Educational Conference on the Use of Vegetation as Near-Roadway Mitigation for Air Pollution

June 2-3, 2015 | Sacramento, CA

Day One

9:30-10:30am **Registration and Breakfast**

10:30-11:00am **Welcome and Introductions** – Ken Elstein, M.B.A., EPA

11:00am-12:00pm **Issue Overview**
- Barbara Weller, Ph.D., California Air Resources Board
- Doug Eisinger, Ph.D., Sonoma Technology, Inc.
- Jeff Pietrzak, Caltrans

12:00-12:30pm **Break, Grab Box Lunch**

12:30-2:15pm **Research Presentations**
- Suzanne Paulson, Ph.D., University of California, Los Angeles
- David Holstius, Ph.D., Bay Area Air Quality Management District
- Tom Cahill, Ph.D., University of California, Davis & Health Effects Task Force
- Rich Baldauf, Ph.D., EPA
- K. Max Zhang, Ph.D., Cornell University

2:15-2:45pm **Break**

2:45-3:45pm **Policy and Implementation Considerations Panel**
- Carolyn Brown, Caltrans
- Austin Kerr, Ascent Environmental, Inc.
- Cindy Blain, California ReLeaf

3:45-5:00pm **Implementation Examples**
- Greg McPherson, Ph.D., USDA Forest Service
- Randy Sater, Stonebridge Properties
- Tom Cahill, Ph.D., University of California, Davis & Health Effects Task Force
- Anne Fenkner, Davey Resource Group

5:00pm **Wrap-Up** (Dinner on Your Own) – Ken Elstein, M.B.A., EPA

Welcome to:

Educational Conference on the Use of Vegetation as Near-Roadway Mitigation for Air Pollution

- Sit anywhere you wish.
- Restrooms are just outside auditorium

Workshop Steering Committee

- Chad Bailey (EPA)
- Rich Baldauf (EPA)
- Thomas Cahill (UC-Davis)
- Christina Hemphill Fuller (GSU)
- Katie Valenzuela Garcia (BCSET)
- Jananne Sharpless (BCSET)
- Kori Titus (BCSET)
- Linda Wheaton (HCD)
- Earl Withycombe (BCSET)
- Max Zhang (Cornell)
- Ken Elstein (EPA)

Logistics

- Restrooms – outside auditorium
- Wireless: "PFA," then certification
- Food
  - Box lunch
  - Snacks – cafeteria/vending 2nd floor, left all the way down
  - Dinner (map)
- Let Kori know if you don't want your slides shared (sheet at lectern)

Meeting Objectives

1. Common understanding of current state of science on potential for mitigating near-roadway air pollution with roadside vegetation.
2. Identify how planners/developers may use roadside vegetation as a tool in mitigating near-road air quality impacts.
3. Share best practices for using vegetation as a near-roadway air pollution mitigation strategy.

Product: paper summarizing research & best practices

Agenda Flow – Day 1

- Introductions
- Issue overview
- Box lunch
- Research presentations
  - Table discussion (~15 min) → 3 take-aways
- Policy and Implementation Panel
  - Q&A
- Implementation Examples
  - Table discussion (~15 min) → 3 takeaways
- End-of-day Assessment
- Dinner on own

Agenda Flow – Day 2

- Green Prescription: Urban Tree Canopy Cover & Health
- Discussion Activity (with Box Lunch)
  - Small breakouts
  - Propose integrated solution(s) in context of:
    - Research, policy, and implementation
    - Where we've been, what we've learned, where we need to go
    - Persistent challenges
    - Leveraging resources & ongoing activities
  - Report out and discussion
    - Proposal details
    - 30-60 sec. sound-bite

Managing Our Time

- What you can do
  - Load PPT files during breaks
  - Hold questions for the Q&A sessions
  - Please return promptly from breaks
- What I'll do….

Managing Our Time

- 15 Minute Presentations
  - –Green for 12 min.
  - –Yellow = 3 min. left
  - –Red = 45 sec. left

And then…

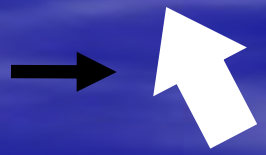
A Couple Other "Pointers"

- Advancing slides

or

- Pointing:

or



Ground Rules

- **Everyone shares responsibility for the meeting's success.**
- Stay on topic.
- Listen and understand.
- Be transparent.
- First brainstorm, then critique.
- Provide everyone an equal opportunity to speak.
- Commit to being fully present.

15-Second Introductions

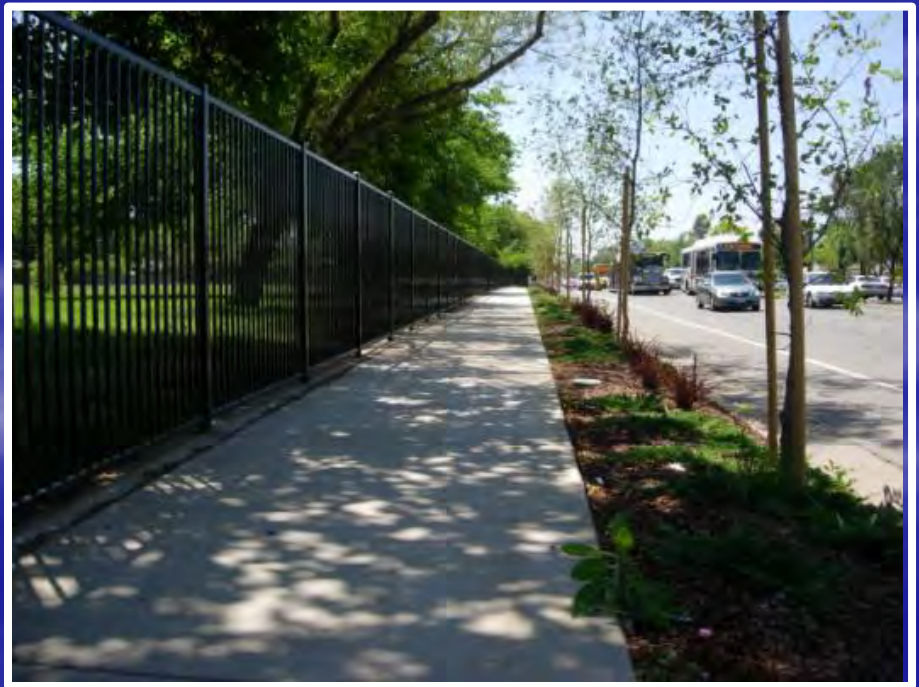
- Name
- Organization
- What about this meeting is most important to you?

Before You Leave for the Day!

- Write name on sheet at lectern if you don't want your presentation shared
- Breakfast @ 8:30; start @ 9:00
- Take valuables; can leave rest
- Molly Wright needs a lift downtown (Sacramento Air District)!
- If you signed up for dinner, meet in Lobby at 5:25
- Thanks to all our presenters!!

Welcome to Day 2 of

Educational Conference on the Use of Vegetation as Near-Roadway Mitigation for Air Pollution



Summary of End-of-Day Assessment

- Need more table heterogeneity!

Discussion Activity

- Form 5-6 small mixed groups (research & policy & implementation)
- Develop at least 1 integrated proposal of where this effort should focus over the next 2-3 years to have the biggest impact
- Consider:
  - Where we've been
  - What we've learned (what's worked, challenges)
  - Where we need to go
  - How to leverage resources & ongoing activities

“Deliverable” #1

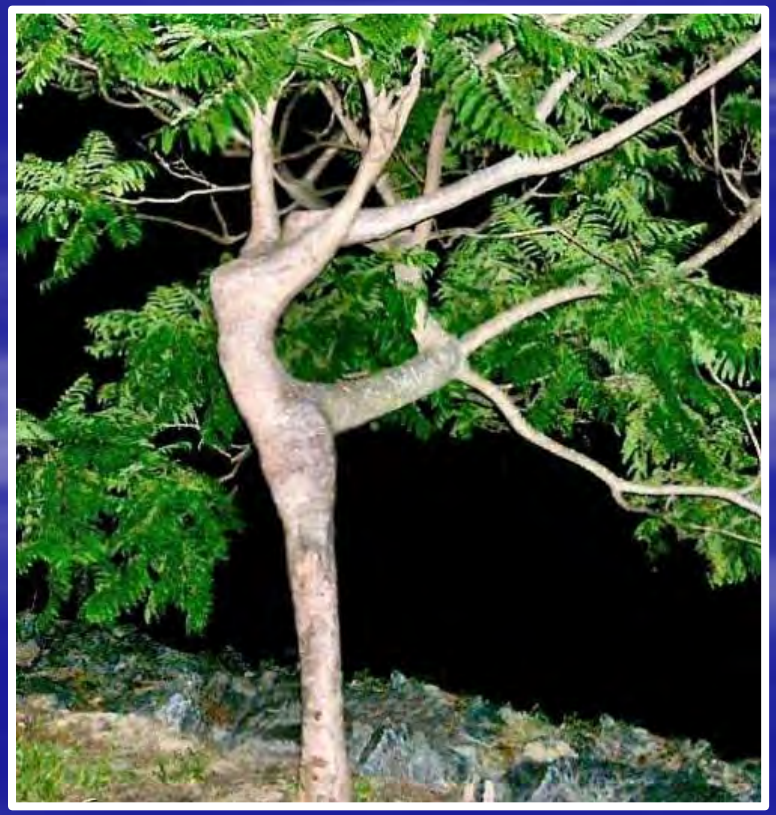
- 3-5 min proposal report-out, including:
  - Chosen focus and why most important
  - Critical research, policy, and implementation factors for success
  - Anticipated challenges
  - Strategies to overcome challenges

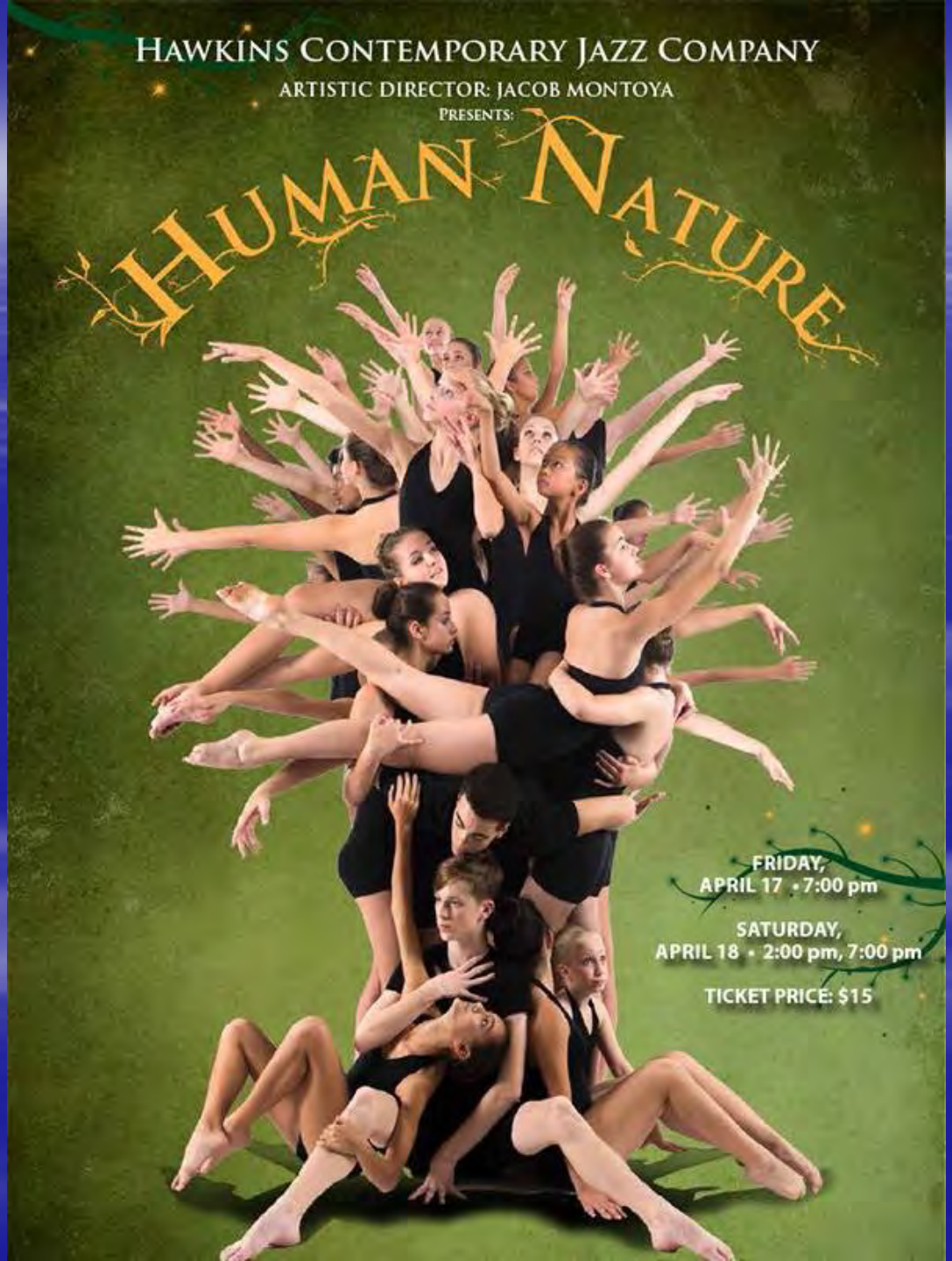
Managing Our Time

- 5 Minute Presentations
  - Green for 4 min.
  - Yellow = 1 min. left
  - Red = 15 sec. left

"Deliverable" #2

- 30-60 second sound-bite targeted to an influential stakeholder. Tell us:
  - Who's the stakeholder and why are they important to your project's success?
  - What do you want from them?
  - Your compelling "pitch"
    - You can be creative! (e.g., commercial, news story, skit, song, graphic/metaphor)
    - Please: NO INTERPRETIVE DANCE!
    - Except for Kori!




HAWKINS CONTEMPORARY JAZZ COMPANY
ARTISTIC DIRECTOR: JACOB MONTOYA
PRESENTS:
HUMAN NATURE
FRIDAY,
APRIL 17 • 7:00 pm
SATURDAY,
APRIL 18 • 2:00 pm, 7:00 pm
TICKET PRICE: $15

Max-Mix!

- Everyone get up
- Choose a group reflective of your expertise/passion
  - Research,
  - Health
  - Policy,
  - Implementation
  - Trees
- Each group counts off 1-7
- Go to appropriate table for your discussion

"Deliverables"

- 3-5 min report-out
  - Chosen focus and why most important
  - Critical research, policy, and implementation factors for success
  - Anticipated challenges
  - Strategies to overcome challenges
- 30-60 sec compelling pitch
  - First, set up:
    - Who's the stakeholder and why imp't?
    - What you want from them

Before You Leave!

- Let Kori know if you don’t want your presentation shared
- Label any flipcharts with Group and page number.
- Provide Ken with any electronic files.
- Fill out emailed survey
- Thank you!!

The Near-Roadway Health Impacts of Particulate Matter

Barbara L. Weller, Ph.D.

June 2, 2015

California Air Resources Board
California Environmental Protection Agency

Overview

- Who is at risk?
- What health effects have been seen?
- Which components of traffic are important?
- How have regulations had an impact on health and exposure?
- What research is ARB conducting on mitigations?

Background

- PM2.5 is a known health hazard
  - Mortality[1]
  - Cardiovascular effects[2]
  - Respiratory effects[1]
- Traffic pollution is an active area of investigation
  - Linked to health effects
  - Some research on the toxicity of components
  - Diesel is a known health concern

1. U.S., E. P. A. (2009). "Integrated Science Assessment for Particulate Matter (Final Report)." U.S. Environmental Protection Agency **600**(R-08): 139F
2. Brook et al 2010 Particulate matter air pollution and cardiovascular disease and update to the scientific statement from the American Heart Association Circulation 121:2331-2378

Who is at Risk?

