STATE OF CALIFORNIA
AIR RESOURCES BOARD

MEETING OF THE

RESEARCH SCREENING COMMITTEE

October 18, 2013
9:00 a.m.

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

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 510, 5th Floor
Sacramento, California 95814
(916) 445-0753

October 18, 2013

9:00 a.m.

AGENDA

lll. Discussion of Responses to a Request for Proposals (RFP):

1) “Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars,” RFP No. 13-313

IV. Other Business

1) Update on Annual Research Plan

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 510
Sacramento, California 95814
(916) 445-0753

May 17, 2013
9:00 a.m.

MINUTES

RSC Members in Attendance via teleconference

Harold Cota
Steven Japar
Irva Hertz-Picciotto
Suzanne Paulson
Tracy Thatcher
Alan Vette
Forman Williams
Philip Fine

The Research Screening Committee (RSC or Committee) convened the meeting at 9:08 a.m. The minutes of the March 8, 2013 meeting were approved.

I. Draft Final Reports

1) "Study of In-Use Emissions from Diesel Off-Road Equipment," University of California, Riverside, $300,000, Contract No. 08-315

   A Committee member commented that he thought the project was costly, noted that the portable emissions measurement system (PEMS) validation was good, and said he thought that the report was satisfactory. He then asked a question about the emissions results and what the next steps were going to be, noting the relatively poor correlations for some pollutants such as hydrocarbons.

   Research Division staff responded that Planning and Technical Support Division (PTSD) staff was present and would respond to the question. PTSD staff noted that the data collected were much needed, and that PTSD staff expect to make further use of the project emissions data in the future. Problems recruiting project participants, and possible solutions, such as working with members of affected industries, were briefly discussed.

Another Committee member commented that there was a lot of information in the report, and passed along a couple of editorial comments to improve the clarity of the presentation of some of the emissions results. He also noted that one can conclude that some engines (e.g., John Deere) had high total hydrocarbon emissions.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

2) "Integrated Physical and Chemical Measurements of Heavy-Duty Diesel Emissions at West Virginia University Full Scale Wind Tunnel," University of California, Davis, $419,914, Contract No. 08-322

Staff summarized their responses to the five comments that the Committee provided before the meeting. Those comments and staff responses are incorporated in the discussions below.

The Committee asked how the diesel particulate filter (DPF) regeneration event during the post-2007 truck test affected the test results, and what the impact on the data quality was. Staff responded that an unexpected DPF regeneration occurred during the test, which affected 20 mph and 35 mph tests for the post-2007 truck. The DPF regeneration event is not steady state, so that changes over time confound changes measured across plume locations. Also, although the regeneration event was completed during the 20 mph test, the regeneration event left the DPF without a soot coat. The soot coat builds up over time and increases particle collection efficiency with time during the 35 mph test. Therefore both the 20 mph and 35 mph tests were affected by the regeneration event. In addition to the DPF regeneration event, the investigators found a crack on the DPF after the tests. The crack on the DPF decreased the filtration efficiency during the entire tests, and caused high accumulation mode particle concentrations. Although particle emissions from the cracked DPF provide interesting data, they did not represent the intent of the test, which was to measure emissions from a vehicle with a functioning DPF.

The Committee noted that the report indicates that some phenomena observed during the tests are currently unexplainable. The Committee also noted that the tests exhibiting the unexplained behavior were not identified, the unexplainable phenomena were not explained in detail, nor were possible explanations for the unexplained phenomena discussed. The Committee asked which tests showed the unexplainable phenomena, what the unexplainable phenomena was, what further investigation is needed for the unexplainable phenomena, and what publications could be made. Staff responded that particles measured from the tests show unexplainable physical and chemical behaviors that were probably due to the DPF regeneration event, the cracked DPF for the post-2007 tests, and the very low particle emissions (near the background level) for the post-2010 tests. Staff thinks that further data analysis should follow to investigate the

unexplained unique particle behaviors in the tunnel that may be related to the crack in the DPF, uncertainties in the aerosol instruments, or other potential causes. Staff seeks any guidance or suggestion from the Committee, while communicating with the project investigators for the further investigation. Staff sees a high value of publishing the outcomes from the project such as the experimental set-up and tracer gas (CO_2) and flow simulation approach. More publications may follow with further extensive data analysis and investigation, although not as part of this contract.

The Committee asked how much effort was lost waiting for the National Aeronautics and Space Administration (NASA). Staff responded that due to a change in management of the National Full-Scale Aerodynamic Complex (NFAC) from NASA to the Department of Defense, test priorities had been modified to accommodate the military, personnel security restrictions had been elevated, and the researchers could not obtain confirmed test dates. These changes delayed the program for one year, and prospects for successful completion of the study at the NFAC were not good. The research team then decided to build a new wind tunnel at West Virginia University, which took an additional two years. During the one-year delay, investigators developed test plans and fine-tuned tasks through a series of communications and NFAC facility visits, so that the research effort was not entirely lost during that time.

The Committee noted that there are discrepancies between the measurement and flow simulation results. The Committee wondered if the discrepancies were due to issues with sampling plans and instruments. The Committee asked how sampling plans and instruments employed in the tunnel should be improved to make sure that the wind tunnel measurements will deliver their promise. Staff responded that the tunnel operation period for a single test took over two hours (2 hours 40 minutes). During the long operation period, emissions, environmental conditions, and instruments can drift and affect comparisons among plume locations. Although improving the sampling plan and instruments requires further discussion with investigators, staff thinks the sampling plan and instruments can be improved by: adding concurrent multi-point sampling for some instrumentation; focusing on a few selected points within the plume to address specific questions rather than trying to capture the entire plume in one sample set; and employing means to identify the plume center line and either measuring or interpolating measurements at locations relative to plume center.

The Committee requested improvements in the report by including information on tunnel length and by including a description of how to read the plots in the Section 3.3.3. Staff responded that the converging inlet section is 16 feet long, and the straight test section is 115 feet long. The exhaust stack exit is nine feet downstream from the beginning of the straight section. The sample probe can move from seven feet upstream of the exhaust stack to 105 feet downstream of the exhaust stack. Staff will work with the investigators to include more complete information on the lengths of the tunnel and test section in the report, and information on how to read the contour plots in the report.

The Committee stated that the exhaust flow and plume behaviors for a tractor without a trailer are quite different from the behaviors for a tractor with a trailer. In the real-world, tractors mostly run with trailers. The tests conducted at the wind tunnel without a trailer could be significantly different from the real-world. Staff responded that the research team had discussed an option including a trailer for the tests, but decided testing with a tractor cab only because most chemical and physical property changes would happen within the close proximity from the exhaust exit, and because it would be best to model this simpler plume configuration before moving on to more complex conditions.

The Committee asked if there were any emission measurements made at the exhaust tailpipe, especially particulate matter (PM). Staff responded that gaseous emissions of nitrogen oxides, hydrocarbons, carbon dioxide, and carbon monoxide were measured in the raw exhaust, and that particle number was measured in the raw exhaust, but PM mass was not measured in the raw exhaust. Staff also responded that the gaseous emissions, flow properties, and particle number concentrations were measured in the tunnel for the exhaust mixed with ambient air, but PM mass was not measured in the tunnel.

The Committee asked for detailed information of the simulation programs including the effectiveness for particle modeling and relevant references. Staff responded that they will work with the investigators to obtain the detailed information.

The Committee commented that the report did not provide sufficient scientific information on wind tunnel design and construction. Three references for the tunnel design and construction are not sufficient. The Committee expressed that they should have been advised in advance about the wind tunnel design and construction. The Committee also commented that the data collected from the wind tunnel was much more important than the wind tunnel design and construction. Therefore, the Committee suggested excluding the appendix discussing details of wind tunnel design and construction from the report, and instead further emphasizing the data collected in the tunnel and including more complete analyses of data such as the post-2010 test results. Staff responded that the suggestion was fair and would work with the investigators.

The Committee commented that the incomplete data analysis, the incomplete modeling work, and the lack of discussion for unexplained particle behaviors, all affect the quality of the report and are not acceptable. The Committee strongly expressed the opinion that this report is not ready for approval.

Motion: Do not approve the report.

The Committee rejected the report.

3) “Improved Characterization of Primary and Secondary Carbonaceous Particles,” University of California, San Diego, $255,000, Contract No. 09-328

The Committee was complimentary of the report, and some minor revisions were requested. These included:

In the abstract, the report states that biogenic secondary organic aerosols are likely formed from condensation of secondary organic vapors produced from nitrate radical oxidation reactions during nighttime hours; on 400 to 700 nm sized primary particles. The report should expand the discussion of the emission sources of these small primary particles.

The Committee also noted that the submicron particles were dried prior to the cyclone. Since drying submicron particles may result in a size cut different than that of federal reference or equivalent sampling methods, it was suggested that the report should add a statement, for example, the study did not follow the federal method procedure because it would make the collection efficiency of particulates vary with relative humidity, which would make the size-resolved composition vary as well.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

II. New Research Projects

1) “Examining Factors that Influence ZEV Sales in California,” University of California, Los Angeles, $295,377, Proposal No. 2758-276

Staff provided an update on the revised budget of $302,993, resulting from unanticipated salary/benefit increases.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal. Suzanne Paulson recused herself.

