second, while emission reductions in NO_X and volatile organic compounds (VOC) have historically lowered PM2.5 levels, the ongoing decline in the NO_x:VOC ratio could alter ozone and secondary aerosol sensitivities in complex ways. Third, ammonia emerged as an important factor in controlling both nitrate and secondary organic aerosol formation, particularly in agricultural and mixed urban regions such as the San Joaquin Valley. Fourth, meteorological variability, especially relative humidity, temperature, and wind direction, significantly influenced day-to-day PM2.5 concentrations and composition, complicating attribution of changes solely to emissions. The study concludes that integrating long-term data analysis with targeted, high-resolution field measurements provides a robust framework for understanding PM2.5 sources and formation mechanisms. These insights are essential for the development of the State Implementation Plan (SIP) for California.

II. Technical Summary

Objective

The objective of this project was to provide an integrated assessment of PM2.5 sources, formation mechanisms, and controls across key regions of California.

Background

The study combined retrospective analysis of historical PM2.5 data with a series of intensive field campaigns to understand both long-term and present-day drivers of particulate pollution. These efforts aimed to support CARB by improving the understanding of chemical and meteorological processes controlling PM2.5 and by informing strategies to meet NAAQS.

Project Summary

<u>Task 1: Evaluation of Long-term Trends of PM2.5 Across California</u>

This task analyzed multidecadal PM2.5 in California using a GAM to improve the understanding of chemical and meteorological parameters that correlate with PM2.5 concentrations. The GAM characterized PM2.5 response to meteorological and chemical variables, and a subsequent sensitivity analysis ranked the relative importance of these parameters in deriving the PM2.5 variabilities. The analysis incorporated long-term data from the Chemical Speciation Network (CSN) and focused on metrics such as mean bias, root mean square error, and R^2 for PM2.5 and major species including nitrate, sulfate, ammonium, and organic aerosol. The GAMs were constructed for total PM2.5, particulate nitrate, and organic carbon at three locations: Bakersfield, Riverside, and San Jose. Sensitivity analysis showed that the drivers of PM2.5 varied among these locations, with meteorological conditions, precursor emissions, and secondary formation processes each playing distinct roles. In Bakersfield, PM2.5 mostly responded to gaseous precursors; in Riverside, meteorological factors – particularly relative humidity – played a larger role; and in San Jose, PM2.5 responded to both meteorology and precursor gases. This modeling approach provided both quantitative and mechanistic insights into seasonal and interannual variability, helping to guide the design and interpretation of subsequent field measurements.

Task 2: Design and prepare for field campaigns to Examine PM2.5 Sources and Formation Regimes

This task encompassed the design, preparation, and execution of four field campaigns aimed at characterizing ambient PM2.5 concentrations and evaluating the potential for secondary PM formation in EJ communities across California. Campaigns were conducted in Riverside (winter and summer), Wilmington, and Bakersfield—each selected for their distinct sources of elevated PM levels. Each campaign lasted about one month and combined advanced online instrumentation to measure ambient PM concentrations and potential secondary PM formation. A multi-tiered strategy was employed that combined measurement of: i) ambient PM and precursors; ii) secondary PM formed through gas- and aqueous-phase chemistry in an oxidation flow reactor (OFR); and iii) secondary PM formed from ambient air in parallel chambers with and without added precursors including Isoprene+α-pinene (as biogenic VOC), Toluene (as anthropogenic VOC), NO_x, and NH_3. The Accelerated Production and Processing of Aerosols (APPA) reactor further complemented these efforts by enabling controlled studies of secondary PM formation under varying oxidation and humidity conditions. Together, these integrated approaches provided a comprehensive understanding of both ambient and secondary aerosol composition and size distributions, supporting the identification of key sources and formation mechanisms relevant to air quality management.