- 40% of Californians live near high volume roads[1]
- Infants and Children
  - Schools
    - About 10% of California schools are located near a major roadway[2]
  - Daycare
- Elderly
- Workers near/on roadways
- Commuters
  - Commute can result in the highest contribution to your total exposure[3]
- Lower Socioeconomic Groups
  - High traffic areas have a larger percentage of low income and minority groups[1]

1. Rowangould A census of the US near-roadway population: Public health and environmental justice considerations Trans Res Part D 2013 25:59-67
2. Green, R.S., et al. Proximity of California public schools to busy roads. Environ Health Perspect 2004; 112: 1.
3. Fruin et al Black carbon concentrations in California vehicles and estimation of in-vehicle diesel exhaust particulate matter exposures

Birth Outcomes

- Spontaneous abortions associated with living 50m from heavy trafficked roads in African American women[1]
- Low birth weight was associated with
  - Traffic pollution in the San Joaquin Valley[2]
- Increased risk for autism was seen in children born to mothers that lived near a freeway at the time of delivery[3]

1. Green et al 2009 Residential exposure to traffic and spontaneous abortion Envir Health Perspect 117(12): 1939-1944
2. Padula et al 2012 Exposure to traffic-related air pollution during pregnancy and term low birth weight: Estimation of causal associations in a semiparametric model Am J Epidiol 176(9):815-824
3. Volk et al 2011 Residential proximity to freeways and autism in the CHARGE study Environ Health Perspect 119(6):873-877

Children

- Asthma exacerbation[1]
- Increased symptoms in asthmatics
  - East Bay Children's Respiratory Health Study[2]
  - Southern California Children's Health Study[3,4]
- Reduced lung function[5]
  - Both regional particulate matter pollution and local near roadway exposures have independent impacts[6]
- Increased body mass index[7]

1. Traffic-related air pollution: a critical review of the literature on emissions, exposure, and heal effects HEI Special Report 17 2010
2. Kim et al 2008 Residential traffic and children's respiratory health, Envir Health Perspect 116(9):1274-1279
3. Gauderman WJ, et al. Childhood asthma and exposure to traffic and nitrogen dioxide 2005 Epidemiology, 16:737-743
4. McConnell R, et al. Traffic, susceptibility, and childhood asthma 2006 Environ Health Perspect. 114(5):766-72 (2006)
5. Gauderman et al. 2007 Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study 369:571-577
6. Urman et al. 2014 Associations of children's lung function with ambient air pollution: joint effects of regional and near-roadway pollutants Thorax 69(6):540-547
7. Jerrett et al 2010 Automobile traffic around the home and attained body mass index: A longitudinal cohort study of children aged 10-18 Pev Med 50(0):S50-S58

Adults

- Cardiovascular mortality and morbidity[1]
  - Ischemic heart disease causes, especially in women[2]
- Exacerbation of asthma in adults[1]
- Progression of atherosclerosis[3]
- Lung cancer mortality[4]

1. Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects HEI Special Report 17 2010
2. Hart et al 2013 Changes in traffic exposure and the risk of incident myocardial infarction and all-cause mortality
3. Kunzli et al 2010 Ambient air pollution and the progression of atherosclerosis in adults Plos One 5(2)1-10
4. Jerrett et al 2009 Spatial analysis of air pollution and mortality in Los Angeles Epidemiology 16(8):727-736

Pollutants as Markers and Noise Effects

- CO
  - Traffic pollution exposures associated with preterm birth in Los Angeles[1]
- NO_2 /NOx
  - Reduced fetal growth[2]
  - Increased risk of autism[3]
  - Increase in some childhood cancers with prenatal exposures[4]
  - Increased development of asthma[5]
  - Increased risk for cardiovascular mortality[6]
  - Increase the risk of type 2 diabetes in African American women[7]
- Noise may also have an effect
  - Noise and other neighborhood problems are associated with reduced physical abilities in older adults[8]
  - Effects of noise from traffic are difficult to separate from effects of traffic pollution

1. Ritz et al 2007 Ambient air pollution and preterm birth in the environment and pregnancy outcomes study at the University of California, Los Angeles Am J Epidemiol 166:1045-1052
2. Ritz et al 2014 Prenatal air pollution exposures and ultrasound measures of fetal growth in Los Angeles, California Envir Res 130:7-13
3. Volk et al 2013 Traffic related air pollution, particulate matter , and autism JAMA Psychiatry 70(1):71-77
4. Ghosh et al. 2013 Prenatal exposure to traffic-related air pollution and risk of early childhood cancers am J Epi 178(8):1233-1239
5. McConnell et al. 2010 Childhood incident asthma and traffic-related air pollution at home and school 118(7):1021-1026
6. Jerrett et al2013 Spatial analysis of air pollution and mortality in California Am J Resp Crit Care Med 188(5):593-599
7. Coogan et al 2012 Air pollution and incidence of hypertension and diabetes in African American women living in Los Angeles Circul 125(6):767-772
8. Balfour et al 2002 Neighborhood environment and loss of physical function in older adults: Evidence from the Alameda County Study Am J Epidemiol 155(6): 507-515

Which Components of Traffic are Important?

- Few studies on components of traffic
- Diesel Particulate Matter
  - Diesel engine exhaust recently classified as carcinogenic[1]
- Toxics
  - Low birth weight with benzene, toluene, ethyl benzene and xylene[2]
- Organic carbon
  - Increased blood pressure in the elderly[3]
- Tire and brake wear
  - Metals in dust may induce oxidative stress[4,5]
- Ultrafine PM
  - May play a major role in toxicity: results are not confirmed[6,7]
  - Mortality for ischemic heart disease in post menopausal women using a model of ultrafine components[8]

1. 2012 Carcinogenicity of diesel-engine and gasoline-engine exhausts and some nitroarenes the lancet oncologyhttp://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf
2. Ghosh et al 2012 Assessing the influence of traffic-related air pollution on risk of term low birth weight on the basis of land-use –regression models and measures of air toxics
3. Delfino et al 2010 Traffic-related air pollution and blood pressure in elderly subjects with coronary artery disease Epidemiol 21(3):
4. Cassee et al 2013 Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources on emission Inhal Toxicol 25(14):802-812
5. Grogoratos and Martini 2015 Brake wear particle emissions: a review Environ Sci Pollut Res 22:2491-2504
6. Delfino et al 2005 Potential role of ultrafine particles in association between airborne particle mass and cardiovascular health Environ Health Perspect 113(8): 934-946
7. Sioutas et al 2005 Exposure assessment for atmospheric ultrafine particles (UFPs) and implications in epidemiologic research Environ Health Perspect 113(8): 947-955
8. Ostro et al. 2015 Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: Results from the California Teachers Study Cohort Envir Health Perspect advanced publication

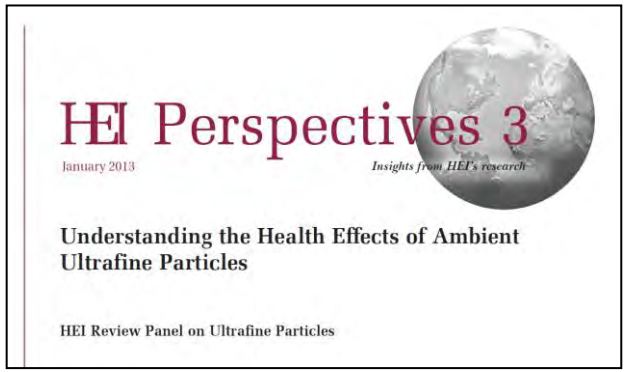
Ultrafine PM

- Linked to respiratory, cardiovascular effects[1]
- Reasons for our concern
  - Inhalation of ultrafine particles leads to deposition on the lung surface[2]
  - Surface effects of ultrafine particles may be important in deposition[3]
  - Particles can enter the blood stream, can be translocated to the liver[4]
  - Particles can enter nervous system by nasal deposition, translocated to the brain through the olfactory nerve[5]

1. Kumar et al 2013 Ultrafine particles in urban ambient air and their health perspective Rev Environ Health 28(2-3):117-128
2. Peters et al 2006 Translocation and potential neurological effects of fine and ultrafine particles a critical update Particle and Fibre Tox 3:13
3. Geiser et al 2003 Influence of surface chemistry and topography of particles on their immersion into the lung's surface –lining layer J Appl Physiol 94:1793-1801
4. Oberdoster et al 2002 Extrapulmonary translocation of ultrafine carbon particles following whole-body inhalation exposure of rats J Toxicol Envion Health 65:1531-1543
5. Oberdorster et al 2004 Translocation of inhaled ultrafine particles to the brain Inhal Toxicol 16:437-445

Ultrafine PM

"..the considerable body of research that has been conducted has not provided a definitive answer to this question."


HEI Perspectives 3

January 2013

Insights from HEI's research

Understanding the Health Effects of Ambient Ultrafine Particles

HEI Review Panel on Ultrafine Particles

U.S.EPA Integrated Science Assessment for Particulate Matter (2009)
Data on health effects and air quality data insufficient for a separate standard for ultrafine particles

U.S.EPA Ultrafine Particle Workshop (2015)
Reviewed the latest findings for ultrafine exposure and impacts

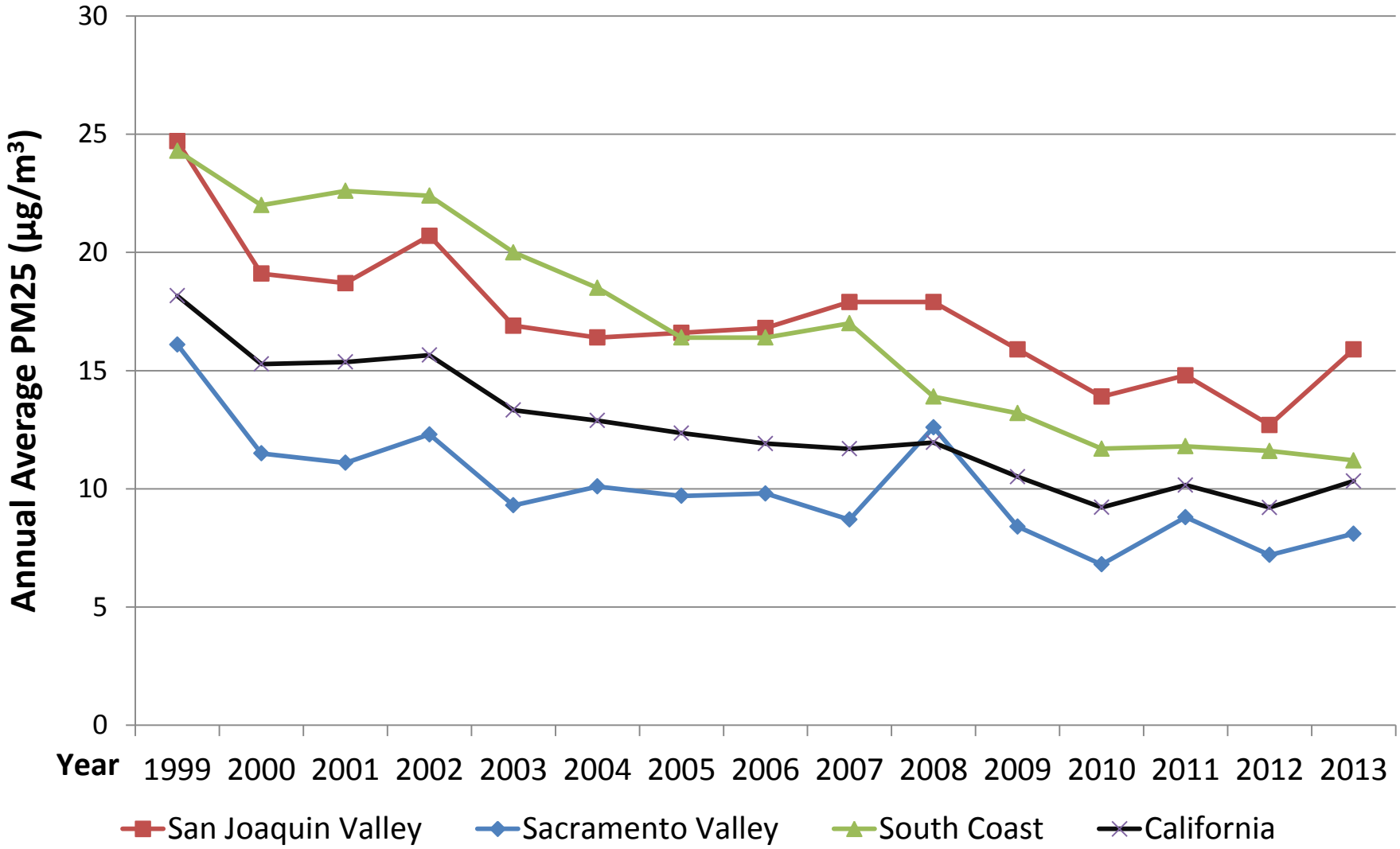
ARB funded research
Association of long-term UFP exposure and premature death

California Air Resources Board
California Environmental Protection Agency

ARB Regulations to Reduce Emissions

- Many of the ARB's regulations are targeted to reduce traffic pollution, including PM2.5, NOx and UFPM
- ARB Programs to Reduce Sources of Emissions
  - Diesel Risk Reduction Plan
  - Sustainable Freight Transport Initiative
  - Climate Change Regulations

Annual Ambient PM2.5 Concentration Trends in California



Health Impacts from Improved Air Quality

- Children showed increased lung function growth when relocated to areas with lower pollution[1]
- Significant improvements in lung function growth of children in the Los Angeles air basin where air quality has improved[2]
- Cardiovascular health improved in the elderly in the San Joaquin Valley air basin and reductions in particulate matter were seen from wood-burning regulations[3]

1. Avol et al 2001 Respiratory effects of relocating to areas of differing air pollution levels Am J Respir Crit Care Med 164:2067-2072
2. Gauderman et al 2015 Association of improved air quality with lung development in children N Eng J Med 372:905-913
3. Yap et al 2015 Effectiveness of residential wood-burning regulations on decreasing particulate matter levels and hospitalizations in the San Joaquin Valley Air Basin Am J Public Health 105(4):772-778

Potential Mitigation Measures

- Air quality is improving, but some areas may have higher exposures
- ARB's research on possible mitigation measures to reduce traffic exposures
  - Soundwalls and Vegetation
    - Soundwall increased the levels of ultrafines in areas further from the sound wall[1]
    - Benefits of vegetation barriers have been variable and may be due to the density of the barrier[2]
    - Current study will examine the impacts of sound walls and vegetation
  - Studies on Urban Design
    - Light Rail, Complete Streets, Transit Stops
  - In Home Filtration
  - In Cabin Filtration for Motor Vehicles

1. Sioutas 2011 Fine-scale spatial and temporal variability of particle number concentrations within communities and in the vicinity of freeway sound walls ARB final report
2. Hagler et al 2012 Field investigation of roadside vegetative and structural barrier impact on near-road ultrafine particle concentrations under a variety of wind conditions Sci of the Total Envir 419:7-15

Conclusions

- Health impacts from traffic exposures well established
- Ultrafine PM health impacts unclear
- PM/Ultrafine significantly reduced by ARB regulations
  - public health improvements have been seen
- Current ARB research will provide information help to further reduce exposures

http://www.arb.ca.gov/homepage.htm

Best Practices for Reducing Exposures to Traffic Emissions Near Larger Roadways

Ashley Graham, **Doug Eisinger** – Sonoma Technology, Inc.
Dahlia Chazan – Arup North America Ltd.
Rich Baldauf – U.S. EPA Office of Research and Development
John Thomas, Lori Zeller – U.S. EPA Office of Sustainable Communities
Chad Bailey – U.S. EPA Office of Transportation and Air Quality
Katie Stewart – U.S. EPA Region 9 Air Division

Presented at the
Educational Conference on the Use of Vegetation as Near-Roadway Mitigation for Air Pollution

Sacramento, CA

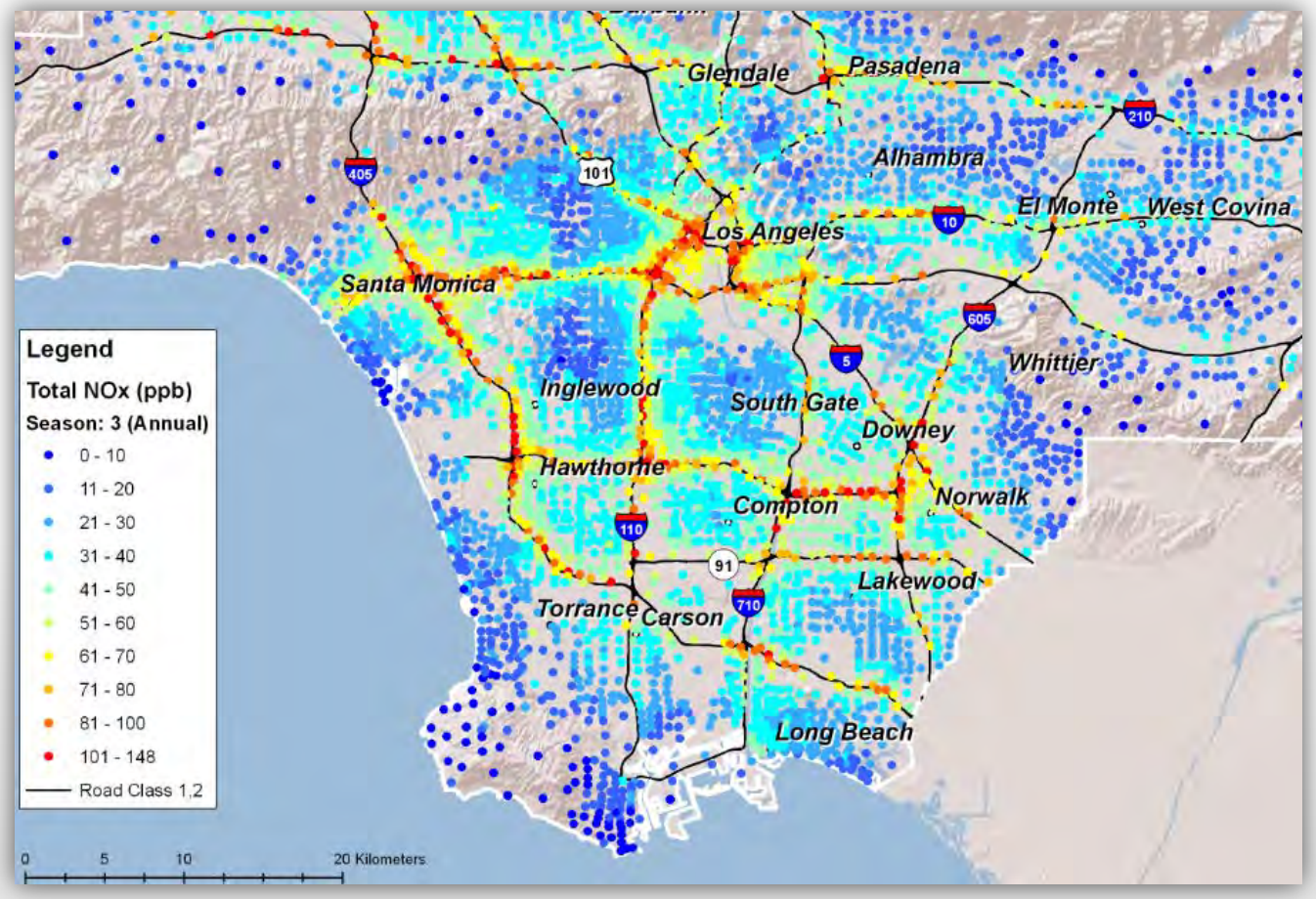
Sonoma Technology, Inc.