2) “The Future of Drop-In Fuels: Life-Cycle Cost and Environmental Impacts of Bio-Based Hydrocarbon Fuel Pathways,” University of California, Berkeley, $400,000, Proposal No. 2759-276

The Committee was concerned that the project budget is large relative to what the proposal is offering and that the lack of detail in the report made it difficult to determine if ARB would get its money’s worth from funding the project.

Response by staff emphasized that the project would be useful for multiple ARB initiatives including the implementation of the Low Carbon Fuel Standard (LCFS)

and in-house scenario production for transportation. Staff from multiple divisions was involved in the proposal selection process and all believe that this project will provide valuable information to inform ARB's implementation of LCFS and related greenhouse gas reduction goals. The review team was also confident that the work outlined in the proposal is appropriately reflected in the budget, given the expertise and time required for the research team to perform the work. The budget for this project is on par with similar studies funded by California Energy Commission (CEC) and ARB, including the proposed project on renewable natural gas. However, the budget on this project is large, in part, due to high overhead rates for one key researcher on the project from Lawrence Berkeley National Lab. ARB staff is confident of the methods that will be used by the researchers. The Berkeley team has already interacted with ARB staff that uses the California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model in-house to ensure that the Berkeley team's lifecycle analysis uses the same metrics for model inputs and outputs.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

3) "The Feasibility of Renewable Natural Gas as a Large-Scale, Low-Carbon Substitute," University of California, Davis, $330,934, Proposal No. 2760-276

A Committee member wanted to make sure that the scope of the project included natural gas activity outside of California. The response by staff provided background on how the proposal fit in with other efforts that the research group in pursuing for the CEC and Biomass Collaborative. The staff also explained that the scope of the project included examining production and use in California as well as the impact of production and use outside of California.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

4) "Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles," University of California, Riverside, $371,724, Proposal No. 2761-276

The Committee asked why the overhead exceeded more than 10 percent of the direct cost. Staff responded that the overhead is exactly 10 percent of the modified total direct cost. The appropriate incentives were discussed as well.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

5) "Air Quality Impacts of Low Impacts of Low Vapor Pressure-Volatile Organic Compounds," University of California, Riverside, $405,338, Proposal No. 2757-276

A Committee member submitted written comments which summarized that this is an excellent proposal describing a comprehensive approach to address the Low Vapor Pressure-Volatile Organic Compounds (LVP-VOC) issue. The Committee member believed that the smog chamber and instrumentation resources at College of Engineering-Center for Environmental Research and Technology are extensive and ideal for the scope and goals of the project.

A Committee member asked for clarification of LVP-VOC mixtures that will be tested in the proposal. Staff explained that the LVP-VOC mixture is defined in the consumer products regulations. Staff also added that the products (mixtures) that will be tested are real consumer products sold in California and the formula will be acquired from the industry and included in the project report. The Committee member also asked to add a schematic diagram to clarify the process in selecting and employing different approaches for volatility measurement, and more specific information on the nebulizer used to deliver LVP-VOCs into the chamber. Staff will send the comments to the PI for revision of the proposal.

The Committee discussed the pros and cons of ozone forming potential measurements using the flow tube and the environmental chamber. The Committee agreed that ozone forming potential measurements for LVP-VOCs is a difficult research problem but believed that the proposal is the best we can get to address it.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

6) "Environmental Fate of Low Vapor Pressure – Volatile Organic Compounds from Consumer Products: A Modeling Approach," University of California, Davis, $200,000, Proposal No. 2762-276

A Committee member submitted written comments, and asked for more detailed information regarding the modeling tools and the overall integration of the models and approach. Staff responded that the details of the functionality of the models are currently referred to in the literature on the reference list. Staff will ask the PI to include more details in the body of the proposal. The Committee member also suggested that straight-to-air evaporation pathway should dominate over down-the-drain downstream emissions. Staff agreed and explained that the focus of this project will be on the environmental fate of evaporated LVP-VOCs. The Committee member had concerns that, although the described approach may study the issue to the best extent possible, there is some uncertainty as to whether the objectives can be achieved and if any definitive answers will result. Staff responded that we understand that this is our first effort in developing

environmental fate models for LVP-VOCs, and we agree that there may be relatively large uncertainties in the modeling results. However, it is believed that the project can provide ARB with a first-order estimation of emission correction factors for LVP-VOCs.

The Committee was concerned that no actual measurements of specific LVP-VOCs in wastewater are included in the proposal. Staff responded that for this first project, a focus on the modeling is believed to be the most productive use of the limited funds. The specific LVP-VOCs that may be disposed down the drain and in the wastewater will be determined by reviewing the literature and consulting with the advisory group which includes staff from ARB and South Coast Air Quality Management District, and representatives from the consumer products industry.

One Committee member commended staff on dividing the LVP-VOC research into two complementary projects, and believed that the project will be successful because of the experience and expertise of the investigators in environmental fate modeling.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

7) "Co-Exposure to Particulate Matter and Ozone: Pulmonary C-fiber and Platelet Activation in Decreased Heart Rate Variability," University of California, Davis, $600,782, Proposal No. 2763-276

The Committee indicated that the proposal was clearly written, was technically strong, and likely to be successful. Several minor points were raised, with the request that the investigator address them in the final proposal. The Committee asked that the mention of translocation of particles in the introduction, including PM2.5, be edited to reflect that this has not been demonstrated for PM2.5. The Committee also asked that the investigators use Teflon filters rather than glass fiber filters in the PM2.5 monitor due to well-known bias issues with use of glass fiber filters in this type of application.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal. Irva Hertz-Picciotto recused herself.

8) "Cardiovascular Effects of Multi-Pollutant Exposure: Mechanisms and Interactions, "University of California, Irvine, $600,782, Proposal No. 2764-276

After this proposal was sent to the Committee, staff asked the investigator to submit an addendum to the proposal that added two experiments to the project,

at a cost of an additional $156,808. Staff presented the addendum to the Committee, which commented that the additional experiments strengthened the value of an already strong project. The Committee asked that several clarifications be made in the final proposal. In response to questions from the Committee, staff confirmed that a sentence was missing on page 19 under Aim 3. The text should have indicated that the denuder experiment would also be performed during a period of low ambient ozone. Committee members asked that the hypotheses be clarified with reference to the comparisons between experiments performed during periods of high and low ambient ozone, that it be clarified whether experiments for aims one and three will be performed simultaneously, and that the investigator indicate whether the electrocardiogram (ECG) will be monitored continuously, and what time period(s) will be used for the analyses. The Committee noted a typo on page 33 with reference to the ozone concentration. On this page the text indicates that the investigator will use an ozone concentration of 0.1 ppm, while elsewhere in the proposal it says 0.2 ppm. A Committee member also noted that some text is missing from the justification section on page 12 of the budget.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

9) "Developing a New Methodology for Analyzing Potential Displacement," University of California, Berkeley, $695,792, Proposal No. 2765-276

Overall, the Committee found the proposed project to be innovative, timely, and very policy-relevant—addressing a critical question that will shape how sustainable communities strategies are developed and their long-rang impacts among diverse communities. A few minor suggestions from the Committee included explaining how the analysis might apply to Bus Rapid Transit; providing more detail on the metrics to be used in the demographic analysis; expanding the interview of key stakeholders to gain preliminary input to inform neighborhood change metrics and the methods to be used to evaluate anti-displacement policies; more robust description of how some of the data in Task 4 is appropriate; and expanding details on how the collected qualitative data will be analyzed. In addition, the Committee had a question about the operational definition of Transit-Oriented Development defined as ½ mile from light rail transit and asked that the ability to expand this definition be explored. Staff found this feedback to be useful and will have the research team address these points.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the proposal.

10) "Effectiveness of Sound Wall-Vegetation Combination Barriers as Near-Roadway Pollutant Mitigation Strategies," University of California, Los Angeles, $516,139, Proposal No. 2766-276

There were two major concerns that were identified with the proposal. First, there was concern about the relevance of making noise measurements as the effects of sound walls and noise were already well-documented. Second, there was a recommendation to increase 3D wind measurements from 3 anemometers to 5 anemometers to better characterize the flow regime by a sound wall. Committee members felt at least five were needed for a successful study. It was suggested by Committee members that additional meteorological measurements replace the sound measurements. Response by staff and management highlight the interest and need for concurrent sound and noise measurements as there have been health effects associated with sound. To address the concern with meteorological measurements, a phone call will be set up with the PIs and concerned Committee members to discuss and resolve the issue. The proposal was approved provisionally pending discussion with PIs on issues stated above.

Motion: Moved to accept subject to inclusion of comments from staff and Committee, and sufficient 3D sonic anemometer measurement to determine velocities along the tower and at the air monitoring locations; removal of sound pressure levels measurements is acceptable if this will provide additional resources to allocate to collection of meteorological data.

(Shortly after the RSC meeting, staff coordinated a discussion with concerned RSC members and PIs to resolve the issue of micrometeorological measurements. The PIs were receptive to RSC comments and it was agreed that two additional 3D sonic anemometers should be added to the complement of measurements proposed; these sonics would be purchased by RD. Sound measurements were removed from the proposal.)

The Committee approved the proposal.

III. Response to a Request for Proposal (RFP)

1) "Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles," Southwest Research Institute, $1,599,744, Proposal No. 2767-276

The Committee agreed with staff's suggested selection of the Southwest Research Institute's proposal for this project.

Motion: Move to accept.

The Committee approved the proposal.