Task 3: Field Campaign Results

This task reveals the findings from the field campaign. Across all sites, organic aerosol consistently accounted for the largest fraction of PM2.5 mass. However, the relative abundance and composition of organic, nitrate, and sulfate PM varied by location and season. At the Riverside site, Nitrate contributed significantly during cooler months due to enhanced gas-to-particle partitioning of ammonium nitrate. In contrast, Wilmington and Bakersfield sites were impacted more by contributions of organics and sulfate. The data demonstrated that secondary aerosol formation, particularly from organic and nitrate species, was sensitive to local precursor availability and meteorological conditions such as temperature, relative humidity, and wind patterns. The perturbation experiments provided direct evidence of chemical sensitivities under real-world atmospheric conditions. The results showed that added NO_X generally had minimal influence on PM2.5 or its components, while added ammonia enhanced nitrate formation, particularly under high relative humidity. The results showed that the response of PM2.5 to changes in precursor emissions is nonlinear and highly dependent on local chemical regimes. The experiments also demonstrated day-to-day variability in potential secondary PM2.5 formation and its dependence on environmental conditions. Aqueous-phase chemistry is shown to be an important contributor to PM2.5 formation at each of the three sites.

Task 4: Data analysis

Task 4 focused on the analysis and synthesis of field campaign data using two complementary approaches: PMF and GAM. PMF was applied to high-resolution organic aerosol mass spectra to identify and quantify dominant PM sources and formation pathways. Factors resolved by PMF included hydrocarbon-like organic aerosol associated with primary traffic emissions, oxygenated organic aerosol (OOA) linked to secondary formation, and nitrate- and sulfate-rich components indicative of aged aerosols. Correlation analyses between PMF factors and external variables such as temperature, humidity, and gas-phase precursors further highlighted connections between emissions and secondary chemistry. In parallel, the GAM approach developed in Task 1 was expanded and applied to the field campaign data to identify key meteorological and chemical drivers associated with organic aerosol. The modeling revealed strong regional contrasts and, through sensitivity analysis, revealed the relative importance of various covariates in influencing organic aerosol (OA) levels. Together, these analyses provide valuable insight into the formation regimes of OA in California and offer guidance on targeting controllable variables for effective PM2.5 reduction strategies.

III. Staff Comments

Following an initial review, staff shared the draft report with CARB staff in RD and AQPSD. All comments have been provided to the PIs, and staff are currently awaiting a revised version.

The draft presents findings from the application of GAM to analyze multidecadal PM2.5 trends, along with results from four extensive field campaigns involving multiple online measurement techniques. These campaigns generated rich datasets that have the potential to inform the SIP by providing a detailed assessment of fine particle matter composition, sources, formation mechanisms, and sensitivities to precursors.

While the current draft highlights several important findings from both the GAM analysis and field studies, reviewers noted that many of the results would benefit from comparison with existing literature. Additionally, the GAM analysis could be improved by incorporating insights from atmospheric chemistry. Clarifying unexpected outcomes observed during the field campaigns would also enhance the impact of the findings.

The draft covers most of the analytical methods specified in the agreement with CARB. However, staff also noted that Task 4 does not appear to utilize the Source Finder (SoFi) program for PMF analysis, as originally proposed. Additionally, as outlined in the proposal, findings from Task 4 should be evaluated against those from Task 1 to ensure consistency and to improve the overall interpretation. Addressing these areas would improve the relevance of the field measurements in supporting the development of effective air quality control strategies.

IV. Staff Recommendation

Staff recommends the RSC recommend that CARB approve this report, subject to inclusion of any changes and additions specified by the Committee.

Item No.: III.3
Date: December 1, 2025
Contract No.: 21RD003

Staff Evaluation of a Draft Final Report

Title:	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke
Contractor:	University of California, Irvine
Principal Investigator(s):	Jun Wu, Ph.D.
Budget:	$525,000
Contract Term:	48 Months

For further information, please contact Dr. Barbara L. Weller at (916) 324-4816.