June 2, 2015

Reducing Pollution Exposure

1. Problem illustration: modeled and measured
2. Core concepts for reducing near-road pollutant emissions, concentrations, and exposure
3. Six strategies to mitigate near-road air pollution exposure
4. Case study: HVAC filtration in schools
5. Summary
6. Acknowledgments

Modeled: Los Angeles NO_x



STI modeling to support multi-university health effects research collaborative. *Near-Roadway Pollution and Childhood Asthma,* Perez et al., 2012.

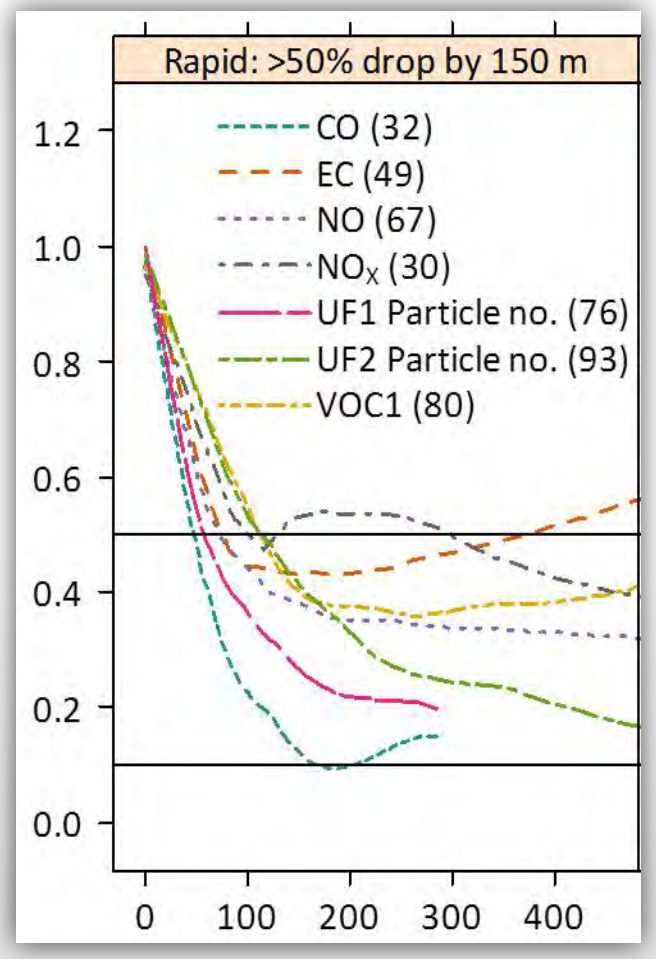
Measured: Worldwide Synthesis

Measured near-road concentrations
41 studies, 13 countries, 30 years

Key findings, by distance from road:

- 150 m – rapid (50%) decline
- 400 m – most at background
- 600 m – nearly all at background

(nighttime exceptions)



Source: Karner, Eisinger, Niemeier (2010) *ES&T*, 44, 5334-5344.

Core Concepts

To mitigate traffic-related air pollution exposure near high-volume roadways, planners can target:

Emissions

Image: noaa.gov

Concentrations

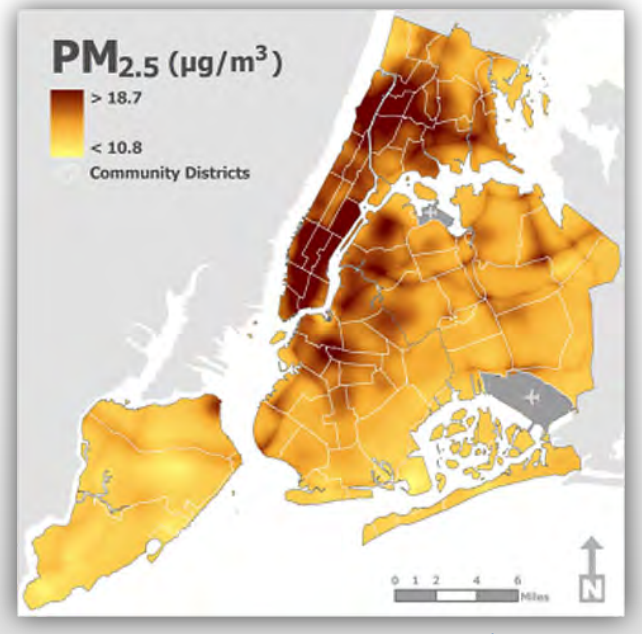


Image: nytimes.com

Exposure

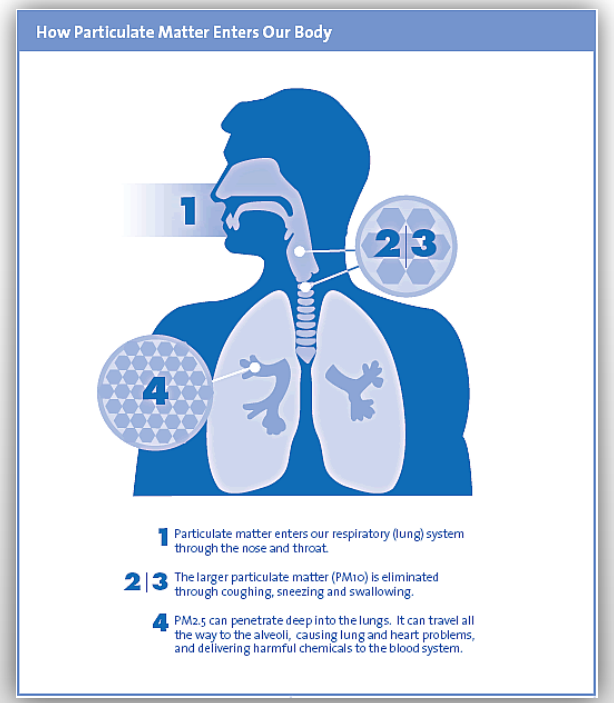


Image: bcairquality.ca

Six Strategies to Mitigate Near-Road Air Pollution Exposure

Emissions Concentrations Exposure

Transportation Infrastructure	Roadside Features	Site Planning	Building Design, Ops.
1. Corridor Mgt. • Improve traffic flow • Reroute trucks • Increase trips by foot, bike, or transit **2. Street Design** • Lower volumes • Buffer people from roads	**3. Barrier Use** • Install walls • Add vegetation	**4. Design** • Locate sensitive uses farther from roads • Phase parcels closest to road later in build out	**5. Design** • Optimize occupant placement **6. Operations** • Use/improve HVAC filtration

1. Corridor Management

Truck rerouting reduced diesel PM in San Diego residential areas.
Image: Karner et al., 2009.

Reduce Emissions

- Improve traffic flow
- Reroute, restrict truck traffic away from sensitive land uses
- Promote land use strategies that encourage the accessibility and use of transit and active transportation

2. Street Design

Reduce Emissions

- Design complete streets
- Improve traffic flow

"Complete streets" support multi-modal travel (ULI image, 2012).

Reduce Exposure

- Create landscape and parking zones to buffer people from roads

Wider sidewalks and landscaping create buffers.

3. Barriers: Sound Walls/Vegetation

Image credit: Missouri DOT.

Image excerpt: Baldauf et al., 2013.

Reduce Concentrations

- Walls: 15-50% reduction
- Walls plus vegetation: 60% reduction
- Vegetation can filter, block
- But… gaps can allow pollutants to pass through and accumulate

Fine Print:

"Effects are still uncertain and depend on factors such as roadway configuration, height, barrier design, and meteorology. Models for quantifying impacts are still under development."

3a. Sound Walls

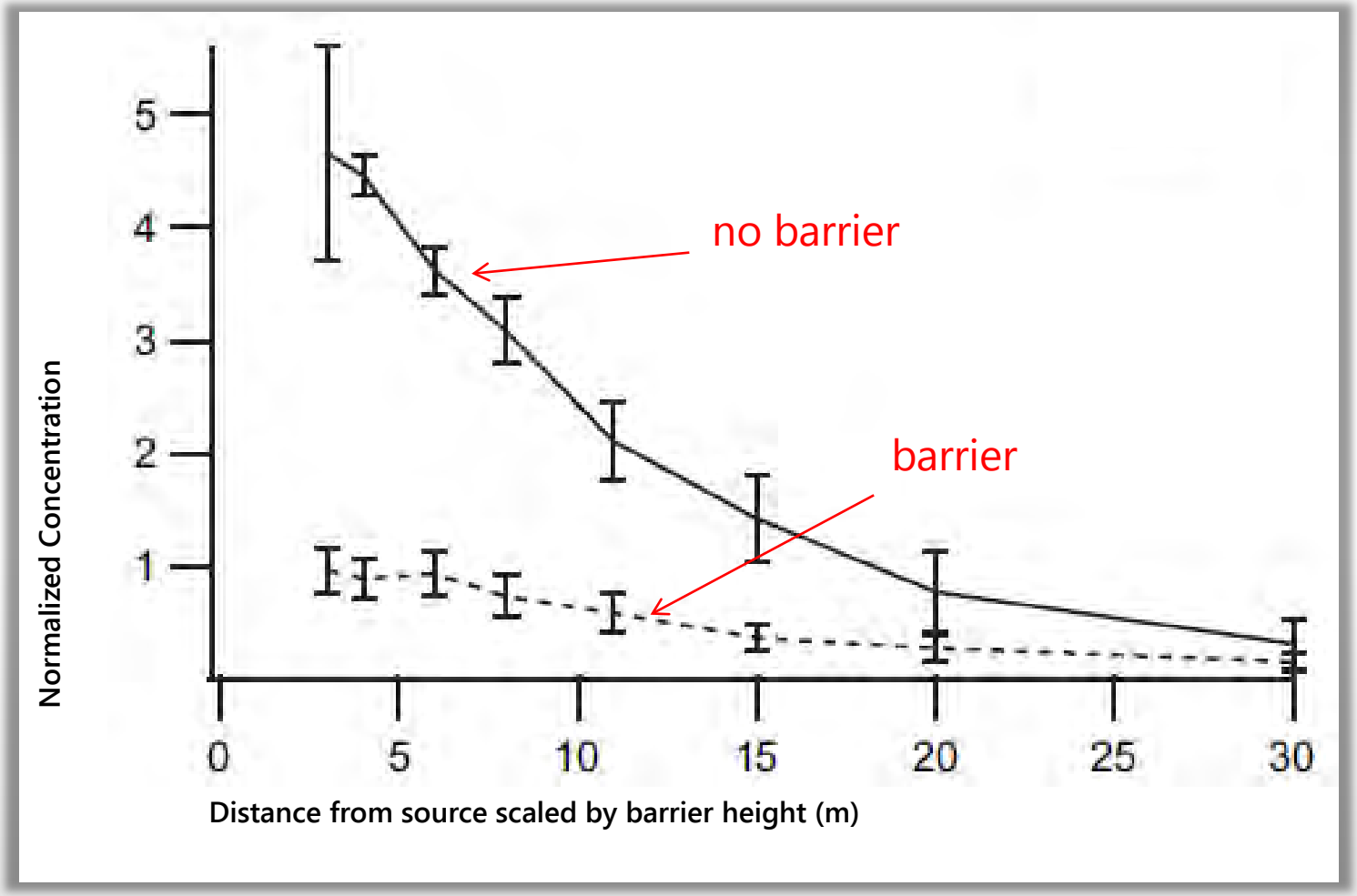
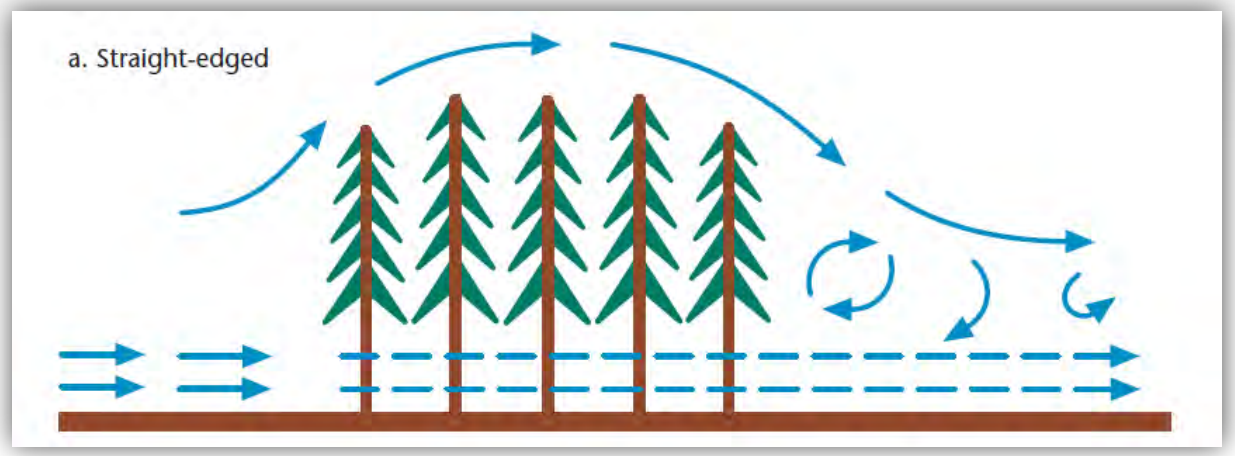
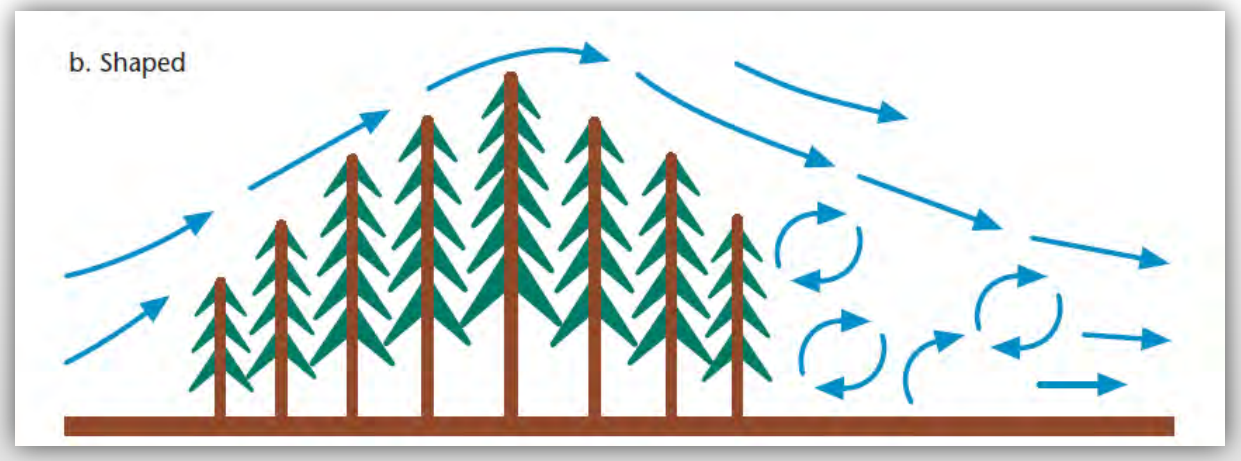


Image: Finn et al., 2010.