The meeting adjourned at 12:25 p.m.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.1
DATE: October 18, 2013
CONTRACT NO.: 10-303
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Persistent Immune Effects of Wildfire Particulate Matter Exposure during Childhood Development
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Lisa A. Miller, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$268,029
CONTRACT TERM:	36 months

For further information, please contact Dr. Alvaro Alvarado, Ph.D. at (916) 445-4843.

I. SUMMARY

Little is known about whether air pollution exposure during early life has life-long impacts. Some have speculated that air pollution exposure during the early childhood lung development period could alter lung and immune system development in ways that increase susceptibility to lung-related disease later in life. This project investigated the impact of early childhood exposure to ozone and particulate matter on lung function development, and development of immune system parameters that modulate responses to infectious disease and contribute to lung function decline with aging. The study involved a cohort of rhesus monkeys that were born during the three-month period prior to the wildfires that impacted the Sacramento Valley during June and July 2008. Half of the cohort lived outdoors from birth, and was exposed to the elevated air pollution concentrations that occurred during the fires, while the other half of the cohort was born during the same months of 2009, and was also raised outdoors. The results suggest that early life exposure to combined ozone and wildfire PM2.5 can result in immune and lung function decrements that persist with maturity.

II. TECHNICAL SUMMARY.

Objective

The primary objective of this proposal was to determine the impact of early life exposure to ambient ozone and wildfire PM on development of lung function and immune parameters that modulate responses to infectious disease. Toll-like receptors (TLR) are key regulators of immune responses to infectious diseases, and they are responsible for recognizing and activating the body's immune responses to microbial assaults. There are several TLRs, each of which recognizes genetic material from specific microbial pathogens (ligands). The specific objectives were: 1) to determine if the response to Toll-like receptor ligands in venous blood samples was persistently modulated with combined episodic ozone and PM exposure during early childhood: and 2) to determine if lung function and mechanics were persistently compromised with combined episodic ozone and PM exposure.

Background

Epidemiologic studies support a link between air pollution exposure during early life and lung function decrements during childhood and young adulthood. Furthermore, early life exposures in children appear to be distinguished by the establishment of a persistent effect on lung function that is retained at maturity. Although these findings provide important correlative data in human subjects, the biologic mechanisms for these effects are not understood. Moreover, direct scientific evaluation of children is restricted due to limitations in experimental assessment and methodology.

During June and July 2008 a series of wildfires burned in Northern California. Smoke from the fires led to high PM2.5 levels for several weeks throughout the Sacramento Valley, including the area where the University of California, Davis (UC Davis) Primate Center is located. Previous research at the UC Davis Primate Center found that the first several months of life appears to be a highly sensitive window for development of susceptibility to ozone and/or allergen effects in the airways that persist into adulthood. Based on these observations, the investigators proposed to evaluate the effect of the smoke exposure in a cohort of rhesus monkeys that was born during the three months prior to the July 10, 2008 peak PM2.5 concentration event of the summer 2008 wildfires.

Project Summary

The investigators hypothesized that ozone and PM exposure during early life would result in persistent effects on innate immunity and lung function. To address this hypothesis, they investigated in rhesus monkeys (1) whether the peripheral blood response to Toll-like receptor ligands was modulated with exposure; and (2) whether lung function was compromised with exposure. The immune system and lung architecture of the rhesus monkey is very similar to that of humans, compared with other laboratory animal models.

To complete these objectives, the investigators assessed whether the exposures altered inflammatory mediator production (interleukins 6 and 8) that is controlled through signaling pathways regulated by Toll-like receptors 3, 4, and 5 in peripheral blood samples collected from a cohort of rhesus macaque monkeys that were born within the three months prior to the summer wildfires of July 2008. The animals were born and have continued to live in outdoor field cages. The control group, which was also born and always lived outdoors, was selected from animals born during the same three months of 2009. The 2008 animals were studied first, followed by the 2009 animals so that all were three years of age at the time of testing. The investigators also performed pulmonary function testing on the same animals to determine if airway mechanics have been compromised with fire smoke exposure. Finally, the investigators investigated whether there were correlations between lung function, immune parameters, and air pollution exposure. This was a non-terminal and minimally invasive experiment, involving one series of lung function testing and a peripheral blood draw that was performed while the animals were sedated for lung function testing.

Lung function studies included quasi-static respiratory system compliance, total lung capacity, vital capacity, inspiratory capacity, functional residual capacity, and expiratory flow rates, and methacholine challenge for measurement of airways hyperresponsiveness using standard techniques. Previous studies suggested that prior history of ozone exposure can modulate the peripheral blood response to ligands for Toll-like receptors 4 and 5. Based on these observations, production of interleukins 6 and 8 were measured in peripheral blood mononuclear cell cultures that were

stimulated with toll-like receptor, 4, and 5 ligands using well-established methods. Data analysis was by analysis of variance, with appropriate post-hoc tests.

The results show that peripheral blood cells from the fire smoke-exposed rhesus monkeys produced significantly less cytokine in response to stimulation with microbial ligands in culture, as compared with animals born in 2009, indicating that the fire smoke exposed animals were less able to mount an immune defense against infectious agents. There was no significant effect of fire smoke exposure on lung function overall, although there was a significant correlation between both increased airways hyperresponsiveness and reduced lung compliance with reduced peripheral blood cell cytokine synthesis in animals born shortly before the fires. An unexpected finding was that the degree of immune dysregulation was gender dependent and was correlated with lung function in female monkeys. The data show that early life exposure to episodic ozone and wildfire PM2.5 exposure during infancy can lead to both reduced innate immunity and lung function decrements that persist at maturity.

III. STAFF COMMENTS

The investigator submitted one previous draft of the report that was reviewed by four ARB staff. The present version incorporates the comments from the initial review, and was reviewed by six ARB staff and a scientist from the U.S. Environmental Protection Agency.

There are several typos and minor editorial issues that will be corrected in the final version of the report. Although the figure captions mention statistical methods, there is no specific description given. The investigator will add a paragraph to the methods section describing the methods used for the statistical analysis. The investigator will make clearer which bars are statistically different in the right-hand panel of figure five.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.2
DATE: October 18, 2013
CONTRACT NO.: 09-342
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	In-Duct Cleaning Devices: Ozone Emissions Rates and Test Methodology
CONTRACTOR:	University of Missouri Science & Technology
PRINCIPAL INVESTIGATOR:	Glenn Morrison, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$325,000
CONTRACT TERM:	42 months

For further information, please contact Peggy Jenkins at (916) 323-1504.

I. SUMMARY

This study examined the ozone emission rates and the increase in indoor ozone concentrations from the use of electrically connected in-duct air cleaners through a combination of laboratory experiments, test method development, field studies and modeling analyses. A complete laboratory test apparatus and standard test method (STM) were developed simultaneously during this study. Emission rates from the models tested in the laboratory ranged from below the detection limit, to greater than 100 mg per hour. In addition to laboratory tests, field tests of in-duct devices were completed in seven residential buildings and one classroom. The incremental increase in the ozone concentration due to the operation of these devices ranged from not detectable to as high as 134 parts per billion (ppb). Two models increased the ozone concentration in field residences by greater than 50 ppb. Finally, a standard "mass-balance" model of indoor air concentrations of ozone demonstrated that use of ozone-emitting, electrically connected in-duct air cleaners can raise ozone concentrations substantially in buildings typical of residences in California. For a typical house, the model predicted that an emission rate of approximately 150 mg per hour would raise the indoor concentration by about 50 ppb. For an "at risk" house, or one that

has characteristics that enhance indoor ozone concentrations, 50 ppb could be achieved with emission rates as low as 27 mg per hour. The modeling results and the measured ozone concentrations in the field in this study showed reasonable agreement for most devices. Based on model analysis, laboratory testing and field studies, the project team concluded that the use of electrically connected in-duct air cleaners of the types studied in this research can increase residential indoor concentrations of ozone above the current California limit set for portable ozone generating devices.

II. TECHNICAL SUMMARY

Objectives

The objectives of this project were to: 1) develop and test a method of measuring ozone emissions of electrically-connected, in-duct air cleaners ("device"); and 2) obtain real-world data on increased room ozone concentrations due to use of these devices in field sites. Two secondary objectives were to: 3) apply the method to a number of commercially available units in the laboratory to measure emission rates; and 4) estimate the impact of in-duct air cleaners on indoor concentrations in typical California buildings.

Background

In 2007, the California Air Resources Board (ARB) adopted a regulation limiting the emission of ozone from indoor air cleaning devices. However, due to the lack of a suitable test method for measuring emissions from air cleaners that are physically integrated into the duct work of the central ventilation system, and a lack of ozone emissions data from such devices, so called "in-duct" air cleaning devices were exempted from the requirements of the regulation. There are a number of in-duct intentional ozone generators as well as in-duct electrostatic precipitators, ionizers, electrically-enhanced media (actively connected to AC/DC source), and ultraviolet air cleaners known to emit ozone that are marketed in California. There is reason to believe that some of these may generate significant amounts of ozone and/or ozone reaction byproducts such as formaldehyde.

The presence of ozone in the indoor environment can have serious health consequences in addition to detrimental effects on building and household materials.

Human exposure to ozone, even at relatively low levels, has been found to cause a variety of adverse health effects including decreases in pulmonary function and increases in reported symptoms such as cough, difficulty breathing and chest tightness.