I. Summary

Wildfires in California are becoming more frequent and severe, producing fine particles and toxic chemicals that may be more harmful than regular air pollution and pose distinct health risks due to short, intense exposure patterns. Therefore, updating the estimates of wildfire-related health impacts in California is essential. This project aimed to advance understanding of how repeated, short-term wildfire smoke exposure affects health in California and to help vulnerable communities reduce those risks. The University of California, Irvine (UCI) investigators first reviewed existing studies on wildfire smoke and respiratory health to assess whether wildfire pollution causes stronger effects than other air pollution sources. They then developed a detailed, statewide wildfire smoke model using machine learning and satellite data to distinguish wildfire PM2.5 from other pollution sources at high spatiotemporal resolution. The model also captured short, intense smoke spikes and multi-day "smoke wave" events. Using these data, the investigators linked wildfire exposure to various health outcomes, including respiratory and cardiovascular illnesses, adverse birth outcomes, and depression, applying advanced statistical methods to quantify impacts and identify disparities across socioeconomic groups. To complement the analysis work, surveys and focus groups were conducted in disadvantaged communities in the Coachella and San Joaquin Valleys to explore residents' real-world challenges, risk

perceptions, and preferred ways to receive health and safety information during wildfire events.

The results showed that wildfire smoke in California was clearly linked to short-term health harms, particularly respiratory impacts, which were consistent and robust across analyses. Both literature reviews and new analyses indicated that as wildfire PM2.5 increased, the number of emergency visits and hospitalizations for respiratory conditions also increased, especially those for asthma and Chronic Obstructive Pulmonary Disease (COPD). Wildfire-specific PM2.5 posed greater health risks than PM2.5 from other sources. For example, wildfire PM2.5 was associated with about 2.5 times higher risk of respiratory hospitalizations than total PM2.5 for the same increase in exposure. Wildfires were also the primary source of toxic polycyclic aromatic hydrocarbons (PAH) during fire seasons, with particle-bound PAH contributing to broader population exposure. In addition to respiratory impacts, wildfire PM2.5 was associated with increased cardiovascular visits (notably for stroke), higher risks of preterm birth (PTB) and related pregnancy complications, and more depression-related medical visits. Brief, intense smoke spikes and multi-day smoke waves were particularly harmful. Children, older adults, pregnant individuals, and Asian and Black populations were consistently more affected. Community feedback highlighted that disadvantaged areas face recurring wildfire smoke exposure and communication barriers, emphasizing the need for clear, culturally tailored health messaging. Although awareness and basic protective actions are common, more effective measures remain limited, underscoring the importance of targeted outreach and support for vulnerable populations.

This project delivered critical, strong science-based evidence to support California's public health policies on wildfire smoke. By developing California-specific estimates of health risks from wildfire PM2.5, this study found that wildfire smoke poses greater health risks than ambient air pollution, with longer and more intense smoke events causing more severe impacts. While the period of this study included urban-wildland interface fires, most of the smoke exposure was from wildfires. The findings revealed that pregnant women, older adults, and communities of color face disproportionate health impacts, underscoring the urgency for targeted protection measures. Importantly, the research highlighted key gaps in communication and risk reduction strategies, showing that current guidance often fails to meet the needs of vulnerable communities. These insights can help inform and improve wildfire health impact assessments, equitable interventions, and emergency response and communication systems. Overall, the project offers actionable, evidence-based direction to help California build more resilient public health policies in the face of growing wildfire threats.

II. Technical Summary

Objective

The project's overarching objective is to advance the science on health effects from repeated, short-term (i.e. smoke-wave) exposure to wildfire air pollution in California and to address the specific concerns and needs for outreach and information to socially vulnerable communities at greater risks.

The specific aims of this study include:

- Synthesize evidence using a literature review focused on short-term respiratory impacts of wildfire smoke.
- Model wildfire pollution statewide at high spatiotemporal resolution across multiple years to develop exposure data for smoke wave events.
- Conduct epidemiologic analyses linking modeled wildfire exposure to health outcomes.
- Engage communities (surveys/focus groups) to study risk communication and identify practical strategies to better inform disadvantaged populations.

Background

California's wildfires are becoming increasingly frequent and severe, generating air pollutants such as PM and AHs that may be more toxic than emissions from conventional sources (e.g., industrial and traffic combustion). The health impacts of wildfire smoke, however, remain less well understood. Wildfire smoke is chemically different and occurs in intense, intermittent "smoke waves," unlike the chronic more constant exposure to ambient PM typically studied. Communities with lower socioeconomic status and minority populations face disproportionate exposure and vulnerability due to factors such as a higher number of people with outdoor occupations, limited healthcare access, substandard housing, and the lack of air purifiers or air conditioning, making general public guidance like "stay indoors" often impractical. Thus, there is a critical need to quantify the health effects of wildfire-specific air pollution, understand how disadvantaged communities are uniquely impacted, and communicate actionable risk reduction strategies that work under real-world constraints in disadvantaged communities.