3b. Vegetation





Barrier shape can affect wind flow

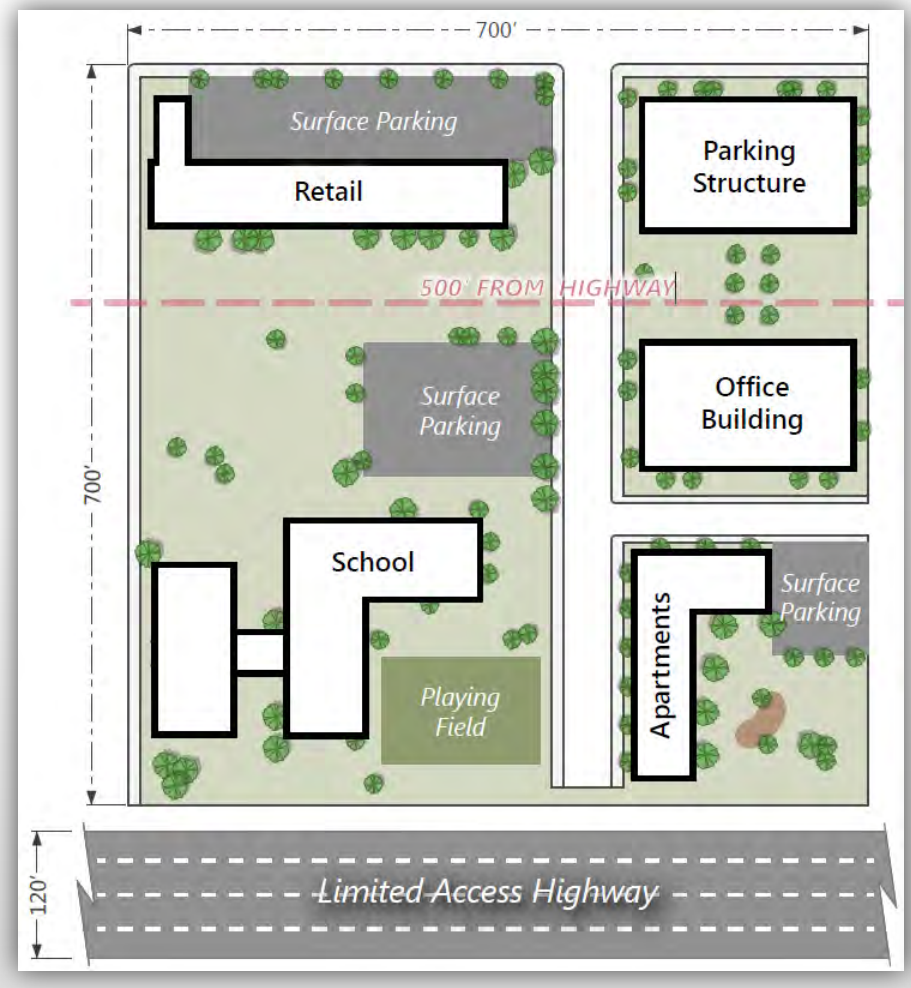
Image source:

"Principles of Using Woods for Shelter," Gardiner et al., 2006

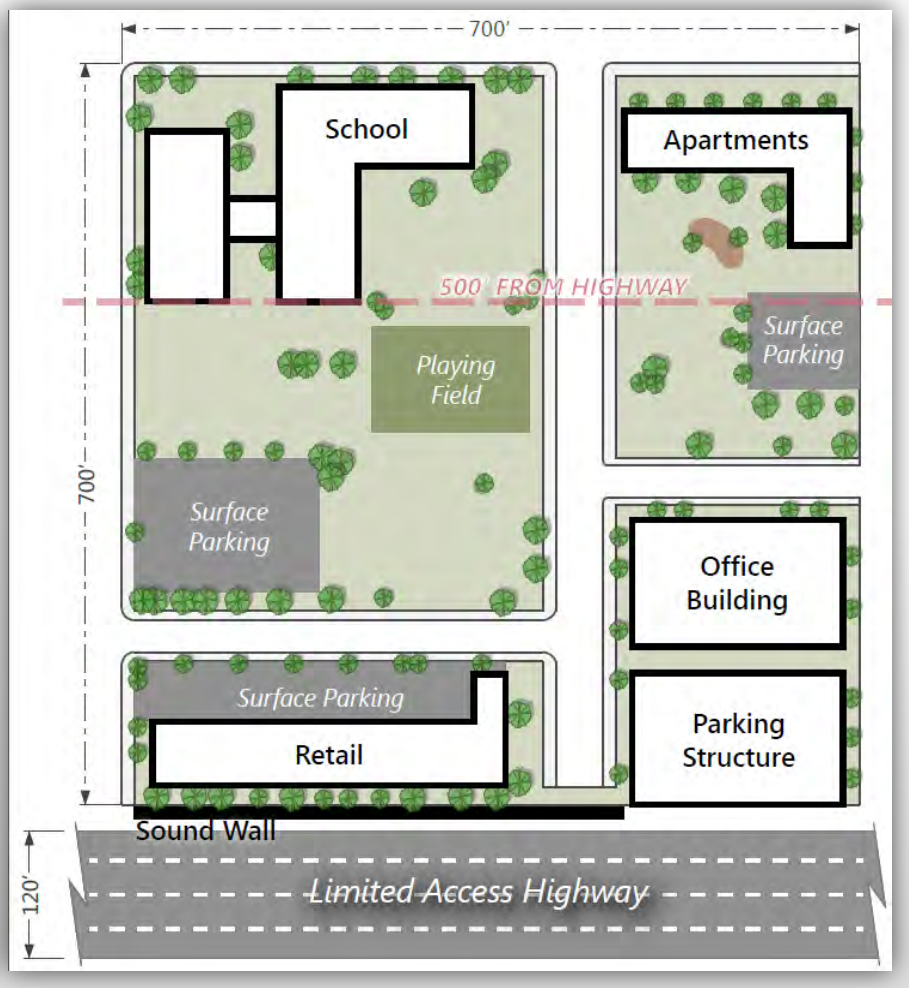
www.forestry.gov.uk

4. Site Design

Less desirable

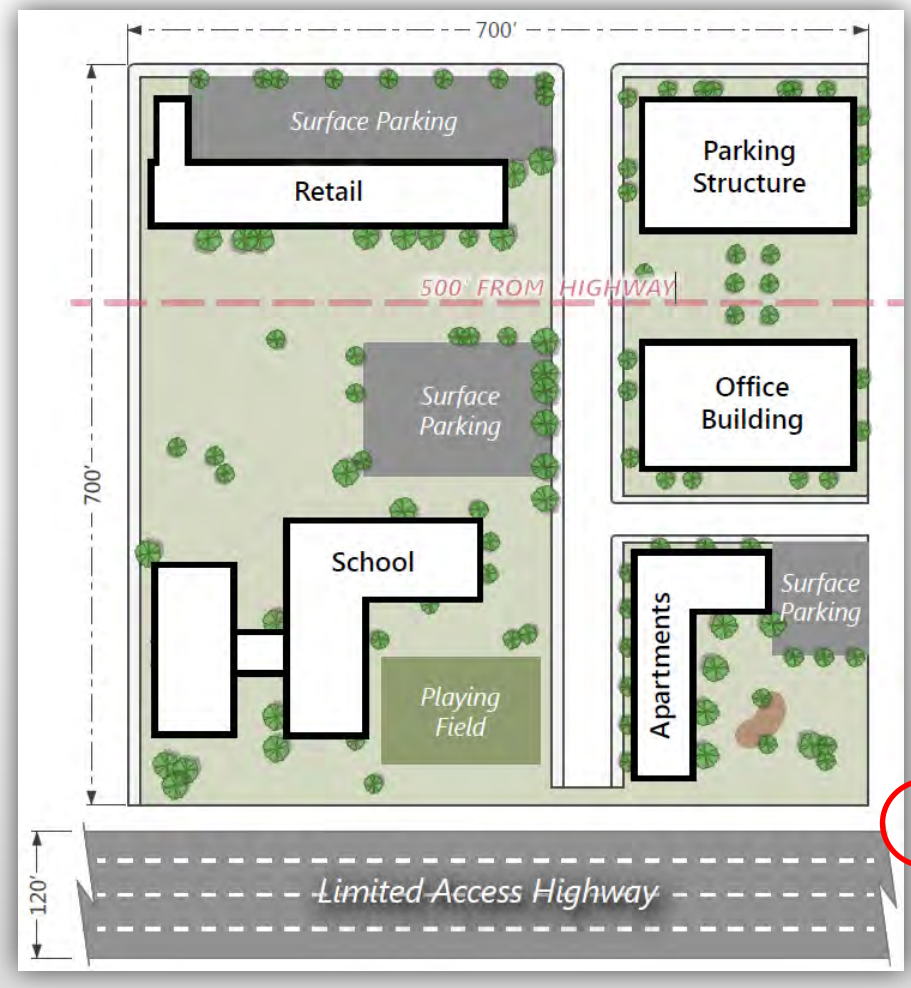


Improved

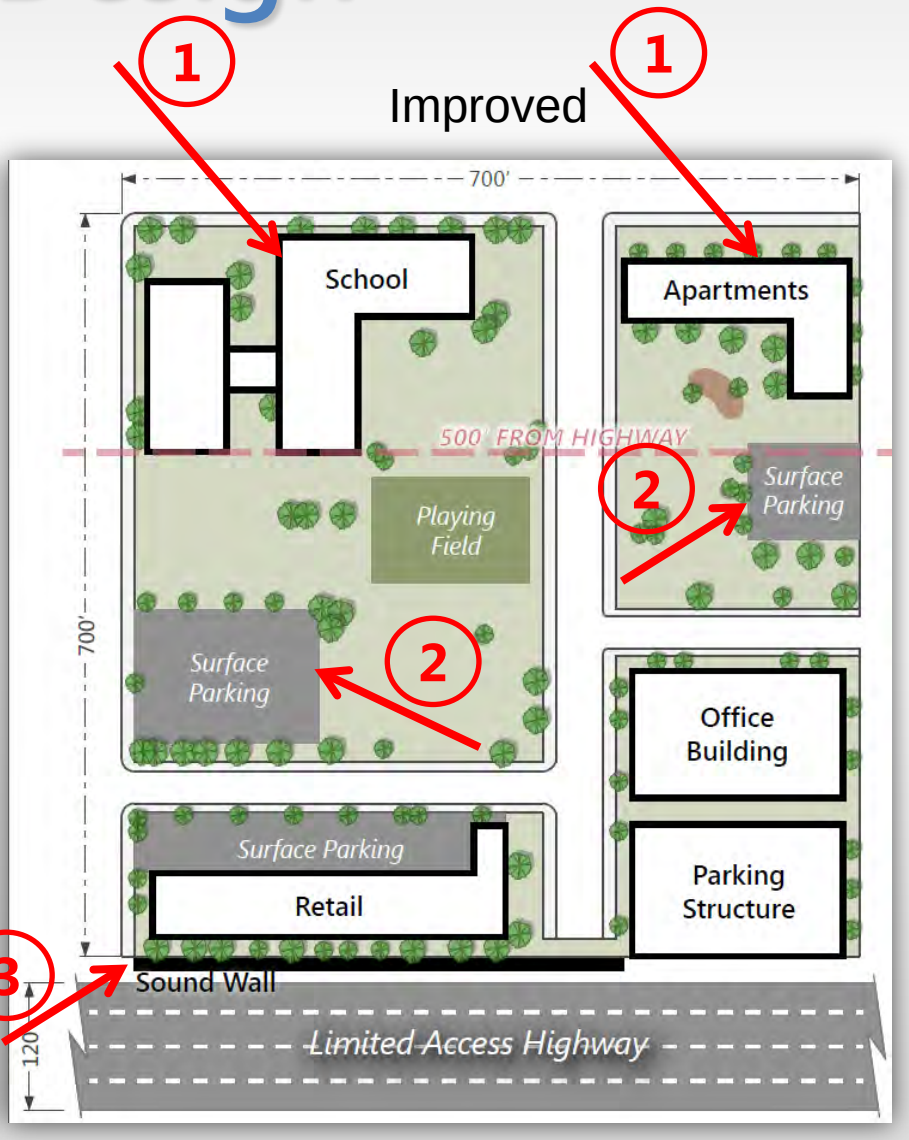


4. Site Design

Less desirable

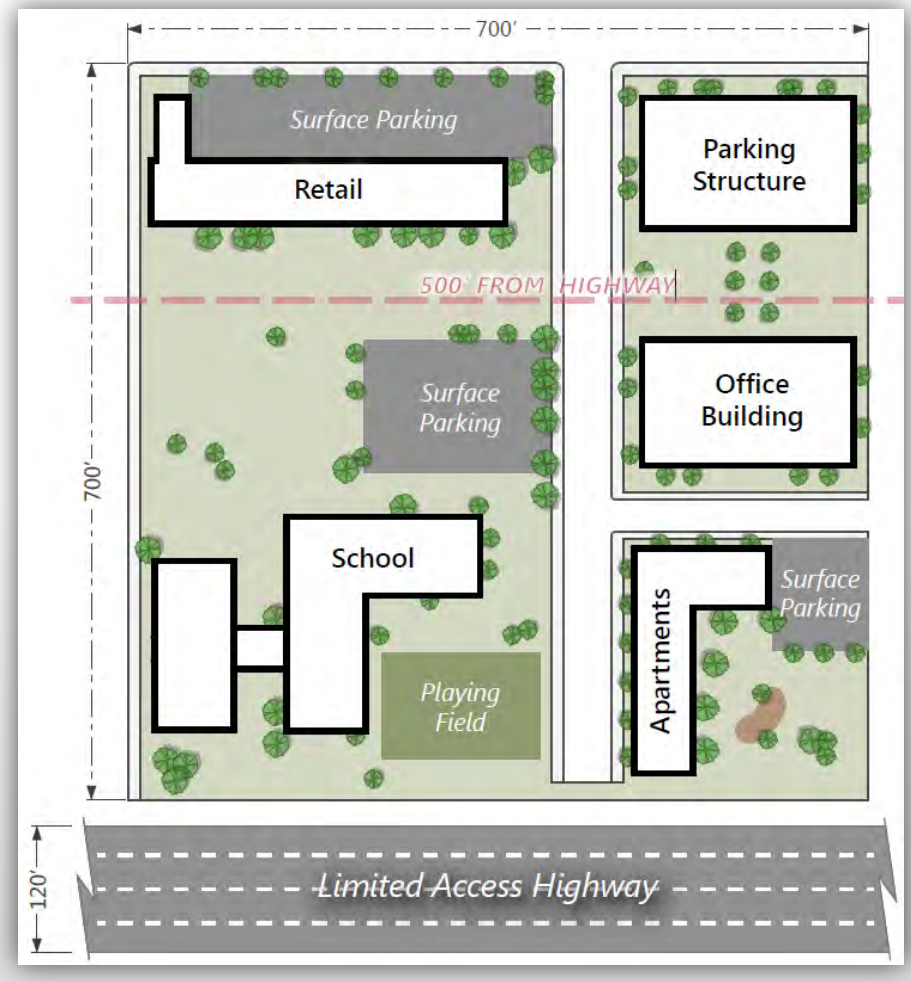


Improved

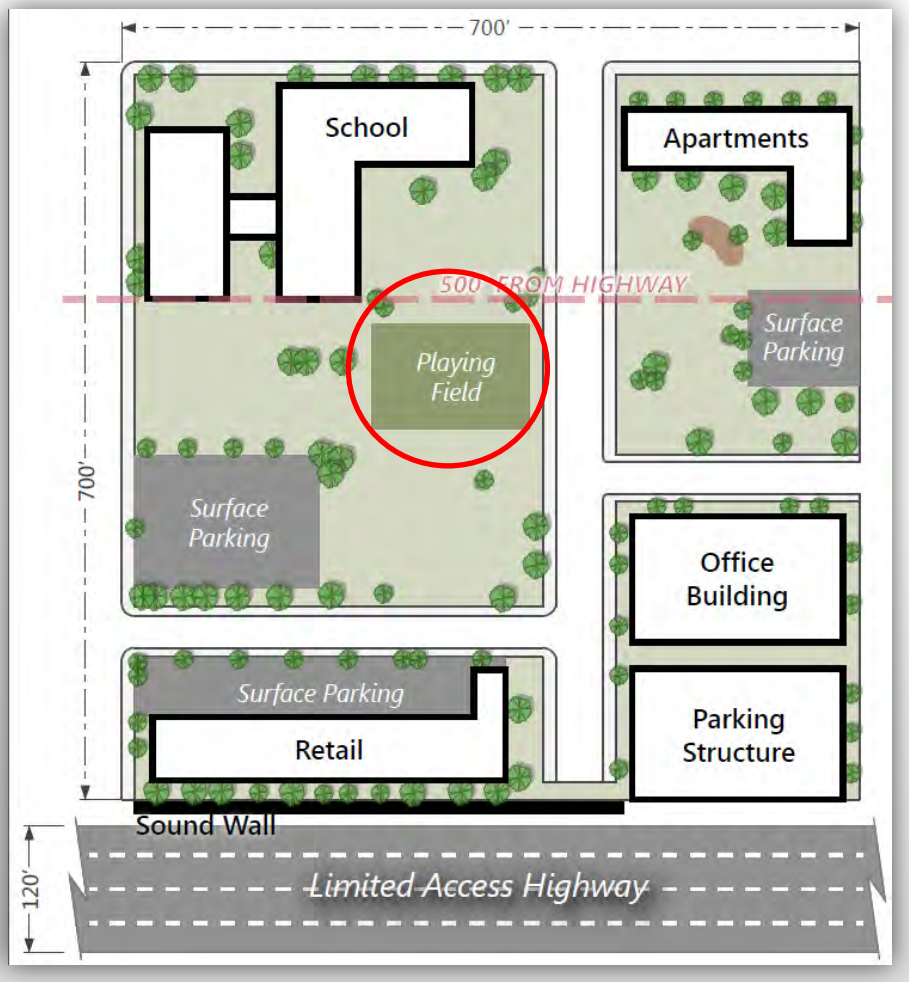


4. Site Design

Less desirable

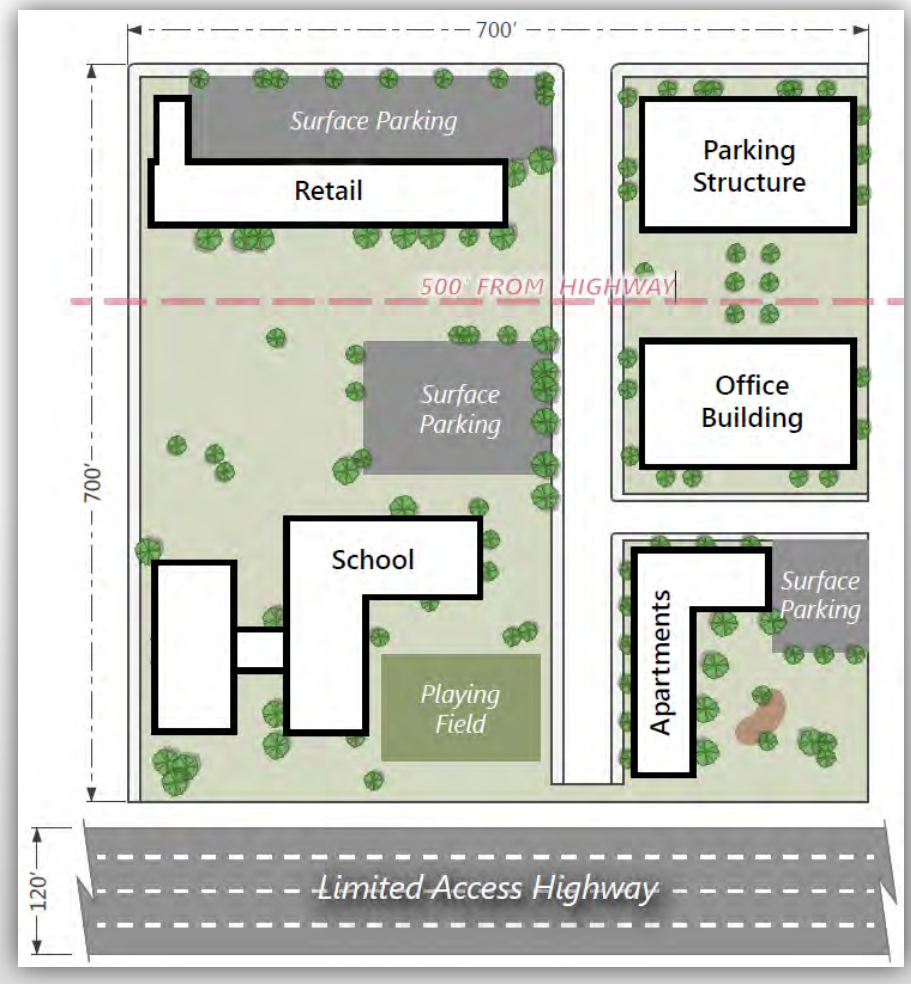


Improved

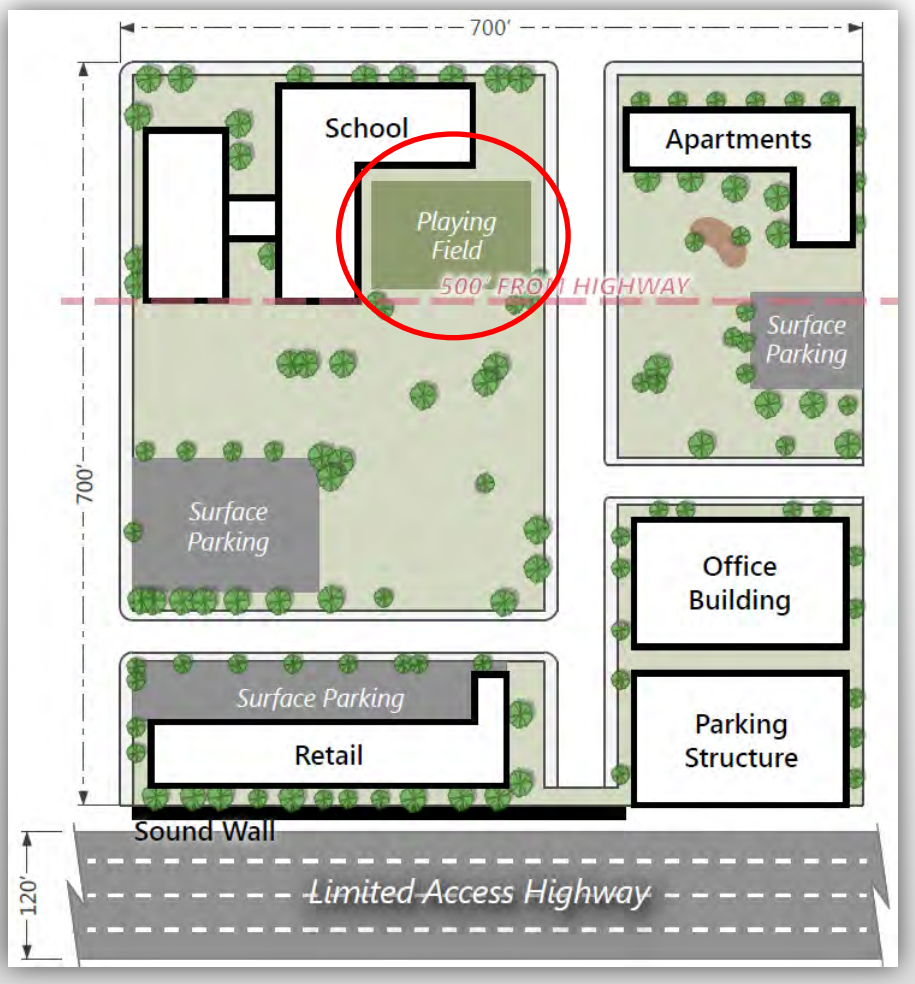


4. Site Design

Less desirable



Even better



5. Building Design & 6. Operations

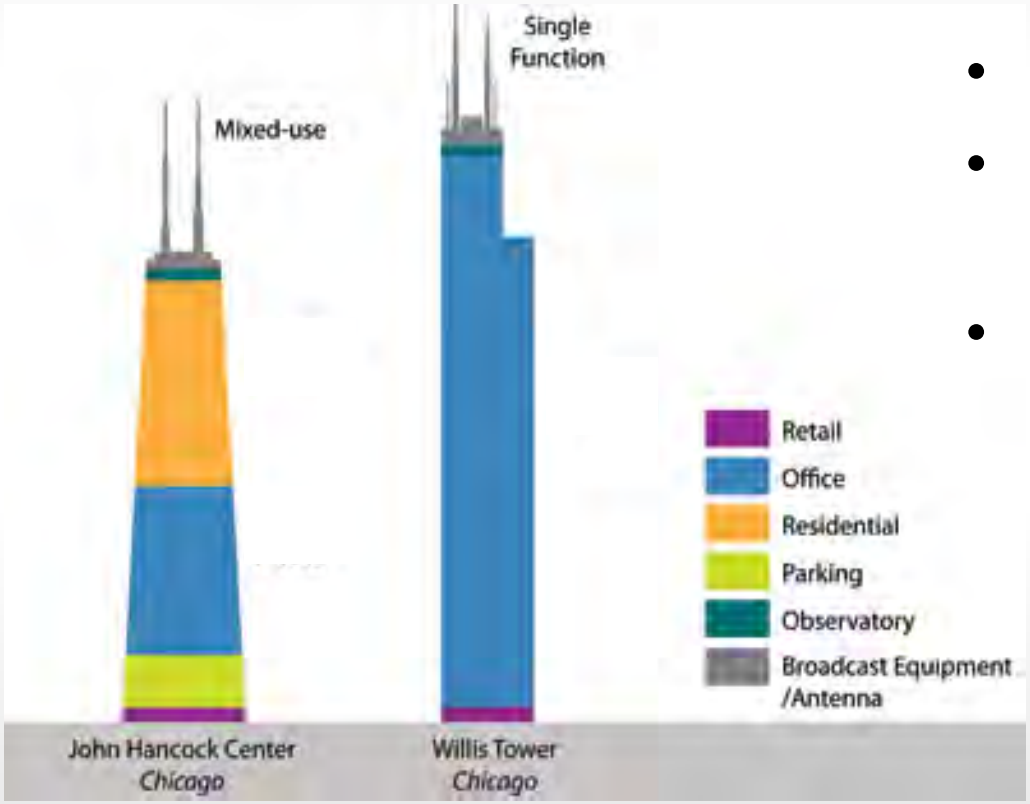


Image: ctbuh.org

Reduce Exposure

- Optimize occupant location
- Place air intakes away from pollutant source
- Improve filtration (next slides)

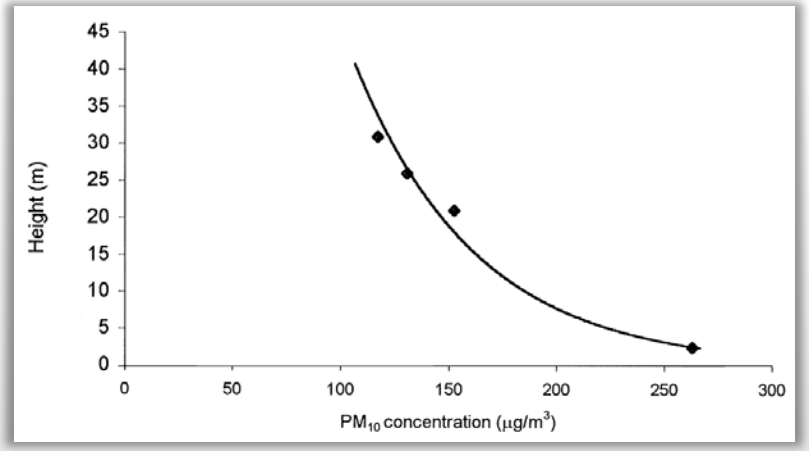


Image: Chan et al., 2000. Vertical dispersion of PM, Hong Kong street canyon.

Building Operations Case Study

Fyfe Elementary, near US 95, Las Vegas (one of several schools studied)

Before widening

After widening

Roberts et al., 2010; McCarthy et al., 2013

Building Operations Case Study

HVAC Filtration Efficiency for Black Carbon

School	Original Efficiency (old filters)	Upgraded Efficiency (2008, new filters installed)	2013 Efficiency (5 Years later)
Adcock Elem.	66%	97%	**91%**
Fyfe Elem.	50%	72%	**50%**

Roberts et al., 2013

Note: Original filter rating of MERV 6 was used in all three schools.
MERV = Minimum Efficiency Reporting Value, per ASHRAE. This is the typical efficiency of particle removal in the size range of 0.3 to 10 microns in diameter.

Mitigation: Consider as a Package

Emissions Concentrations Exposure

Transportation Infrastructure	Roadside Features	Site Planning	Building Design, Ops.
1. Corridor Mgt. • Improve traffic flow • Reroute trucks • Increase trips by foot, bike, or transit **2. Street Design** • Lower volumes • Buffer people from roads	**3. Barrier Use** • Install walls • Add vegetation	**4. Design** • Locate sensitive uses farther from roads • Phase parcels closest to road later in build out	**5. Design** • Optimize occupant placement **6. Operations** • Use/improve HVAC filtration

Acknowledgments

Best practice work was supported by several U.S. EPA offices

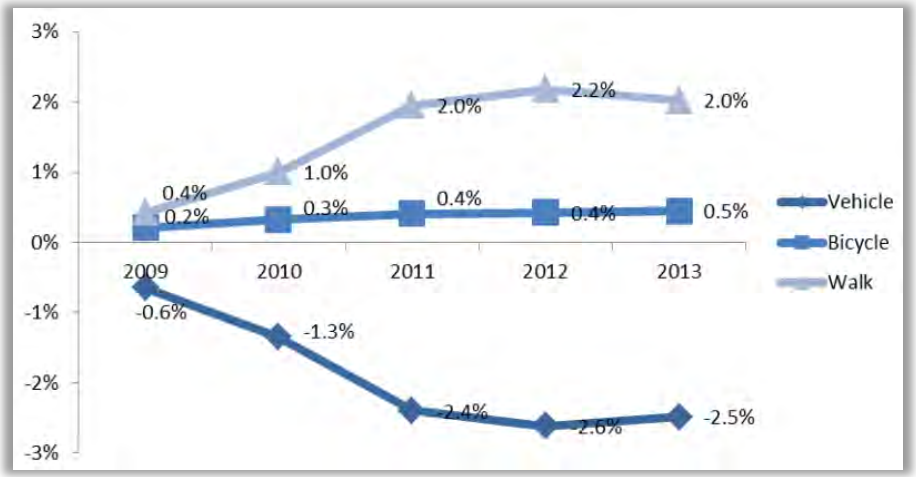
- Office of Sustainable Communities
- Office of Research and Development
- Office of Transportation and Air Quality
- Region 9 Office
- Office of Children's Health Protection

School filtration pilot testing work was supported by

- Nevada Department of Transportation
- Clark County School District

Supplemental Slides for Questions and Answers

Supporting Active Transport Can Reduce Vehicle Use

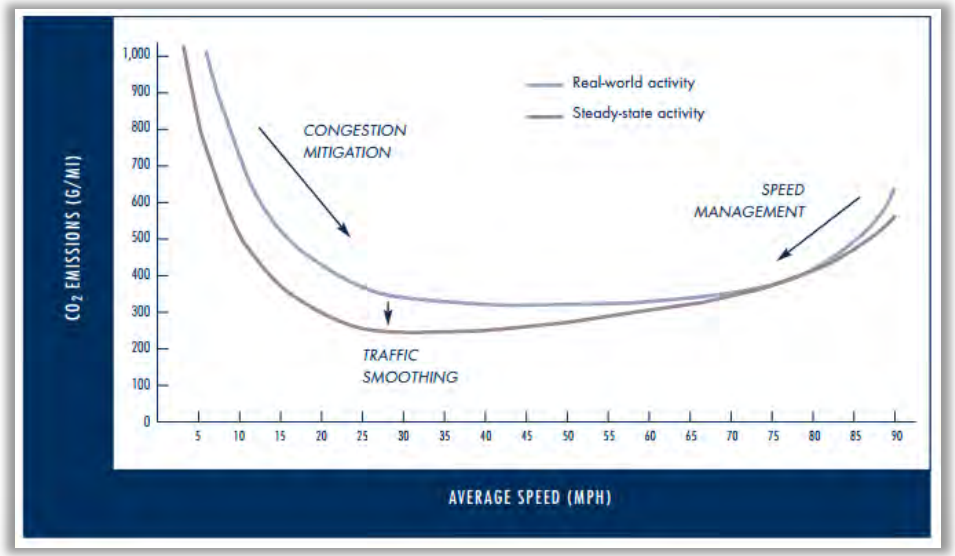


Changes in vehicle, bicycle, and pedestrian travel compared to 2007 baseline for four communities receiving ~$25M each in a pilot program to support walking and biking infrastructure and other non-motorized programs. Data presented are three-year moving averages. Image from Federal Highway Administration (2014).

Additional Resources

- **U.S. Environmental Protection Agency (2001)** Improving Air Quality Through Land Use Activities. Available at www.epa.gov/otaq/stateresources/policy/transp/landuse/r01001.pdf.
- **National Research Council (2009)** Driving and the built environment: The effects of compact development on motorized travel, energy use, and CO_2 emissions. Available at http://www.nap.edu/openbook.php?record_id=12747.
- **Federal Highway Administration (2014)** Nonmotorized Transportation Pilot Program. Available at http://www.fhwa.dot.gov/environment/bicycle_pedestrian/ntpp/2014_report/hep14035.pdf.