Given the paucity of data on the operation of in-duct electronic air cleaners, measurement of emission rates of modern devices is needed. Further, if a maximum ozone emission rate standard is deemed necessary to protect health, an accurate, readily transferrable test method for emission rates would also be needed. Finally, the impact of in-duct air cleaners on the resulting ozone concentration in California homes will help ARB determine whether an emission rate standard is necessary, and provide guidance on an appropriate standard level.

Materials and Methods

The first task of the study was to develop a list of in-duct electronic air cleaners that may emit ozone and are likely (or potentially) installed in California buildings. The investigators contacted manufacturers; distributors; 72 heating, ventilation, and air conditioning (HVAC) installers in California; and various agencies and organizations to obtain information on the brands sold and installed in California and devices of greatest concern. Based on the information obtained, and in consultation with ARB staff, the investigators developed a list of devices to acquire and test.

A primary goal of this study was to develop a standard test method (STM) to measure the ozone emission rates of the in-duct air cleaners identified in the first task. To accomplish this, it was crucial that the measurement apparatus and the test method be both technically accurate and easy to follow and apply. Several key requirements were considered in the development of the apparatus and method. For example, the test apparatus needed to be non-reactive with ozone, large enough to accommodate the in-duct devices, able to generate variable flows comparable to those of common residential systems and obtain accurate flow measurements with a relative uncertainty of 10 percent or better, and able to prevent ozone release into the lab and subsequent contamination of the emissions results. Additionally, the ozone measurement device needed a stated accuracy of 2 ppb (absolute) or 2 percent (relative) or better and a fast response time.

The investigators built a closed loop test apparatus constructed of galvanized and stainless steel sections that met the above criteria. Airflow was generated by two five-ton residential air handler units and ozone was sampled using a 15-point sampling grid. Once the testing apparatus was constructed and the STM developed, 12 in-duct devices representing eight different models were tested to determine the ozone emission rate, the effect of airflow on the emission rate, the influence of temperature and humidity on the emission rate, and the repeatability of testing.

In-duct air cleaners were field tested in one home located in Tulsa, Oklahoma, and in six homes in the Davis/Sacramento region of California. One commercial air cleaner was also tested in a California elementary school. Measurements taken in the field included indoor and outdoor ozone concentrations, changes in indoor ozone concentrations due to operation of the in-duct device, air exchange rates (AER) and ozone decay rates (ODR), and an estimated ozone emissions rate (OER) for the device. Air exchange rates were determined using CO_2 as a tracer gas and following its decay. The AER and ODR methods were both based on ASTM standard E741-11, as well as other methods described in the literature. Changes in the ozone concentration due to the installed in-duct device were monitored at the supply and return of the central air system. Ozone levels were monitored for 30 minutes using a 2B Tech (model 202) ozone monitor to establish a baseline, after which the in-duct device was turned on and the ozone concentrations at the central air supply and return were recorded at no greater than two minute intervals for 4.5 hours.

Finally, simulated indoor concentrations of ozone were estimated using standard single and multi-zone models. Single zone, steady-state indoor ozone concentrations were modeled for homes using two scenarios. One model assumed a standard California home in which average values of building volume, air exchange rates, ozone penetration, and ozone decay rates were used that were representative of California building stock. The other was an “at risk” home in which parameters such as air exchange and ozone decay would maximize the potential indoor ozone concentration. In addition to the single zone models developed in this study, more refined multi-zone models using CONTAM 3.0 (a model designed for estimating indoor concentrations

using product emissions data) were also used to simulate ozone concentrations that might be expected in individual rooms of a home when air movement between rooms, wind direction, reactive chemistry, deposition of contaminants, buildup of ozone in the ducts and other factors were considered.

Results

The investigators first identified the types of in-duct air cleaners available and grouped them into several general classes: electrostatic precipitators; electronically enhanced filtration; ultraviolet light bulbs; photocatalytic oxidation; ozone, hydroxyl, or hydroperoxide generators; and hybrid systems. Hydroxyl ion generators, ozone generators, and ultraviolet (UV) technologies were identified as the major types with high ozone generating potential. The most common class of device mentioned by installers was electrostatic precipitators.

A primary result of this research was the development of the STM, by which the emission rates for in-duct air cleaning devices could be determined. Several key requirements for measuring ozone emissions from an in-duct device were successfully met in the development of the apparatus and method, which are described in the STM. The apparatus developed as part of this study was tested extensively and was determined to have a method quantitation limit (MQL) of 2.3 mg ozone per hour.

The emissions rates from 12 air cleaners (eight models represented) were determined using the STM. Two of the devices had emission rates below the MQL. One device in the ultraviolet light bulbs category that was tested at the highest flow rate in the test apparatus had the highest emission rate among the devices tested, at approximately 350 mg per hour of ozone produced. Emissions rates of the other models tested ranged from approximately 6-100 mg per hour. In general, most devices were insensitive to flow rates in the test apparatus; however, some variability was observed for one device.

Field testing of the in-duct devices was completed in seven residential buildings. One commercial unit was tested in a classroom setting. In the residential buildings, observed incremental increases in ozone ranged from below the MQL to as high as 134 ppb for the HVAC UV 560 device. Two electrostatic precipitator devices raised indoor ozone

concentrations between 5 and 22 ppb. Two other models that intentionally generate ozone with ultraviolet light increased the ozone concentration in residences more than 50 ppb. Taking into account the incremental increase in ozone and other factors such ozone decay rates, it was estimated that the emission rates for the devices tested ranged from below the detection limit, to greater than 400 mg per hour, with the UV light devices consistently being the class of device with the highest emission rates. For the commercial in-duct device, the ozone steady state levels and emission rate were both minimal, at 14.4 ppb and 18 mg/hr, respectively.

Indoor ozone concentrations that would result from the use of in-duct devices were also simulated using standard mass balance models. For the standard home, the model predicted that indoor ozone would reach concentrations of 50 ppb when the emission rate of the device is around 150 mg per hour. However, for an “at risk” home, the model predicted that the same concentration would be reached with a much lower emissions rate of only 27 mg per hour.

The multi-zone models revealed that separate rooms can have very different concentrations of ozone, particularly when considering devices that can remain on when the air handler is not operating. For lower reactivity (high risk) buildings, indoor concentrations can exceed 50 ppb when the air handler is operating. Also, when the air handler is operating, dynamic indoor ozone concentrations can rise to greater than 100 ppb in a matter of a few minutes. For a 100 mg per hour device, the model predicted that indoor concentrations would range from 15-20 ppb to 35-50 ppb for devices with duty cycles of 20 percent and 50 percent, respectively. Measured and modeled ozone concentrations were within a factor of two for most devices. For the model that exhibited the most erratic emission rates, the simulated concentration was within a factor of about three for the measured concentration.

From the results of the study, the investigators concluded that in-duct ozone devices have the potential to raise indoor ozone concentrations above the California limit currently in place for portable air cleaners. Because the measured and simulated indoor ozone concentrations in this study were generally in agreement, they also concluded that the laboratory test method can be used to determine ozone emission rates that can

reasonably be incorporated into mass balance models to predict potential indoor ozone concentrations that might be expected from the use of in-duct devices.

III. STAFF COMMENTS

The investigators of this study put substantial effort into the development of a novel testing apparatus and method, and gathered a considerable amount of data from the field testing. ARB staff reviewed and commented on the preliminary draft of the final report. Several editorial and organizational comments were provided to the investigator, and clarification was requested regarding the modeling and a few other areas. Appropriate changes were made by the investigators. However, staff has a few additional minor comments on the revised report provided to the Committee that will need to be addressed.

IV. STAFF RECOMMENDATIONS

Staff recommends that the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.3
DATE: October 18, 2013
CONTRACT NO.: 09-343
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Quantifying the Effect of Local Government Actions on Vehicle Miles Traveled
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Deborah Salon, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$125,000
CONTRACT TERM:	46 months

For further information, please contact Annmarie Rodgers at (916) 323-1517.

I. SUMMARY

On-road vehicles generate more than one-third of California's greenhouse gas (GHG) emissions annually. While the state is moving forward with vehicle emission standards and low-carbon fuel standards to reduce transportation emissions to meet the goals of Assembly Bill (AB) 32, an overall reduction in vehicle miles traveled (VMT) is also critical to achieve the 2020 climate target. In 2008, Senate Bill (SB) 375 was adopted requiring California regions to prepare a Sustainable Community Strategy that identifies how the region will achieve GHG reduction targets through integrated land use, housing and transportation planning. Regional planners and local government officials have limited information on which strategies will be most effective to reduce VMT in their area. Past research studies provide basic information on whether certain policies may have a positive or negative affect on reducing VMT. Little evidence was available that provided local estimates of how changes in land use and transportation variables, such as access to public transit and land use mix, might lead to local changes in VMT. Local estimates were needed because a strategy likely does not have the same impact across all neighborhood types. For instance, increasing public transit capacity in an urban area that already has a robust system may lead to a greater change in VMT than introducing

public transit to a rural area with little ridership potential. Research was needed to provide information to local governments to assist them in evaluating which policies would be most effective to reduce VMT within each of their existing neighborhood types, also referred to as “local context.” The results of this study are expected to provide local and regional assistance to meet statewide targets to reduce GHG emissions and overall VMT.