Project Summary

<u>Methods</u>

The project began with a systematic review of epidemiologic studies examining the short-term health effects of wildfire-specific PM, with a focus on respiratory outcomes. The goal was to compare wildfire-related PM effects with those from all-source or non-wildfire PM to determine whether wildfire smoke poses unique or stronger health risks.

To estimate wildfire-specific exposure, the team used advanced machine learning models combined with rich spatiotemporal data. A high-resolution (1-km, hourly) wildfire smoke dataset was developed for California for 2017, 2018, and 2020, separating wildfire-related PM from other pollution sources. A new metric was also introduced to capture brief, high-intensity smoke spikes that daily averages often miss. Smoke waves were defined as periods of two to four consecutive days with extreme PM levels, specifically, concentrations exceeding the 75th, 90th, or 95th percentile of exposure, to represent exposure by both intensity and duration. In addition, wildfire-driven PAHs were quantified using vegetation-specific emission factors and satellite-informed fire activity to simulate gas- and particle-phase PAH concentrations.

The project examined multiple health outcomes across diverse population subgroups, linking wildfire exposure data to pneumonia-related medical encounters, hospital admissions and emergency department visits (EDV) for respiratory and cardiovascular conditions (such as asthma, COPD, and stroke), birth outcomes, and depression-related visits. Sophisticated statistical models were applied with adjustments for key covariates, and analyses were stratified by socio-economic status factors to identify disproportionate impacts.

To complement the quantitative analyses, surveys and focus groups were conducted in unincorporated communities of the Eastern Coachella and San Joaquin Valleys to explore how disadvantaged populations experience wildfire smoke and communicate about risk.

Key Findings

The literature review found that wildfire-related PM2.5 exposure is consistently linked to higher rates of EDVs and hospitalizations for respiratory diseases, particularly asthma and COPD, with risks typically increasing by 0.5-1 percent per 1 µg/m3 rise in PM2.5. Children, older adults, and racial and ethnic minority groups were identified as more vulnerable. Several studies also indicated that wildfire PM2.5 has stronger respiratory effects than PM2.5 from other sources.

The project further showed that wildfires are the dominant source of PAH emissions during active fire seasons, with particle-bound PAHs contributing to the greatest population exposure due to long-range transport and atmospheric aging.

Across multiple analyses of wildfire data for 2017, 2018, and 2020, investigators found short-term wildfire PM2.5 exposure was significantly associated with a range of increased health outcomes:

- Pneumonia: Each 1 µg/m3 increase in wildfire PM2.5 corresponded to a 1 percent rise in pneumonia encounters, with the strongest effects occurring on the same day and lasting several days. Short, intense smoke spikes caused notably higher risks than steady, lower exposures.
- Respiratory Health: Wildfire PM2.5 was associated with higher hospitalizations (0.21–0.38 percent per 1 µg/m3 increase in concentration) and EDVs (0.22–0.48 percent) for respiratory conditions, particularly asthma (0.96 percent) and COPD

(0.60 percent). Associations with wildfire PM2.5 were consistently stronger than those for non-wildfire specific PM2.5. For example, the risk of respiratory hospitalizations was about 2.5 times higher for wildfire PM2.5 compared to total PM2.5 (0.38 percent vs. 0.15 percent). While stronger associations were observed during smoke wave events, the effect estimates varied depending on the intensity and duration of exposure.