Smoothing Flow Can Reduce Emissions

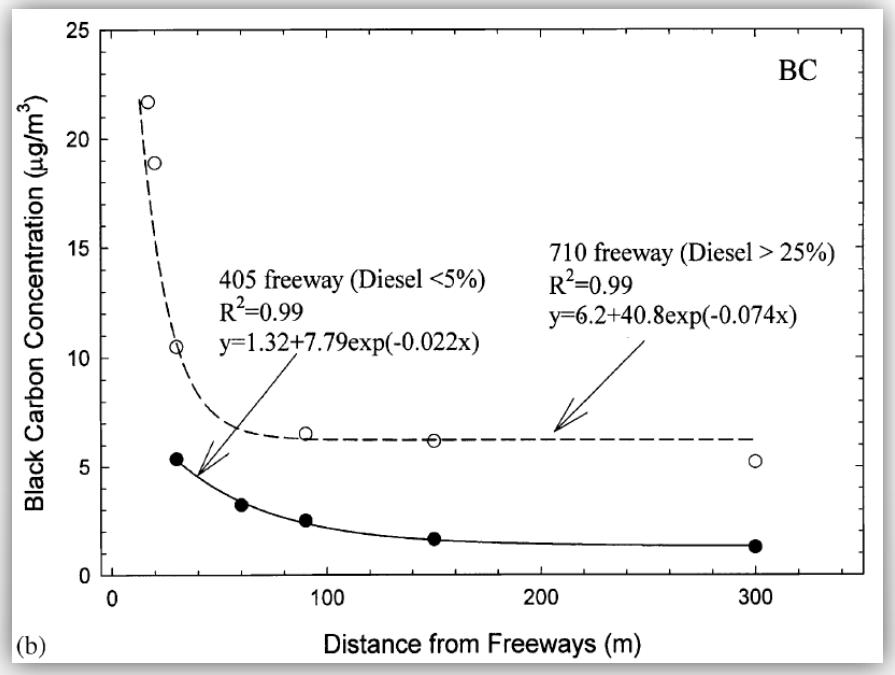


CO_2 emissions versus average vehicle speed, and possible use of traffic operation strategies. Image from Barth and Boriboonsomsin (2009).

Additional Resources

- **Timoshek et al. (2010)** Mobile source air toxic emissions: sensitivity to traffic volume, fleet composition, and average speed. *Journal of the Transportation Research Board*, 2158, 77-85.
- **Keuken et al. (2010)** Reduced NO_x and PM_{10} emissions on urban motorways in The Netherlands by 80 km/h speed management. *Science of the Total Environment*, 408(12), 2517-2526.
- **Dowling et al. (2005)** Predicting air quality effects of traffic-flow improvements. Available at http://trb.org/publications/nchrp/nchrp_rpt_535.pdf.

Rerouting, Restricting Trucks Targets Priority Emissions

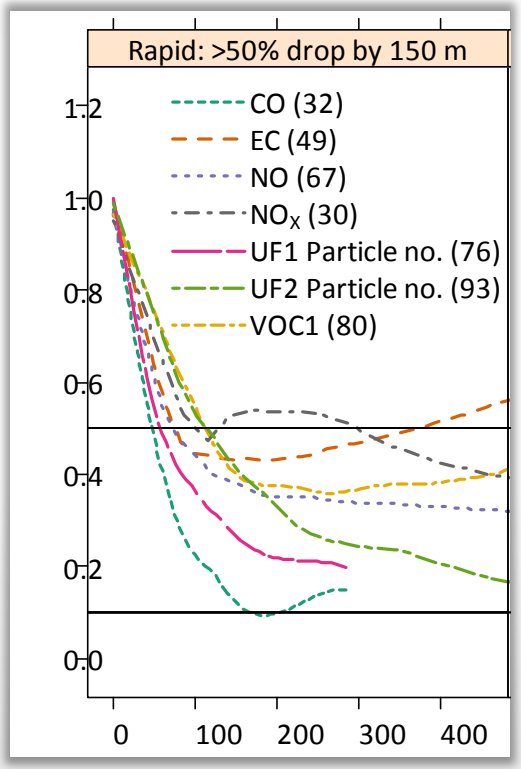


Pollutant concentrations as a function of distance from the roadway for roadways with <5% and >25% diesel traffic. Image from Zhu et al. (2002).

Additional Resources

- **Karner et al. (2009)** Mitigating diesel truck impacts in environmental justice communities: transportation planning and air quality in Barrio Logan, San Diego. *Journal of the Transportation Research Board*, 2125, 1-8.
- **Burr et al. (2004)** Effects on respiratory health of a reduction in pollution from vehicle exhaust emissions. *Occup. Environ. Med.*, 61(3), 212-218.
- **Zhu et al. (2002)** Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmos. Environ.*, 36(27), 4323-4335.

Concentrations Generally Decrease by at Least 50% Within 150 m (~500 ft) of a Roadway

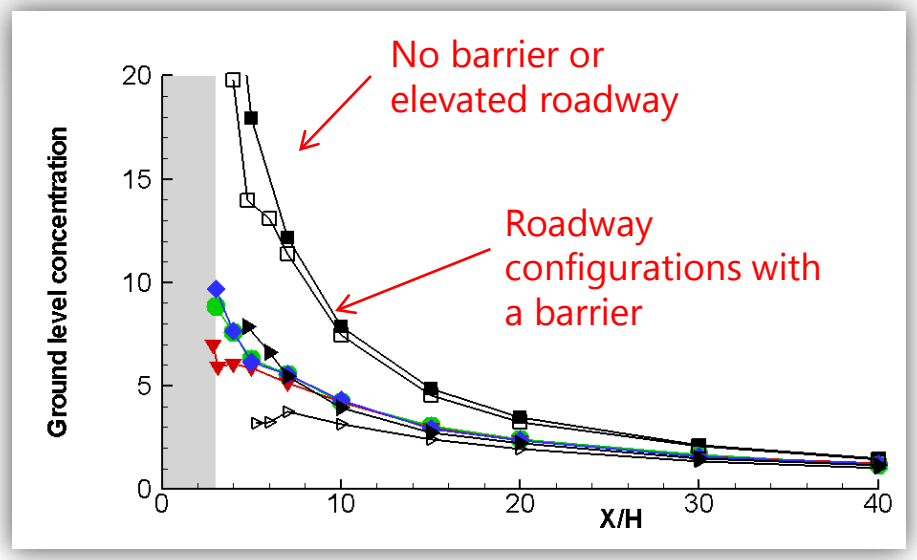


Normalized pollutant concentration as a function of distance in meters from the roadway. Image from Karner et al. (2010).

Additional Resources

- **Karner et al. (2010)** Near-roadway air quality: synthesizing the findings from real-world data. *Environ. Sci. Technol.*, 44, 5334-5344.
- **HEI Panel on the Health Effects of Traffic-Related Pollution (2010)** Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects. Special Report 17 by the HEI, Boston, MA.
- **Zhu et al. (2002)** Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmos. Environ.*, 36(27), 4323-4335.

Barriers Can Reduce Concentrations ~15–60%



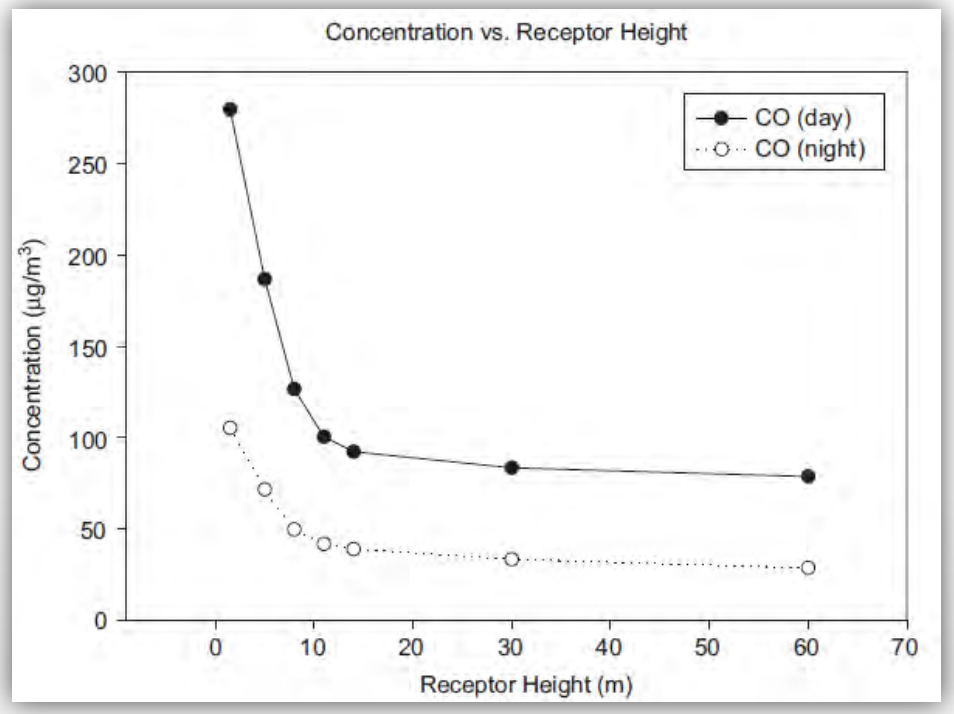
Normalized pollutant concentrations, normalized distance from road, and presence of a barrier. Data from

- Baldauf et al., 2009 (*Near-road air quality monitoring: factors affecting network design and interpretation of data*)
- Heist et al., 2009 (*Wind tunnel study on the effect of roadway configurations on the dispersion of traffic-related pollution*)

Additional Resources

- **Hagler et al. (2012)** Field investigation of roadside vegetative and structural barrier impact on near-road ultrafine particle concentrations under a variety of wind conditions. *Science of the Total Environment*, 419, 7-15.
- **Finn et al. (2010)** Tracer studies to characterize the effects of roadside noise barriers on near-road pollutant dispersion under varying atmospheric stability conditions. *Atmos. Environ.*, 44, 204-214.
- **Baldauf et al. (2008)** Impacts of noise barriers on near-road air quality. *Atmos. Environ.*, 42, 7502-7507.

Site, Building Design, and Use Can Reduce Exposure (Consider Concentration Changes with Height)

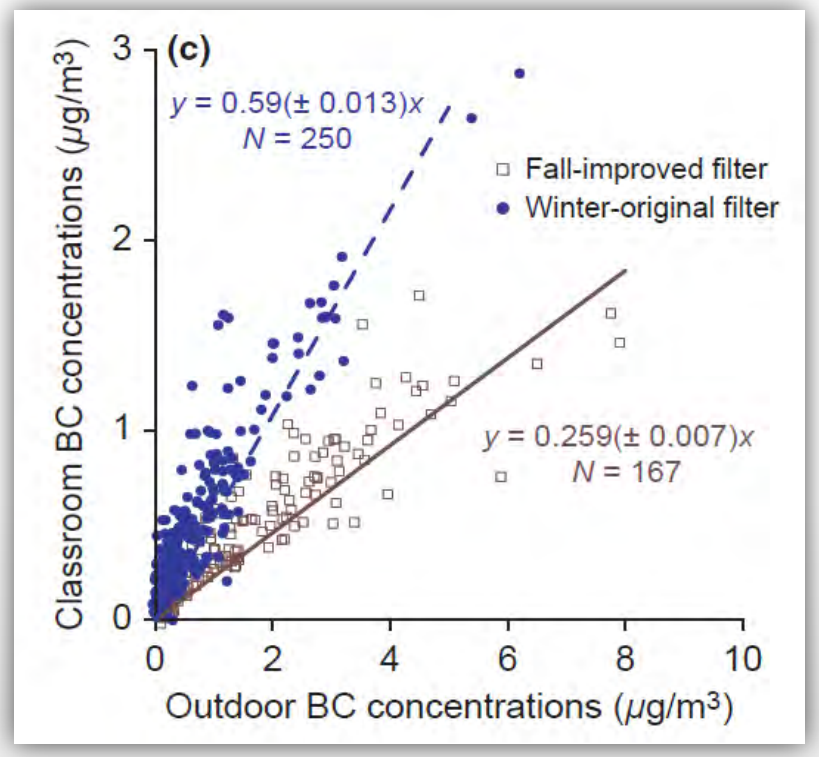


Modeled vertical profiles of CO in a New York City street canyon. Concentration in the graph refers to the contribution from traffic. Image from Zhou and Levy (2008).

Additional Resources

- **Jung et al. (2011)** Effects of floor level and building type on residential levels of outdoor and indoor polycyclic aromatic hydrocarbons, black carbon, and particulate matter in New York City. *Atmosphere*, 2, 96-109.
- **Zhou and Levy (2008)** The impact of urban street canyons on population exposure to traffic-related primary pollutants. *Atmos. Environ.*, 42(13), 2087-3098.

Filtration Can Reduce Indoor Particle Exposure by as Much as 97%



Indoor versus outdoor black carbon concentrations for classrooms using low- (purple) and high-efficiency (brown) filters. Image from McCarthy et al. (2013).

Additional Resources

- **McCarthy et al. (2013)** Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air,* 23(3) 196-207.
- **Polidori et al. (2012)** Pilot study of high-performance air filtration for classroom applications. *Indoor Air,* 23(3) 185-195.
- **Jamriska et al. (2003)** Control strategies for sub-micrometer particles indoors: model study of air filtration and ventilation. *Indoor Air*, 13(2), 96-105.

TRENDS IN HIGHWAY PLANTING AND IRRIGATION

Landscape Architecture at Caltrans

Jeff Pietrzak

Caltrans

Purpose of Highway Planting

- Functional

  (Shading of Roadway, Windbreaks, Erosion Control, Light Glare, Fire Supression)

- Mitigation

  (Biological , Visual)

- Aesthetic

  (Beautification, Limits Outdoor Advertising)

Types of Highway Planting

- New Highway Planting

  (New installation where warranted by policy)

- Replacement Highway Planting

  (Replacement of the investment which was damaged as the result of highway improvements)

- Highway Planting Restoration

  (Restoration of existing highway planting, on a 20 year cycle by policy)

- Required Mitigation Planting

  (Required planting necessary to mitigation environmental impacts due to roadway construction)

- Highway Planting Revegetation

  (Revegetation planting as mitigation for native vegetation removed due to roadway construction)

Past Trends
1920s

- Tree planting by Engineers
- Shade for pavement
- Truck watering to establish
- Maintenance not considered

Planting 1920s

Past Trends

1930s

- Functional planting - erosion control, fast growth needed
- Cost constraints,
- Truck watering,
- Minimal maintenance,
- Exotic plant materials

Planting 1930s

Planting 1930s

A roadside planting of Mesembryanthemum edule effectively controls weeds and reduces the fire hazard. (South of Santa Maria)

Past Trends

1940s

- Functional planting
- Cost constraints,
- Truck watering,
- Minimal maintenance,
- Erosion control plant materials
- R/W constraints - urban

Erosion Control 1940s

Type A stabilization during construction. Topsoil is cast on by dragline. (Seventh Street Interchange, Santa Ana Freeway, Los Angeles)

Arroyo Seco (1939)

Past Trends

1950s

- Interstate era - $ flows
- Few cost constraints
- Aesthetic considerations
- Simple rugged irrigation – metal pipe, skinner line, hand operation