II. TECHNICAL SUMMARY

Objective

The objective of this study was to begin to fill the gap in literature and better quantify the effect of local government actions on reducing VMT. The research team used extensive travel survey data and land use transportation data and multiple statistical models to estimate the elasticity and marginal effects of commute trip VMT, non-work trip VMT, and total household VMT with respect to a variety of policy-relevant variables depending on the local context and the socioeconomic characteristics of the commuter, shopper, and household, respectively. The team also developed a tool for local governments that made the study’s findings accessible, easy to interpret, and informative in improving policy decisions to reduce local and regional VMT.

Background

A number of studies have been conducted to explore the relationship between travel behavior and land use and transportation variables. Most of these studies are only able to provide the directionality of the impacts of land use and transportation variables on travel behavior such as whether a local government action would have a positive or negative effect on reducing VMT. One of the first tasks completed for this research project involved a review of existing literature to explore the relationship between policy variables and the effect on VMT. Individual studies differed in estimating the effect that policies and programs have on VMT. Most of the literature reports average effects over large geographies and diverse populations, but, very little evaluated how the policies can affect VMT differently depending on existing local context. This research study begins to fill this research gap and quantify local government policy options and their effect on VMT as a function of the local or regional context. The research team used multiple statistical methods to estimate the relationships between land use and

transportation system variables and VMT. They developed an easy to use tool to assist local governments with prioritizing future actions based on their existing local context.

Methods

Merging of Datasets

The Principal Investigator (PI) merged observations from five travel surveys; two were from statewide surveys and three were regional surveys. To augment the travel survey data, the PI calculated the distance for each vehicle trip taken and added a number of variables to the dataset to represent the built environment. The land use and transportation system variables were derived from census data and calculated from GIS and other mapping software. In addition to direct census variables, the merged comprehensive dataset included land use variables such as job accessibility, land use mix, restaurant access, road density, and gasoline price.

Classifying Census Tracts into Residential Neighborhood Types

The PI used five steps to classify census tracts into residential neighborhood types using factor-cluster analysis. The analysis resulted in seven named neighborhood types: 1) Urban Low Transit Use; 2) Suburb with Multifamily Housing; 3) Central City Urban; 4) Rural; 5) Suburb with Single-Family Homes; 6) Urban High Transit Use; 7) Rural-In-Urban; and 8) Preserved Land. Classifying census tracts allowed the research team to control for residential self-selection as well as estimate separate effects of policy variables on VMT for each of the neighborhood types.

Generating Weights to Represent California's Population

In order to report summary statistics from the merged datasets that are representative of California's population, the research team calculated and applied post-stratification weights for three important variables: household income, census tract neighborhood type, and life stage. After consulting statistical literature, the research team decided only to use weights related to those three variables and decided not to use weights for the statistical analysis of the other determinants of VMT.

Empirical Estimation Approach

The PI used a multinomial logit (MNL) model to estimate household choice of which neighborhood type to live in. The PI used the tobit model, also called a censored regression model, to address the statistical challenge presented by the large number of zero VMT observations and estimate VMT for each neighborhood type. The PI connected the tobit analyses to the MNL model to control for residential neighborhood type self-selection. Next, the PI used these models to calculate the marginal effects and elasticities for three measurements of VMT: total household VMT, individual non-work trip VMT, and individual commute trip VMT using the following land use and transportation system variables: average gasoline price, local job access, regional job access, transit access, pedestrian and bicycle friendliness, percent of housing that is single family detached, road density, and land use mix. For purposes of this study, the marginal effect is defined as the absolute change in VMT when the land use or transportation variable changes by one unit. Elasticity in the percent change in VMT when the land use or transportation variable changes by one percent.

Development of VMT Impact Spreadsheet Tool

The PI developed a spreadsheet tool which will allow the research findings to be used across the state for local governments' policy making. The tool offers a transparent framework of look-up tables that are quick to use and estimates very localized (neighborhood level) relationships and the effect of new policies on reducing VMT. This tool can be used to quickly come up with regional and local reductions in VMT, but is not meant to supplant the much larger modeling tools.

Summary Statistics of Full Dataset

In order to provide some context for the analysis of the determinants of VMT, the PI developed a summary of the statistics from the merged dataset in the final report. As expected, the mean household VMT varied substantially across all of the variables. Households with young children travel more than those with older adults. Households with more members have higher VMT. Weekly VMT is lowest in rural areas and highest in the San Francisco Bay Area. There was also a significant difference in mean weekday VMT between neighborhood types.

Results and Conclusions

The research findings indicate that local context does affect VMT sensitivity. This study advances the research gap and illustrates the effects of changes in the land use-transport system on daily VMT do depend on the initial built environment. The results of this study will be useful to assist local governments with prioritizing which policies may offer the most effective means of reducing VMT given their existing local context. Additional research is needed to better understand the synergistic effects of implementing more than one policy at the local level. The research team suggested performing natural experiments with "before-after data collection and carefully selected control groups" to improve understanding of causal relationships between factors and VMT. There is also a need to improve the links between land use and transportation system variables used in the literature and real-world policies implemented by local governments.

III. STAFF COMMENTS

This project addresses a critical gap in research to quantify changes in VMT as a result of local government policies and local context. The draft final report was reviewed by staff members of the Research and Air Quality Planning and Science Divisions as well as staff from the California Department of Transportation. The following comments were integrated into the revised draft final report.

The draft final report mentioned this significant point, "We find that the effects of some land use and transport system characteristics do depend on neighborhood type, in ways that are intuitive but had not previously been empirically verified." The review team suggested emphasizing this important point of the research as part of the Abstract/Executive Summary and also in the Conclusion.

The review team also recommended expanding the text on the significance of the five travel survey data merging effort, explaining why this has not been done before and what more it offers. Similarly, the research team suggested that the report include

recommendations for improvements to travel survey questions, to improve future surveys and refine the tool further in the next five to 10 years.

The review team asked for the PI to explain why the block group with the highest density was taken to represent the census tract as opposed to the distance-weighted sum of jobs for each block groups averaged or the median. The PI agreed with this recommendation and recreated this variable as a population-weighted average of jobs access for each tract and re-estimated the models.

The review team suggested expanding the conclusions of the report to explain the main research goal to quantify the effect of local government actions on reducing VMT as a function of local context. They also suggested that the report conclusion be updated to better address how this research will relate to local governments and their choices; how the research and the tool can be used by local government and at what state in the planning process given the geographical scale of the data and tool. Finally, the review team suggested that the PI expand the discussion on areas of future research. The draft final report included a bulleted list of four ideas for future research.

In developing the merged dataset, a number of land use and transportation system variables were taken directly from the 2000 census. The review team recommended updating the dataset with the most current 2010 census. This change has not been made. Staff recommends the RSC support this change to the final tool.

There are no remaining concerns or issues regarding the final draft report. Results of the study will be used to assist local governments with quantifying policy decisions and their effect on VMT as a function of local context. Ultimately, the project will advance California efforts for meeting the AB 32 and SB 375 targets.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee approve this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.4
DATE: October 18, 2013
CONTRACT NO.: 10-323
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Residential Energy Use and Greenhouse Gas Emissions' Impacts of Compact Land Use Types
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATORS:	Edward A. Arens, Ph.D. Louise A. Mozingo, M.L.A.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$100,000
CONTRACT TERM:	31 Months

For further information, please contact Annmarie Rodgers at (916) 323-1517.

I. SUMMARY

Nearly 15 percent of statewide greenhouse gas (GHG) emissions are related to heating and cooling residential buildings, which are partly a function of house size and orientation, and are therefore strongly tied to land use planning decisions. A few academic studies examined national data sets of residential energy use as a function of urban form, which indicated that residents living in high-density urban centers emit 20 to 50 percent fewer GHG emissions than residents of low-density suburbs. The objective of this research was to 1) investigate the relationship between land use planning factors and residential energy use in California's various climate zones; and 2) develop a spreadsheet modeling tool that analyzes residential energy use as a function of land use planning factors. The research results will be useful to local planners for comparing various development scenarios when preparing general plans or climate action plans. Until now, there have been no easy-to-use calculators for local land use planners to estimate the GHG emissions of residential energy use from various land use planning designations. This tool is intended to fill that gap and assist local

planners in meeting the State's GHG reduction targets under AB 32 and Executive Order S-3-05.

II. TECHNICAL SUMMARY

Objective

The main objective of this research was to develop a spreadsheet modeling tool that local governments can use to estimate GHG emissions from residential building energy use, which would result from accommodating new growth in different land use types. The tool will be used to evaluate GHG emissions for use at the planning and policy level in California. The goal was that it would require relatively few data inputs to quickly pick and choose between various residential land use policies to reduce GHG emissions.

Background

At the time of approving this research project, there were only two planning tools (I-PLACE^{3}S and Rapid Fire) in existence that examined the relationship between urban form, residential energy use, and GHG emissions. Both tools were proprietary and required a fee for use by local governments. While working on this project, two additional tools have come into the market and offer similar planning guidance: Subdivision Energy Analysis Tool (SEAT) and California Emissions Estimator Model (CalEEMOD). While SEAT is also proprietary, CalEEMOD is free of charge. CalEEMOD is a comprehensive tool for quantifying air quality impacts from California land use projects. The model was designed to be used for detailed environmental impact review for compliance with the California Environmental Quality Act and the National Environmental Policy Act purposes. All of these existing tools were developed for use to assist with in-depth analysis of land-use planning, which require users to input maps of street layouts and individual parcel-level data. Additional tools are available that convert residential energy use data into GHG emissions. However, none of the tools can easily estimate residential energy use due to providing new housing in different land use types. The research team developed a spreadsheet based modeling tool to estimate GHG emissions of future residential development; it does not require detailed parcel-level information, rather, it only requires the user to enter information on how many dwelling units (or acres) planned for development in each of the eight standard land use designations.