- Cardiovascular Health: Risks of cardiovascular EDVs rose by 0.15 percent per 1 μg/m3 increase in wildfire PM2.5, with significant associations for stroke (0.27 percent), ischemic stroke (0.30 percent), and cerebrovascular events (0.29 percent). Longer, more intense smoke waves showed the highest risks.
- Birth Outcomes: Wildfire PM2.5, PAHs, and smoke-day exposure were strongly linked to higher risks of PTB and preterm premature rupture of membranes (PPROM), during the 1st–2nd trimesters and across the entire pregnancy. PTB risk rose 10-13 percent per 1 μg/m3 of wildfire PM2.5 and 0.9-1.4 percent per 1 ng/m3 of PAHs, while PPROM risk increased 7.6-10 percent and 0.6-1.4 percent, respectively. Risks grew with smoke intensity, and associations were weaker for non-wildfire PM2.5, suggesting greater wildfire toxicity. The risks of PTB and PPROM were approximately 1.7 and 5.6 times higher, respectively, for wildfire PM2.5 compared to non-wildfire PM2.5 (11.1 percent vs. 6.3 percent for PTB; 7.6 percent vs. 1.3 percent for PPROM).
- Mental Health: Wildfire PM2.5 was significantly associated with increased depression-related visits, with stronger effects during active wildfire periods (lag 0 day; 0.08–0.35 percent increase per 1 μg/m3). The longest and most intense smoke waves produced the highest increases in encounters, and associations were notably stronger in the cold season than in the warm season.
- Vulnerable Groups: Across outcomes, the project identified consistently vulnerable groups, including children, older adults, pregnant women, and Asian and Black populations, who bear disproportionate wildfire-related health burdens.

The qualitative assessment found that wildfire risk perception was shaped by safety awareness and community engagement. In disadvantaged communities, residents reported physical and mental health impacts from repeated smoke exposure, worsened by unstable housing, outdoor work, and limited resources. Participants preferred short Spanish-language messages via TV, radio, text, and social media, but outreach was hindered by language barriers and weak ties to local agencies. Despite challenges, informal networks supported effective neighbor-to-neighbor communication. The study found that while people commonly wore masks during wildfire smoke events, few adopted more effective measures such as using N95 masks or improving indoor air quality. Prior wildfire experience increased mask use but not the adoption of more protective mitigation strategies. Collectively, the findings highlight the need for culturally tailored education, preparedness, and resources to reduce risks in vulnerable communities.

Conclusions

This project conducted a multi-faceted investigation to provide science-based evidence for strengthening public health protections against wildfire smoke. It developed California-specific concentration–response functions for wildfire PM2.5, revealing stronger associations with health outcomes than non-wildfire PM2.5. In particular, respiratory impacts showed consistent and robust associations across analyses, using different exposure estimates and lag periods, and the findings were consistent with previous research. The findings from this study show that wildfire PM2.5 poses greater risk at equivalent concentrations, prolonged smoke events amplify health risks, and disadvantaged groups, particularly pregnant women and communities of color, bear disproportionate impacts. The research also identified critical gaps in communication and protection strategies, offering actionable insights to inform future interventions and policy development.

III. Staff Comments

This draft report was thoroughly reviewed by staff from the Office of Environmental Health Hazard Assessment, as well as by CARB staff from RD and the Industrial Strategies Division. Overall, reviewers agreed that the report presents scientifically rigorous and comprehensive work. The investigators produced an impressive and timely contribution to understanding the health impacts of wildfire smoke, both quantitatively and qualitatively, providing valuable California-specific insights.

Because the project spanned four years and included multiple published studies, reviewers noted that the multi-chapter format feels somewhat fragmented. They recommended improving cohesion by enhancing the organization, expanding the Introduction to better connect chapters to the overall contract outcomes, and strengthening the discussion of regulatory and policy implications. Clearer links between scientific findings and actionable insights would further align the report with CARB's mission and enhance its policy relevance. The investigators addressed these comments and clarified technical details, with revisions incorporated into this updated version.

One outstanding issue concerns the qualitative data analysis from focus groups conducted by the community partner, the Central California Asthma Collaborative (CCAC). During the study, the investigators faced engagement challenges, likely due to limited staffing and personnel transitions within CCAC. Despite these challenges, the research team maintained ongoing communication and remains committed to obtaining and incorporating the focus group results once they become available. While this missing information may provide additional community insights, its absence does not compromise the overall value or integrity of the report.

IV. Staff Recommendation

Staff recommends the RSC recommend that CARB approve this report, subject to inclusion of any changes and additions specified by the Committee.