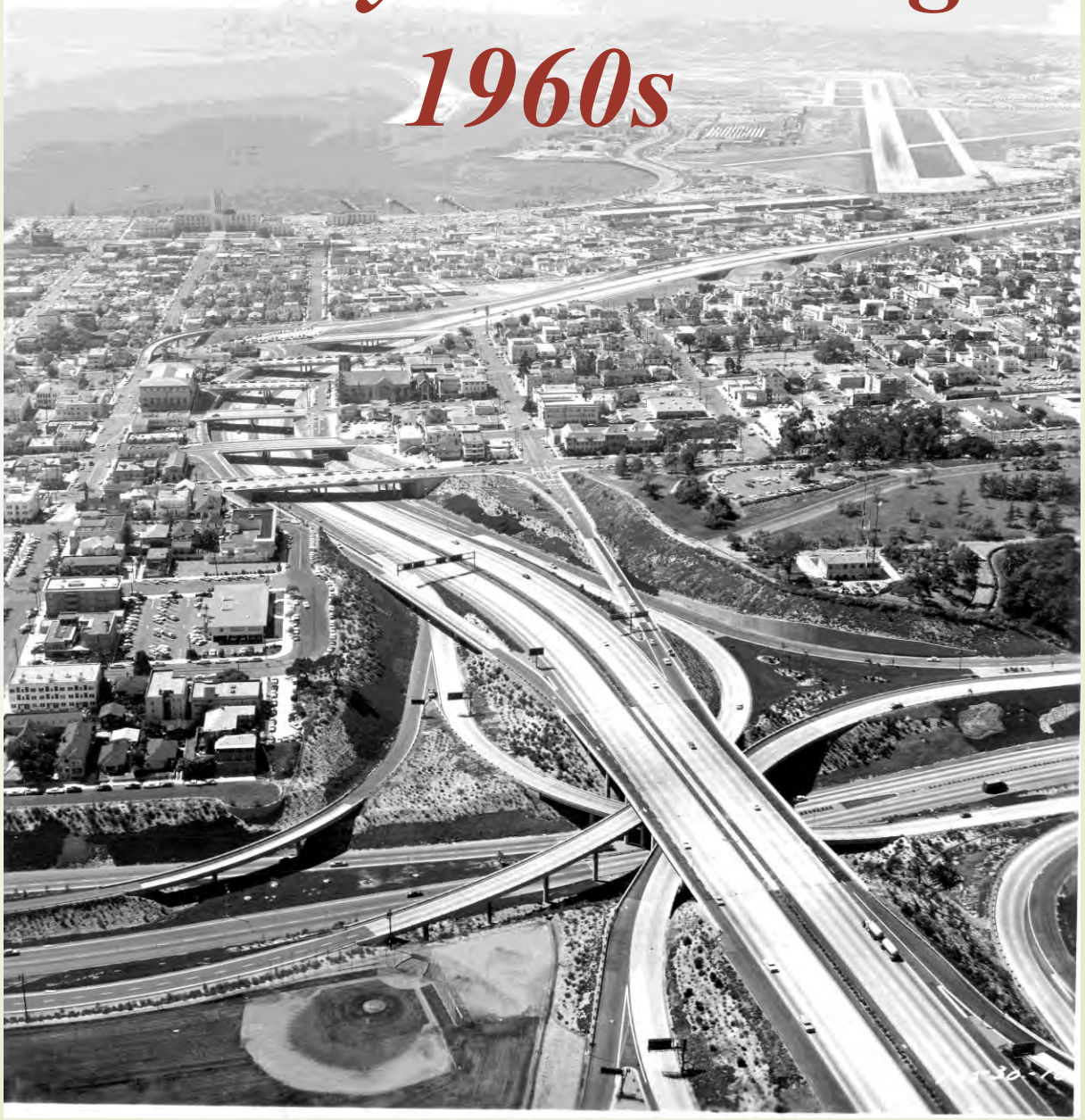
Parkways 1950s

Past Trends

1960s

- Interstate Era continues
- Highway Money flows,
- Simple aesthetics are routine
- Mixed shrub planting
- Eucalyptus & acacia trees
- Ice plant & ivy
- Large scale impact irrigation
- Routine maintenance.

Freeway Interchanges 1960s



Planting 1960s

Past Trends
1970s

- Environmental movement
- Human factors
- Aesthetics required
- Detailed planting design emerges
- Exotic species
- Spray irrigation
- Maintenance available.

Irrigation 1970s

Urbanism 1970s

Environmentalism 1970s

"World's Most Beautiful Freeway"

Past Trends
1980s

- CTC actions, Cost constraints
- Freeze & Drought
- Plantable right-of-way shrinks
- Aesthetics a routine consideration
- Detailed planting design + trees and weeds too
- Exotic species
- Drought again drip irrigation
- Maintenance reductions.

Planting 1980s

Planting 1980s

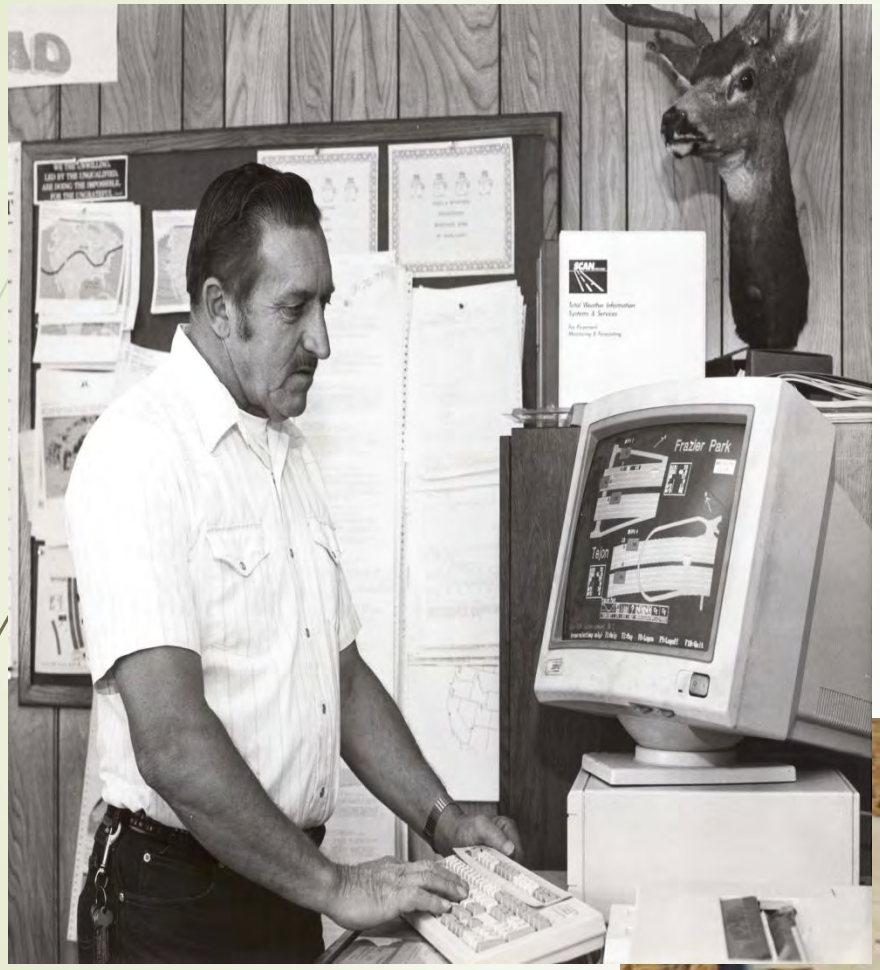
Deep Freeze 1980s

Past Trends

1990s

- Drought again,
- Aesthetics a routine consideration
- Detailed planting design emerges
- Inert ground cover materials,
- Exotic species + natives
- Bubbler irrigation
- Maintenance reductions
- Clear Recovery Zone (CRZ)

Irrigation 1990s



Planting 1990s

Maintenance 1990s

Past Trends

2000s

- Worker safety
- Stakeholder involvement
- Detailed planting design re-emerges
- Inert ground cover materials
- Natives
- Bubblers return
- Maintenance reductions.

Roadside 2000s

Current Trends

2010s

- Drought again (1976, 1988, 1998, 2014)
- Stakeholders as lead
- Simplified planting design re-emerges
- Site design on the roadside
- Inert ground cover materials
- Regionality
- Natives
- Bubblers and impact irrigation returns
- More maintenance reductions

Irrigation 2010s

Planting 2010s

After

Before

The Context

Stakeholders
Water availability
New Technology
Scenic Vistas
Farmland
Historic Districts
Residential Neighborhoods
Wildlife Habitat
Scenic Byways
Wildflowers
Endangered Species
Rivers
Parks
Business Districts
Pedestrian Route
Bikeways
Lakes
Inter-Regional Corridors
Wetlands
Mass Transit
"Main Streets"
Archaeological Sites
Local plans

Trends and Influences

What are the external factors that influence your design decisions?

Takeaway

- **Much of the local highway roadside was designed in the 1960's and has not been rehabilitated.**
- **Rehabilitation and new highway planting projects now consider local context, funding constraints, environmental considerations, and long term maintenance requirements.**
- **Plant materials must be placed in safe locations meeting standard setback requirements.**
- **Trees = 30' min. from edge of traveled way.**

Trends in Highway Planting and Irrigation

Thank You

Questions?

Vegetation and Soundwalls around Freeways: Can trees help? Overview of CARB 13-306

Pollution Characterization:

Dilhara Ranasinghe, Wonsik Choi, Eon Lee, Yifang Zhu, and Suzanne Paulson

Vegetation Characterization:

Ulli Seibt

UCLA

With meteorological characterization support by UCR (Amini, Ahangar, Venkatram)

Supported by the California Air Resources Board

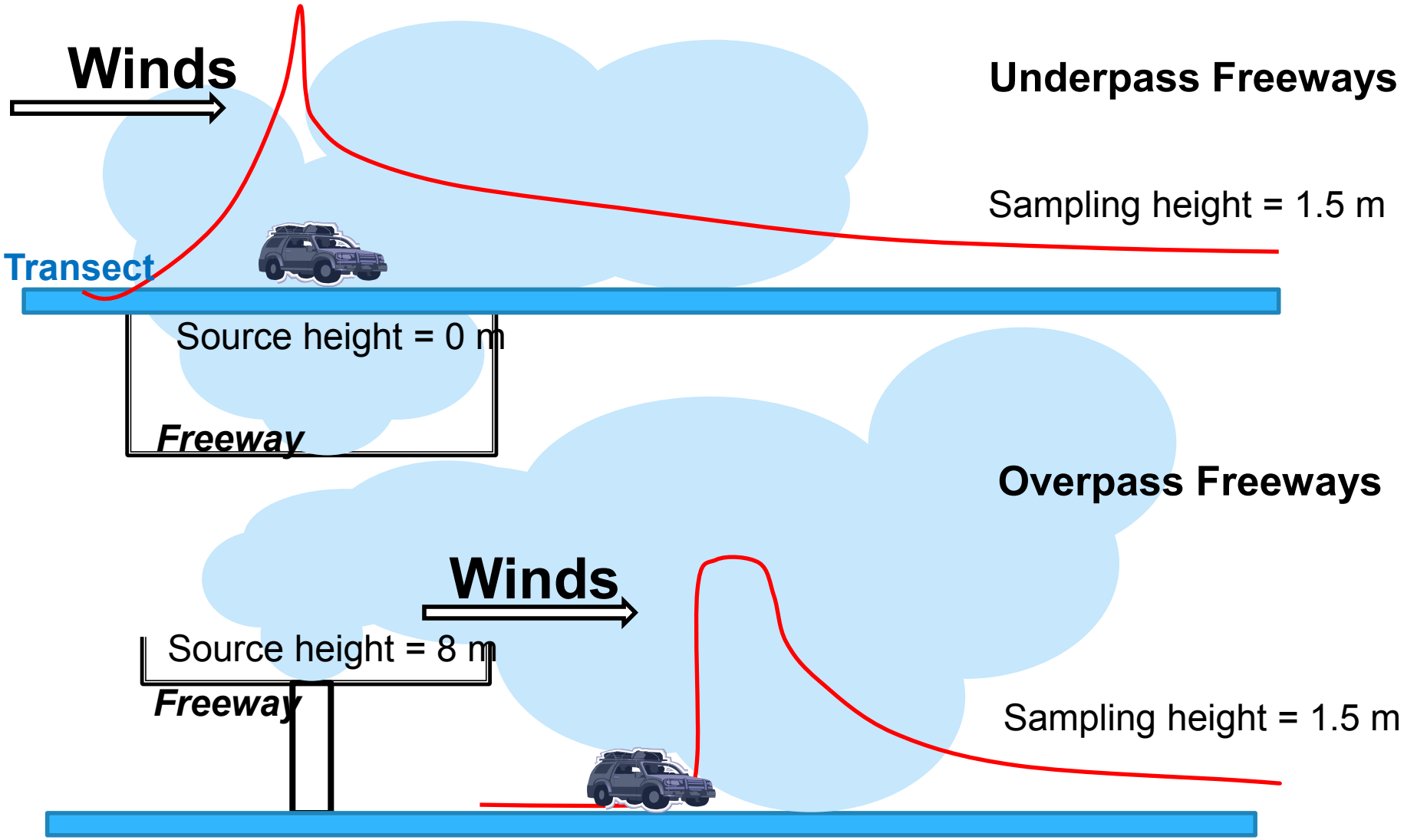
OVERVIEW OF CARB 13-306

- Perform four soundwall measurement campaigns, at three sites; 2 in the South Coast Air Basin, 1 in the Sacramento area.
- Site conditions:
  - Four possible configurations
    - No Soundwall
    - Soundwall
    - Vegetation
    - Vegetation + Soundwall
  - Difficult to find good sites with even two of these conditions.

OTHER CONSIDERATIONS

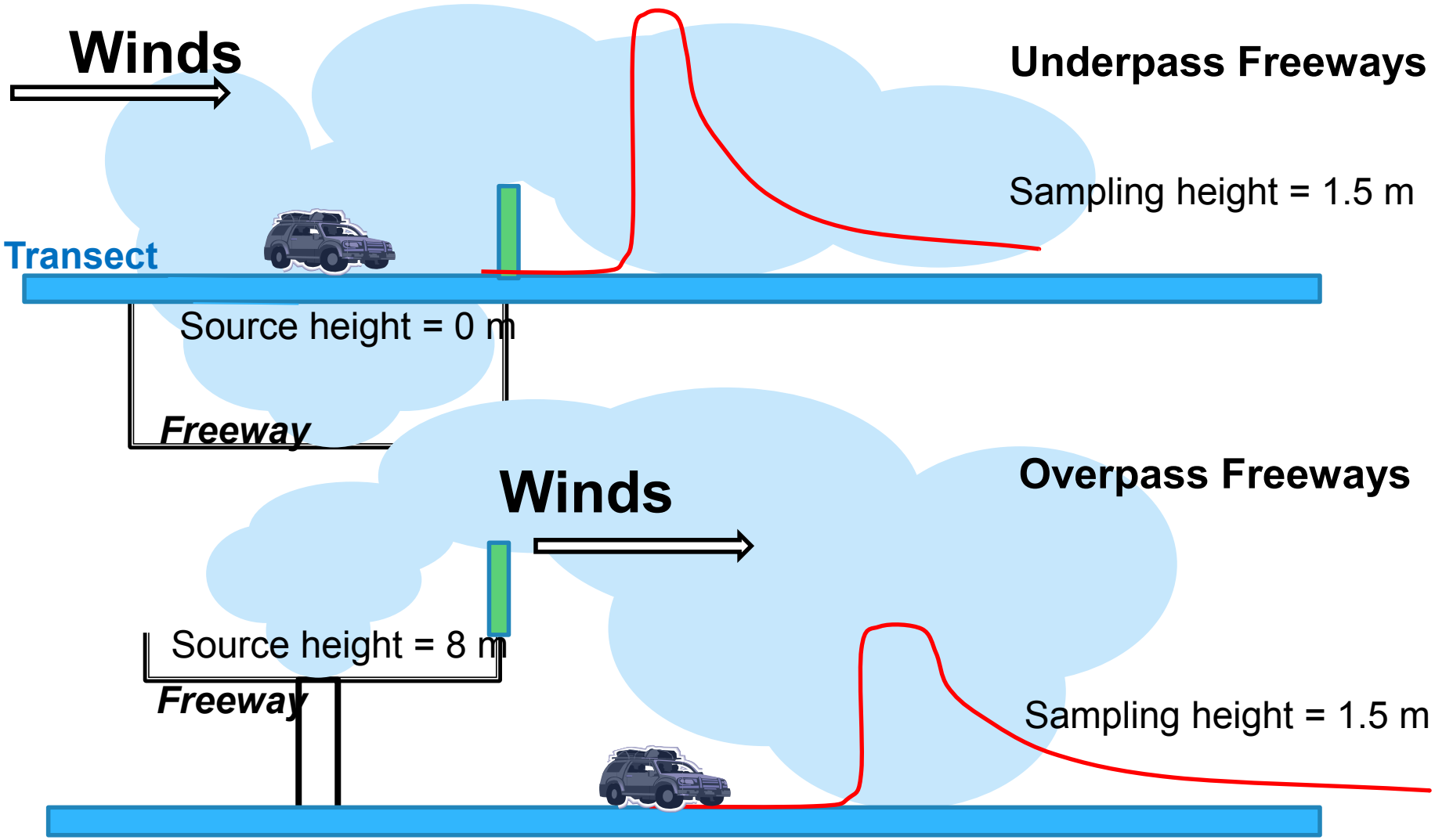
- Prefer winds that are ~ perpendicular to the roadway → larger, clearer effects, larger impact of the freeway on neighbors.
- Prefer flat terrain adjacent to the freeway → simpler to interpret.
- Soundwalls at roadways at or below grade will likely produce larger impacts and will be simpler to interpret. Rural freeways are often at grade.
- In dense urban areas, freeways are generally not at grade. Often they are elevated. What is the most relevant?

AT, ABOVE OR BELOW GRADE?



Choi, W.S. et al. (2014) *Atmos. Chem. & Phys* **14(13):** 6925 - 6940.