Proposal Summary

The research team completed research in three major phases. They conducted interviews, created the spreadsheet calculator, and completed an evaluation of the calculator using four separate methods: preliminary validation, field-testing, validation, and comparison.

Interviews

The research team interviewed professional planners and designers of other GHG estimation tools. They focused on interviewing planners from different regions throughout the state. One of the main comments initially was that there was concern about the "proliferation of tools" to develop GHG inventories and estimating GHG reductions. There was also concern that many of the existing modeling tools run too slowly.

Development of Spreadsheet Calculator

Design of the calculator first required analyzing the relationship between land use type and median size of dwelling units within those land use types for a major metropolitan region in California. The research team developed two statistical models explaining electricity and natural gas use observed in the 2005 Residential Energy Consumption Survey (RECS) dataset. They also identified the anticipated GHG intensity of electricity and natural gas provided by every utility in California from 2012 to 2035. Lastly, they designed the spreadsheet calculator using Microsoft Excel, which provides users with the option of comparing up to three different land use scenarios.

Calculator Evaluation

This phase involved evaluating the spreadsheet calculator using four separate methods. First, the research team conducted preliminary validation of the calculator against the 2009 Residential Appliance Saturation Survey (RASS) dataset. Second, they completed field testing with local planners and tool designers. Third, the research team validated the tool against actual energy use data provided by the Sacramento Municipal Utility District (SMUD). Lastly, they compared the calculator results with CalEEMOD assumptions and results.

Results and Conclusions

Since local governments are essential partners in meeting the goals of AB 32, the calculator can be added to the suite of tools ARB is developing to assist cities and counties to quantify GHG emission reduction potential of land use policies adopted at the local level. This tool will also be useful in evaluating the GHG emission reduction potential of new residential development statewide to achieve the 2050 goal of Executive Order S-3-05 to reduce GHG emissions to 80 percent below 1990 levels. Few tools are available to help local governments assess the GHG impacts of land use decisions at the general plan or climate plan level, where a local government broadly outlines the location and form of long-term growth. The calculator tool should be useful to local governments developing climate action plans and general plans to evaluate the GHG emission reduction potential of various land use policies related to residential development. Cities and counties could use the results of the tool as an input to the more detailed proprietary tools to evaluate whether individual projects meet the intent of the climate policies.

III. STAFF COMMENTS

ARB staff in the Air Quality Planning and Science and Research Divisions reviewed and commented on the draft final report. One of the main comments was related to the emission factors used for estimating GHG emissions. The draft tool estimated GHG emissions using utility-specific emission factors. ARB staff suggested that the tool include emission factors associated with marginal electricity, the electricity provided by the utility to satisfy an increase in load rather than the utility's generation mix, which would include all electrical generating resources. The research team updated the spreadsheet to allow users to pick between both options and included a summary of the differences as part of the revised report.

Staff from the California Public Utilities Commission (CPUC) participated in a meeting where the report was summarized and they provided feedback on several key issues related to how the spreadsheet estimates future energy usage and incorporating zero net energy policies. The draft tool estimated future energy use based on recent history. CPUC staff recommended that the tool estimate future energy use based on Title 24 compliance. The research team updated the tool to allow users to estimate

future energy use based on historical usage or Title 24 compliance. Since California has a statewide goal for all new residential construction to be Zero Net Energy (ZNE) by 2020, CPUC staff recommended adding ZNE as the base building in all calculations post 2020. Additionally, ZNE could be a mitigation measure for development occurring prior to 2020. The research team did not incorporate this idea into the tool because they figured that, “planners don't need a calculator to figure that out, since the implied GHG emissions for residential energy from such houses would be zero (or very close to it).” ARB staff believes this may still be a consideration for updating the tool. As ZNE is incorporated into the Title 24 Energy Code, it will be based on “regulated” loads. Plug loads are not currently regulated and may actually cause a home to use energy even if it is designed as ZNE.

Staff met with the research team to identify comments, which have been summarized as part of this staff evaluation. Staff also received an updated version of the final draft report, which incorporates most of the suggested changes. There are no additional major concerns or issues regarding the draft final report at this time. If additional issues arise, they will be presented at the RSC meeting.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.5
DATE: October 18, 2013
CONTRACT NO.: 09-348
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Inverse Modeling to Verify California's Greenhouse Gas Emission Inventory
CONTRACTOR:	California State University, East Bay
PRINCIPAL INVESTIGATOR:	Marc L. Fischer Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$150,000
CONTRACT TERM:	42 months

For further information, please contact Dr. Abhilash Vijayan at (916) 324-0621.

I. SUMMARY

The California Global Warming Solutions Act of 2006 (AB 32) requires ARB to develop a statewide greenhouse gas (GHG) emissions inventory. This GHG emissions inventory is based on the International Panel on Climate Change (IPCC) recommended methodologies which use a "bottom-up" approach and calculate GHG emissions based on emission factors (e.g., grams of methane per gallon of gasoline combustion) multiplied by activity data (e.g., gallons of gasoline combusted). An accurate inventory is important for tracking progress towards meeting the AB 32 goals. As such, it is critical to evaluate the accuracy of the existing GHG emissions inventory, while continuing efforts to better understand and quantify GHG emissions in California.

This study uses ambient methane (CH_4) measurements and inverse modeling to estimate emissions and provide a comparison to the ARB-developed inventory. The inverse model relies on maps of CH_4 source locations and emission estimates to accurately estimate emissions. This study uses two different maps, one based on California-specific data and the other that uses a generalized approach (EDGAR 4.2). Utilizing these different maps as *a priori* emissions, along with ambient measurements, the analyses yield annually averaged posterior CH_4 emissions that are 1.30 - 1.74 times

larger than the ARB estimated CH_4 emissions. However, as can be seen from the large range of emission estimates, the modeling approach has large uncertainties derived from the different emission maps. The other part of the uncertainties lie in the inability of the model to accurately resolve the Southern California area and additional tower measurements in the South Coast air basin are recommended. Additional work is also needed to identify and reduce the remaining model uncertainties.

II. TECHNICAL SUMMARY

Objective

The objective of this project was to use ARB's tower-based ambient measurements along with inverse modeling to estimate emissions and provide a comparison to the ARB-developed CH_4 inventory, which is based on bottom-up (activity-based) methods.

Background

Recent studies have revealed significant differences in top-down ambient air measurement-based emission estimates and bottom-up inventory type estimates for non-CO_2 greenhouse gases. This study was designed to develop a modeling framework to provide more detailed and spatially resolved top-down estimates for comparison to ARB's greenhouse gas estimates. The modeling is based on ambient measurements using ARB's newly established greenhouse gas research network of towers, which currently focuses on methane since it can be accurately measured and has fewer confounding natural sources. This study provides information that can help pinpoint areas of uncertainty for the GHG inventory.

Proposal Summary

This project developed an inverse modeling framework and used it to estimate regional CH_4 emissions using ambient CH_4 concentrations measured at a network of towers. Two CH_4 emission maps were used as inputs to the inverse modeling: (1) based on a seasonally varying "California-specific" emissions map, calibrated to statewide CH_4 emission totals, and (2) the EDGAR4.2 CH_4 emission map, which is based on generalized approaches and data. The model used ambient measurements from ARB's elevated towers throughout the state and inputs on wind patterns and land coverage of

each tower from the Weather Research and Forecast (WRF) and Stochastic Time-Inverted Lagrangian Transport (STILT) models. Uncertainties due to wind velocity and boundary layer mixing depth are also evaluated.

The analyses yields annually averaged CH_4 emissions that are 1.30 - 1.74 times larger than the ARB estimated CH_4 emissions. The relatively large range of total emissions reflects the current limitation to uniquely resolve urban versus rural CH_4 emissions, particularly from southern California, and more measurements are necessary in this area to overcome this uncertainty.

The model also provided regional CH_4 emissions estimates by source. The results are best characterized for central California, where most of the towers reside. Additionally, central California meteorology is easier to model. This source-level analysis suggests that livestock and landfills are the predominant CH_4 emissions sources, though, as with the regional analysis, significant differences are observed between the results obtained with the CA-specific and the EDGAR4.2 CH_4 emission maps. The current inability of the modeling to adequately address southern California CH_4 emission and distinguish between urban and rural emissions is likely influencing the source-level conclusions. The differences in both the state and regional-level assessments points to the importance of the input emission maps to achieving accurate results. Effort must be taken to ensure accuracy of source strength and distribution.

In summary, the study showed that atmospheric CH_4 measurements can be used to estimate CH_4 emissions at regional scales using the inverse modeling approach, and that California's GHG inventory may be underestimating CH_4 emissions in the state, though considerable uncertainty remains. Additionally, the importance of the input inventory becomes readily apparent, suggesting them importance of investing in gridded state inventories for inverse modeling, and doing additional runs to improve the inventory spatially and methodologically.

Recommendations for work to reduce uncertainties include:

- Additional tower measurements and a validated atmospheric transport model for the South Coast Air Basin. The current tower network is effective in estimating CH_4 emissions from the central valley, which likely comprises a majority of the statewide inventory, but it does not strongly capture emissions from Southern California.

- Additional measurements of source specific tracers (e.g., VOC speciation and carbon isotopes) will help apportion emissions to different sources of CH_4.

- Uncertainty in the inverse model estimates of CH_4 emissions are dominated by uncertainty in meteorological modeling of trace gas transport. Additional work is needed to identify the source of these errors and reduce them.

III. STAFF COMMENTS

This project has shown that the inverse modeling framework, in combination with high accuracy greenhouse gas measurement data, can be used to evaluate and improve emissions inventories. As a result of this study, inverse modeling of a suite of major greenhouse gases is being undertaken in a follow-on contract. The project also led to the addition of at least one more ARB tower in the Los Angeles (LA) area. The LA area modeling will be further improved by ARB's collaboration with Caltech, the Jet Propulsion Laboratory, NIST, LBNL, and University of California, San Diego to develop an integrated, high density greenhouse gas measurement network in LA, aimed at understanding CH_4 and CO_2 emissions in the Los Angeles region. Finally, a VOC speciation study is currently underway to further study source attributions at the Walnut Grove tower.

Two minor tasks originally scoped in this project were not conducted. First, due to the lack of high-accuracy carbon monoxide (CO) data from the greenhouse gas measurement network, inverse modeling of CO to evaluate the precision of the model itself could not be carried out. Secondly, one of the tasks was to train ARB staff on the inverse modeling framework but due to changes in ARB staffing, no appropriate person

was identified so this task was not conducted. The allocated budget for both tasks was applied to conduct more modeling for one additional month each season to minimize uncertainties.

This project was previously presented at the October 26th, 2012 Research Screening Committee meeting. The Research Screening Committee discussed and accepted the technical substance of the research. However, the Research Screening Committee asked for clearer communication of the methods and results in the final report. The PI has addressed the clarifying comments and edits from the Research Screening Committee. Overall, ARB staff considers the draft final report to be of high quality. Several clarifying comments and edits were sent to the PI. Additionally, ARB staff asked that additional conclusions and recommendations be considered and included in the report in order for ARB to improve the network in a way to improve the modeling results and address emission inventory concerns. ARB staff thinks the report is complete and provides the agency with valuable information on regional methane emissions.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO: II.6
DATE: October 18, 2013
CONTRACT NO.: 09-325
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Assessment of Nitrous Oxide Emissions in California's Dairy Systems
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	William Horwath, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$82,000
CONTRACT TERM:	36 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Nitrous oxide (N_2O) is known to be a major greenhouse gas (GHG) emitted from agricultural systems. There is, however, substantial uncertainty in its emission estimate due to the variable nature of its emission fluxes from agricultural soils, which can be affected by many environmental and management parameters. Quantifying the N_2O emissions from California agricultural soils is important to improve California's GHG emission inventory. This project, focusing on N_2O emissions from organic nitrogen sources, was conducted as a supplemental study to a previous investigation determining baseline N_2O emissions from nitrogen (N) fertilizer uses in California's cropping systems. The project provided N_2O emission data from three dairy farms with different cropping systems receiving both chemical and dairy manure as fertilizers in California. The results indicated that the annual emission rate of N_2O from the dairy forage fields ranged widely from 4.8 to 17 N_2O-N kg ha^{-1}, with an emission factor of 0.9 -1.7 percent. The N application rate, soil water content, and soil texture are the main factors controlling N_2O emissions. The project improved our understanding of N_2O emissions from California agricultural land and confirmed that California dairy farms

with irrigated forage cropland receiving extraordinarily high N inputs are hot spots of N_2O emissions.

II. TECHNICAL SUMMARY

Objectives

The objective of this project was to characterize N_2O emissions in California forage cropping systems receiving dairy lagoon waste, solid manure, and synthetic nitrogen fertilizers. The N_2O fluxes were measured in three dairy farms with different forage production systems to determine the seasonal and annual emission rates of N_2O and identify key environmental conditions that affect N_2O emissions.

Background

Nitrous oxide emissions from agricultural soils have been estimated using a bottom-up, emission factor approach. However, production of N_2O from agricultural soils is a microbial process, affected by numerous environmental variables such as temperature, soil moisture content, and soil organic matter content. As a result, N_2O fluxes from soils are highly irregular both spatially and temporally, and can change significantly with crop, soil, or management practices. In intensively managed cropping systems, spikes of N_2O fluxes are often coupled with soil management events such as application of N fertilizers, irrigation/drainage, and tillage disturbance. Precipitation can also induce significant N_2O fluxes. Therefore, actual field measurements are needed to better characterize N_2O emissions from agricultural soils.

There have been a number of field studies measuring N_2O fluxes from crop and range land, but data are sparse in California's cropping systems for those with inputs of dairy waste. Approximately 400,000 acres of irrigated forage cropland in California receive dairy waste in various forms as N fertilizers, producing one of the highest annual N throughputs of any cropping system in the world with potentially substantial N_2O emissions. In addition, the soil conditions in the cropping systems receiving dairy waste tend to be more conducive to N_2O production because this N-containing waste has high levels of organic compounds, which could enhance both nitrification and denitrification, the major biochemical processes generating N_2O in soils.

Proposal Summary

The project consisted of the following major tasks:

1) Dairy farm selection: Three representative dairy farms with different forage production systems and N management practices were selected in Stanislaus (Farms A and B) and Sacramento (Farm C) Counties. The soils in Farms A and B are coarse-textured with a sand content of 70-84 percent, and the soil in Farm C is a clay containing 41 percent of clay particles. All three farms grew silage corn in summer. Farm A grew a mixture of grasses and legumes in fall and winter while Farm B grew wheat, and Farm C ryegrass.

2) Manure and N management: In all the farms, the dairy waste (manure) was processed following conventional procedures. The raw manure was first passed through a screen separating the liquid phase and large particles. Both fractions were used as N fertilizers in the forage fields, either as irrigation water or directly incorporated into the soil, together with chemical fertilizer (urea ammonium-nitrate or anhydrous ammonia). The three farms followed distinct N management practices in terms of the fertilizer application method and schedule, but all had very high N inputs, ranging from 750 to 1300 kg N ha^{-1} y^{-1}, which are typical for the forage cropping systems in California.

3) N_2O flux measurements: Measurements of N_2O fluxes in the silage fields were conducted from Spring, 2011 to Fall, 2012, covering two corn growing seasons and one winter season. The monitoring employed a static chamber technique using stainless steel rectangle chambers with a dimension of 50 x 30 x 10 cm. Gas samples were taken with a syringe, injected into sealed vials, and were then analyzed using gas chromatography. N_2O fluxes were collected on a daily basis or once every other day around the fertilization and irrigation events, and weekly or biweekly between these management events when N_2O fluxes were expected to be low.

Significant N_2O fluxes were detected in all the silage fields. The estimated annual N_2O emission rates ranged from 4.8 to 7.4 kg N_2O-N ha^{-1} for sites with sandy soils, corresponding to an emission factor of 0.9 to 1.5 percent, and 11 - 17 kg N_2O-N ha^{-1}

in clayed soils, corresponding to an emission factor of 1.7 percent, based on the amount of available N (NH_4^+, NO_3^-, and total dissolved organic N) applied. The overall mean of these emission factors was 1.2 percent, slightly higher than the default IPCC emission factor of 1.0 percent for synthetic N fertilizers. Emissions occurred during corn growing seasons contributed roughly 50 percent of the total annual emission rates in Farm A, and ≥80 percent in Farms B and C.

Soil temperature, soil moisture content (i.e., Water-Filled Pore Space or WFPS) and inorganic N (NH_4^+, NO_2^-, and NO_3^-) concentrations are all important factors governing N_2O emissions for a given soil, and are positively correlated to N_2O emissions. Soil properties also played a strong role in N_2O emission dynamics. The N_2O fluxes usually lasted in a few days in sandy soils, but as long as a few weeks in clay soils. Extrapolation of these results, however, should not be made to other dairy farms at this stage due to the difficulty to separate influences of N management practices from soil conditions at these sites. The three farms involved were real operating dairy systems and thus the study was not conducted under controlled conditions. Controlled experiments would be needed to better understand the impacts of soil properties on N_2O emissions in dairy systems. Due to the exceedingly high N inputs in the dairy forage systems, it is important to ration N application according to the crop demands in order to reduce the N_2O emissions.

III. STAFF COMMENTS

This project filled a critical data gap in characterizing N_2O emissions from agricultural soils, which is recognized to be one of the areas with the most uncertainty in the current California GHG inventory. The results showed the high emission rates of N_2O from dairy farms growing forage crops, and provided California-specific emissions factors for these systems.

The final report went through review twice by ARB staff from the Air Quality Planning and Science, Stationary Sources, and Research Divisions and by agricultural stakeholders. In response to review comments, the Principal Investigator appended more information on the measurement data and the sampling device imagine to the report.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

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DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: II.7
DATE: October 18, 2013
CONTRACT NO.: 09-329
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Assessment of Nitrogen Oxides Emissions from Soil in California Cropping Systems
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	William R. Horwath, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$83,500
CONTRACT TERM:	36 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Nitrogen oxides (NO_X) are air pollutants that can react with volatile organic compounds (VOCs) under sunlight to produce ozone (O_3). Due to the detrimental effects of ozone to human health and the environment, control of NO_X emissions is critical to improve air quality in California. Agricultural land is a known source of NO_X emissions, but its contribution to California's NO_X inventory is uncertain. On the global scale, it is estimated roughly 16 percent of the total NO_X emissions was produced from soils through processes known as nitrification-denitrification driven by soil microorganisms. Application of nitrogen (N) fertilizers in agricultural land provides N substrate to the nitrification-denitrification process, and therefore enhances NO_X emissions from soils. This project measured soil NO_X emission fluxes from five major California's cropping systems under various environmental conditions and management practices. Significant NO_x emissions were detected in all crop fields, with an average flux ranged from 0.04 g NO_x-N ha^{-1} h^{-1} in wheat to 2.79 g NO_x-N ha^{-1} h^{-1} in tomato at the highest N application rate. The results of the study are expected to be useful in ozone modeling,

providing an estimate of NO_x contribution from agricultural land which is currently missing from California's NO_x inventory.

II. TECHNICAL SUMMARY

Objective

The objectives of this project were to measure NO_X emission fluxes from five cropping systems in California under various management conditions, and to identify key environmental and management variables that influence NO_X emissions from soils.

Background

As an ozone precursor, NO_X is one of the most concerned air pollutants. Emission controls on ozone precursors are essential to reduce O_3 concentrations in California, especially in summer months when O_3 levels in some areas, for example, San Joaquin Valley (SJV), frequently exceed the State's ambient air quality standard. Either NO_X or VOCs can limit O_3 formation. The effects of these precursors on O_3 production vary temporally and spatially across the landscape, depending not only on their concentrations, but also on the mixing ratio of NO_X to VOCs. Therefore, quantifying all major NO_X sources is essential to accurately predict O_3 levels.

Agricultural soils are known to be a source of NO_X, but there have been few studies on NO_X emissions from soils, especially in California. ARB funded an earlier study monitoring NO_X emissions from the cropland in SJV, but the project did not target specific soil management events, such as fertilization or irrigation, which are expected to produce spikes of NO_X, and thus potentially underestimated the NO_X emissions. The lack of information on soil NO_X emissions not only creates a data gap in California's NO_X inventory, but also restricts ARB's ability to improve O_3 modeling. This project helped address this data gap and provided the much needed field data that can potentially lead to develop better control strategies for the O_3 precursors. This project was cost-effective because it was an add-on to three concurrent studies targeting nitrous oxide (N_2O) emissions. Both gases are generated through the same processes of nitrification and denitrification in soil. NO_X (mainly NO) is a precursor of N_2O, and thus their emissions are expected to be related.

Proposal Summary

This study was supplemental to three concurrent N_2O monitoring projects and measured NO_X emissions from five cropping systems: almond, alfalfa, tomato, wheat, and silage corn in California, under 17 different soil or management treatments. NO_X measurements were made only in the summer months when O_3 in SJV was high, and controlling NO_X emissions is critical. A dynamic chamber method employing a NO_X-analyzer was used to collect and analyze NO_X emissions. The frequency of measurements was on a daily basis around the N fertilizer application and irrigation events, but was changed to weekly or biweekly between the management events when the emission fluxes were expected to be low. Two to six replicates of measurements were included for each treatment. The results derived from each cropping system are summarized below.

Almond: 189 measurements of NO_X fluxes were made in an almond field in Colusa County, CA. The site has a coarse-textured soil with 67 percent sand, and received an annual N rate of 50 kg N ha^{-1}, all in the tree rows where irrigation water and N fertilizer solution were applied through microjet sprinklers. NO_X fluxes were monitored in both tractor and tree rows to characterize the spatial variation of NO_X emissions in the field. As expected, the measured NO_X fluxes were much higher in the irrigated and fertilized tree rows with an average flux of 0.35 g NO_X-N ha^{-1} h^{-1}, almost six times that of the tractor rows (0.06 g NO_X-N ha^{-1} h^{-1}) where soils remained dry all summer. A similar trend was observed in the field for N_2O, a potent greenhouse gas, in a concurrent study. N_2O fluxes, monitored by a different group of researchers, were higher than NO_X, but both gases were in the same order of magnitude.

Alfalfa: The alfalfa site was located in Winters, CA, consisting of two fields with one-year-old and five-year-old stands, respectively. The soil is a clay loam with a high soil organic carbon content of 13 percent. Alfalfa is a legume crop which can fix atmospheric N and thus no N fertilizers were applied in the fields. Based on over 40 flux measurements at each field, the average NO_X flux for the 1-year old alfalfa stand was 0.54 g NO_X-N ha^{-1} h^{-1} and for the five-year old alfalfa stand was 0.19 g NO_X-N ha^{-1} h^{-1}. N_2O was measured concurrently at the site under a different ARB-sponsored project, and its fluxes were in general greater than those of NO_X by a factor of 3 to 15.

Tomato: The tomato site was located in the experimental station of the University of California, Davis (UC Davis). Soil at the site is also a clay loam with a soil organic carbon content of 10 percent. Two irrigation systems (furrow irrigation verses subsurface dripping) were tested at various N fertilizer rates, ranging from 0 to 300 kg N ha^{-1}, resulting in six management treatments. The average NO_X fluxes for the six treatments ranged from 0.07 to 2.79 g NO_X-N ha^{-1} h^{-1}. The irrigation with subsurface dripping reduced NO_X emissions significantly with a mean flux of 0.13 g NO_X-N ha^{-1} h^{-1} at the N application rate of 179 kg N ha^{-1}, close to the control treatment in furrow irrigation (0.10 g NO_X-N ha^{-1} h^{-1}) which received no N application. The highest emissions fluxes (2.79 g NO_X-N ha^{-1} h^{-1}) were found in furrow irrigation at the N rate of 300 kg N ha^{-1}. In all tomato fields, NO_X and N_2O fluxes were comparable and ranged on the same order of magnitude. Soil water content (as Water-Filled Pore Space or WFPS) seemed to be an important control factor in the fate of NO_X. When WFPS was low, NO escaped from the soil quickly. However, when WFPS was higher, consumption of NO to produce N_2O was favored.

Wheat: The wheat experiments were carried out in a grower's field in Dixon, CA in 2011 and in the UC Davis experimental station in 2012. The soils, also a clay loam, are similar at both sites. Three N application rates (192 - 266 kg N ha^{-1}) and a control with no N inputs were studied. The observed NO_X fluxes ranged from 0.01 to 0.07 g NO_X-N ha^{-1} h^{-1}. NO_X fluxes from the control are comparable to other treatments due to high NH_4^+ levels in the soil that remained from previous seasons. Overall, the NO_X fluxes were less than half of those detected for N_2O.

Silage corn: Three private dairy farms, which produced silage corn in summer and other forage crops in winter and fall, were selected for NO_X and N_2O monitoring, which was conducted under a different ARB-sponsored project. Soils in Farms A and B, located in Stanislaus County, are loamy sandy with 70-84 percent sand, and the soil in Farm C is classified as clay with a clay content of 41 percent. N management at all three farms was complicated, comprised of chemical N fertilizers, solid manure, and liquid N from lagoon water. N application rates ranged from 750 to 1300 kg N ha^{-1}, which are typical for the forage cropping systems in California. In addition to different forage crops for the

winter and fall seasons, Farm A practiced no-till, and Farms B and C adopted conventional tillage.

Due to the high N inputs, the measured NO_X fluxes from the silage corn, averaged over 0.39 - 2.03 g NO_X-N ha^{-1} h^{-1}, were among highest compared to other cropping systems tested, especially in Farms B and C (>1.61 g NO_X-N ha^{-1} h^{-1}) where conventional tillage were practiced. No-till management in Farm A led to less NO_X emissions (0.39 - 0.75 g NO_X-N ha^{-1} h^{-1}). Overall, NO_X fluxes in silage corn fields were lower than N_2O by up to a factor of eight.

Farms B and C, along with a corn field in the UC Davis experimental station, were also used to study soil temperature effect on NO_X emissions. Values of the temperature coefficient, Q_{10}, measuring the change of NO_X fluxes as a consequence of soil temperature change by 10^o C, were determined to be 2.5 to 3.4, which means that for every 10^o C increase in soil temperature, emission fluxes of NO_X would be more than doubled. Due to the high sensitivity of NO_X fluxes to soil temperature and other factors, estimate of emission rates from the measured fluxes of NO_X in this project is challenging. The results also show that the relationship of NO_X and N_2O emissions is complicated and varies with environmental conditions. More research would be needed to identify and characterize the key variables that control formation of these two gases.

III. STAFF COMMENTS

This project provided snapshots of NO_X emission fluxes from five California cropping systems. The draft final report has gone through ARB internal and external reviews and two revisions to address reviewers' comments. At the request of ARB staff, the principal investigator (PI) has appended the measurement data and photos of the sampling setup to the draft final report. The staff also requested the PI to provide estimates of emission rates by first-order approximation based on the measured NO_X fluxes and the PI has agreed to complete this task in the final report.

The modeling staff of the Air Quality Planning and Science Division reviewed the draft final reports and commented earlier that the NO_X fluxes data from soils would be useful in ozone modeling. The field measurements gained from this project are expected to

enable the development of an improved O_3 formation module incorporating soil processes.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.