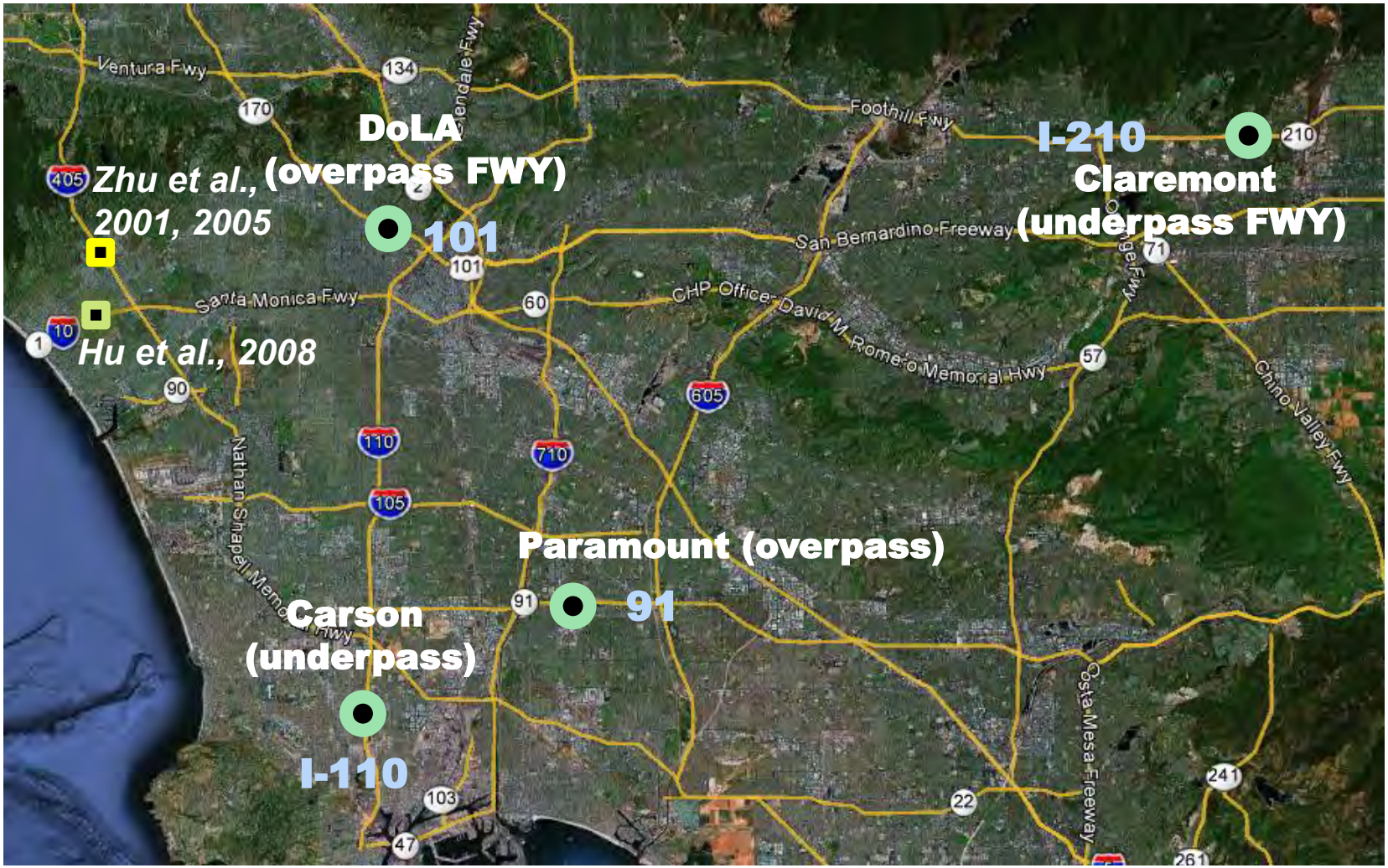
AT, ABOVE OR BELOW GRADE?



Choi, W.S. et al. (2014) *Atmos. Chem. & Phys* **14(13):** 6925 - 6940.

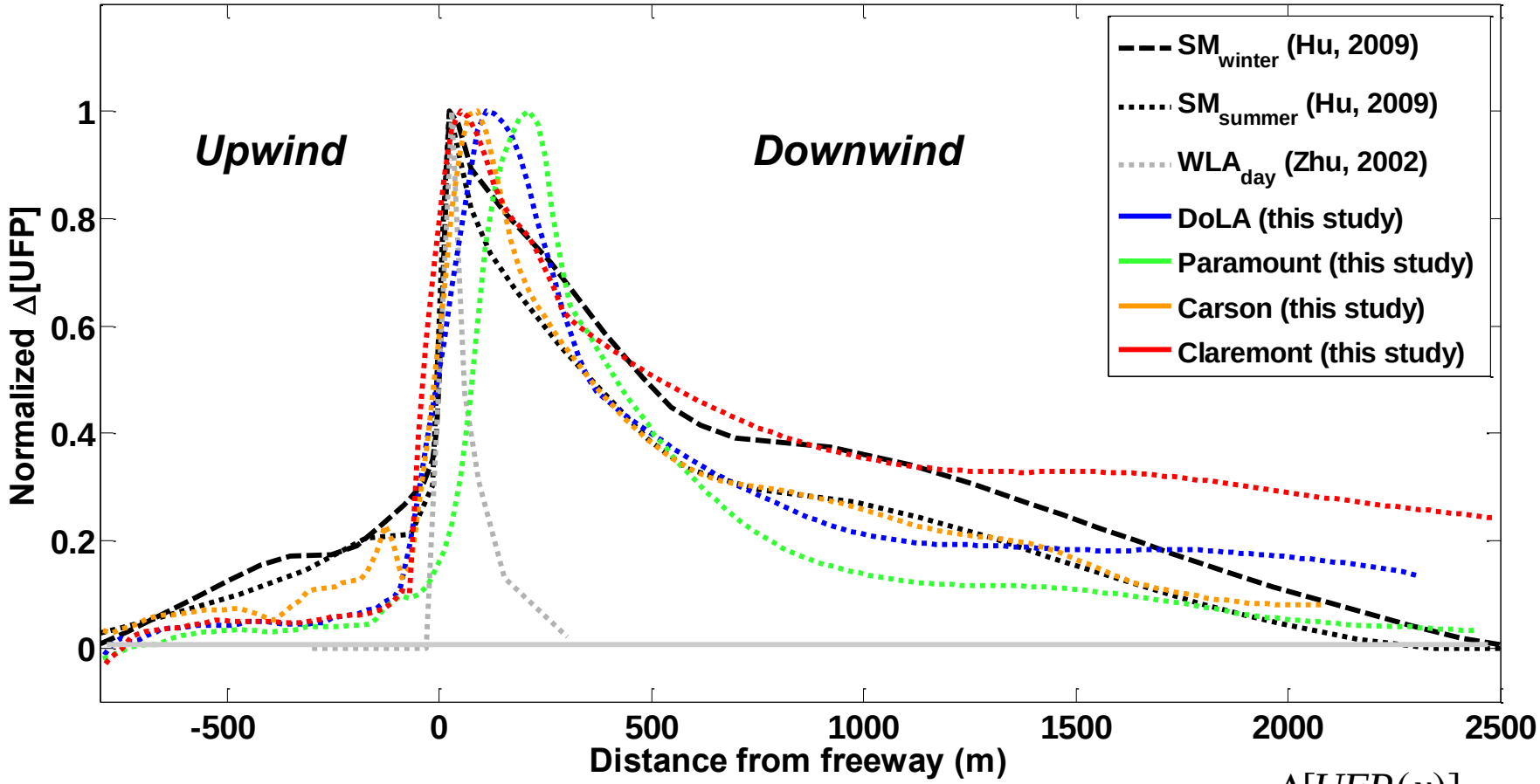
DAYTIME OR EARLY MORNING?

Sampling Area and Transects



Choi, W.S. et al. (2014) *Atmos. Chem. & Phys* **14(13):** 6925 - 6940.

Early Morning Freeway Plumes at Other Locations in Southern California

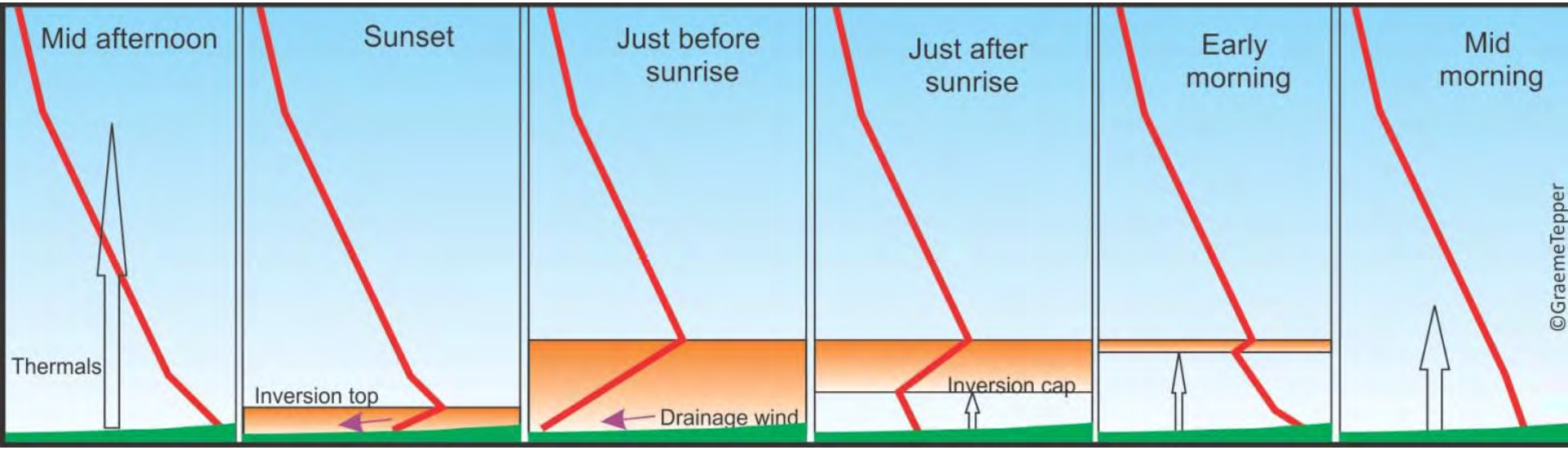


$$\Delta[UFP] = [UFP] - [UFP]_{bkgnd}$$

$$\text{Normalized}\,\Delta[UFP(x)] = \frac{\Delta[UFP(x)]}{\Delta[UFP]_{peak}}$$

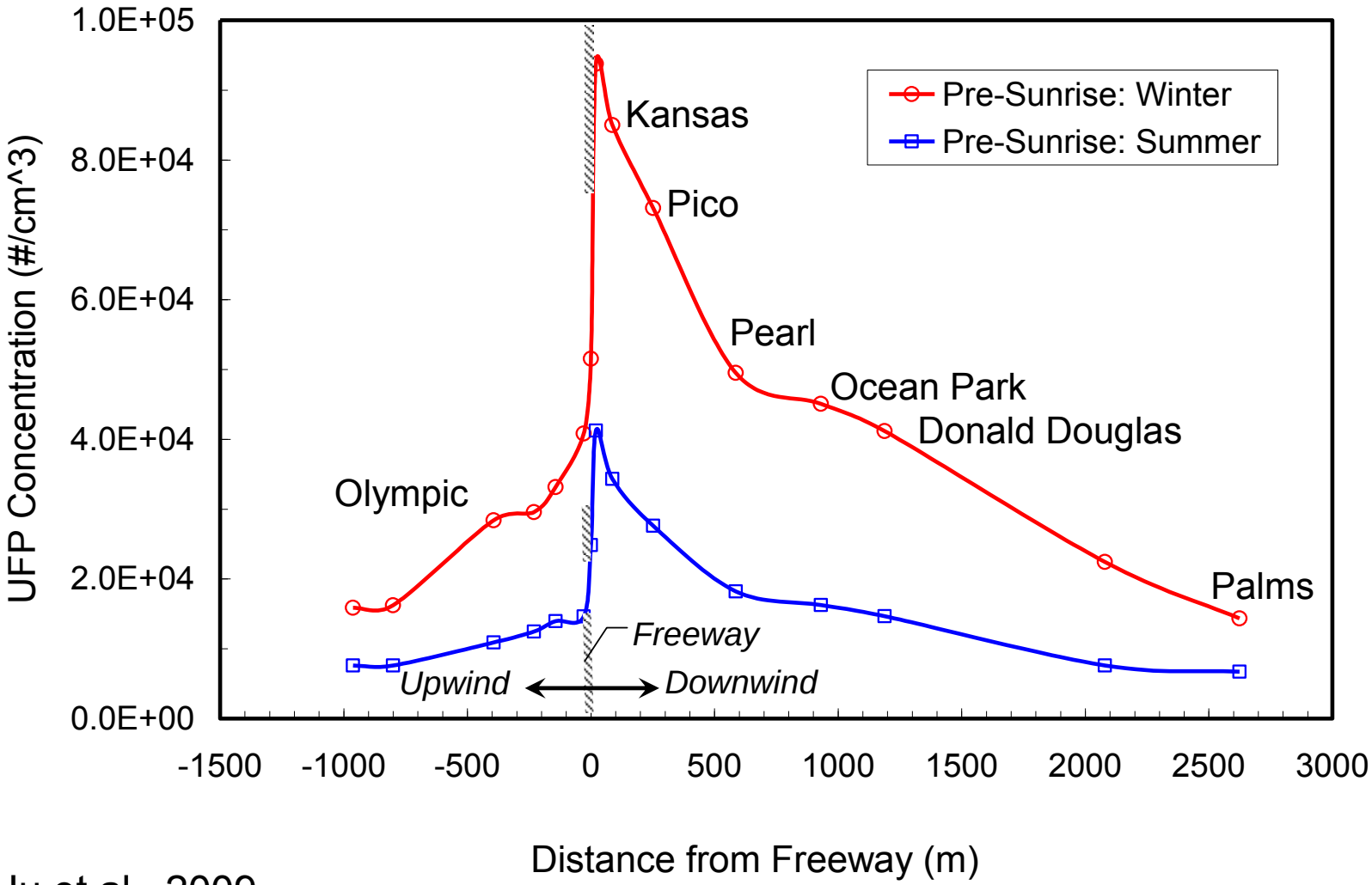
[Choi et al., Atmos. Environ., 62, 318-327, 2012]

The Atmosphere Strongly Traps Pollution Near the Surface in the Early Morning



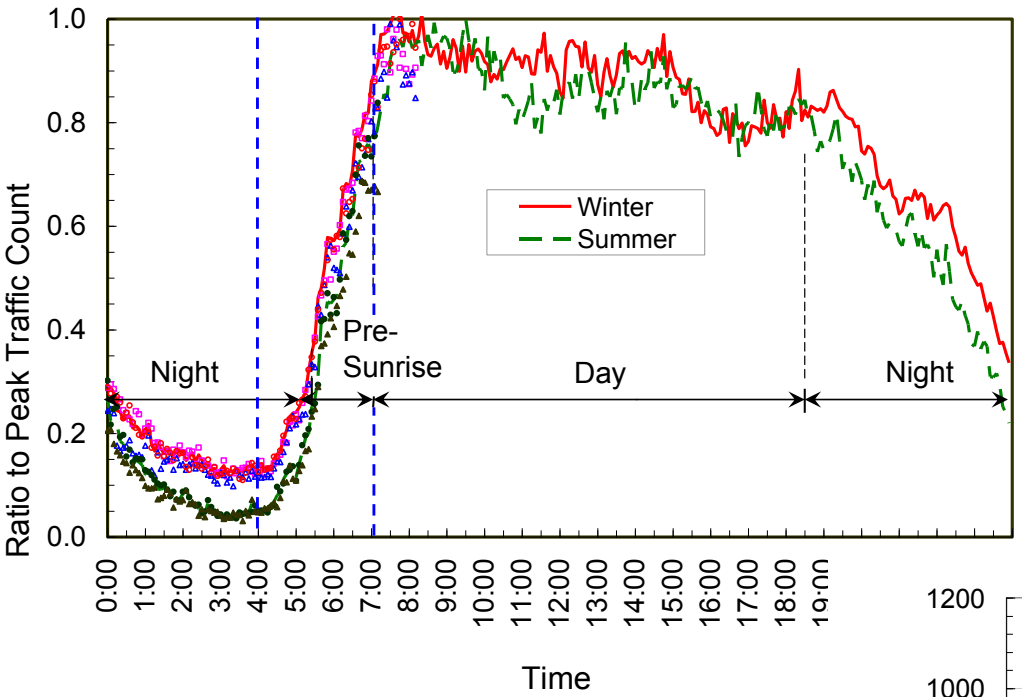
Red line indicates temperature profile

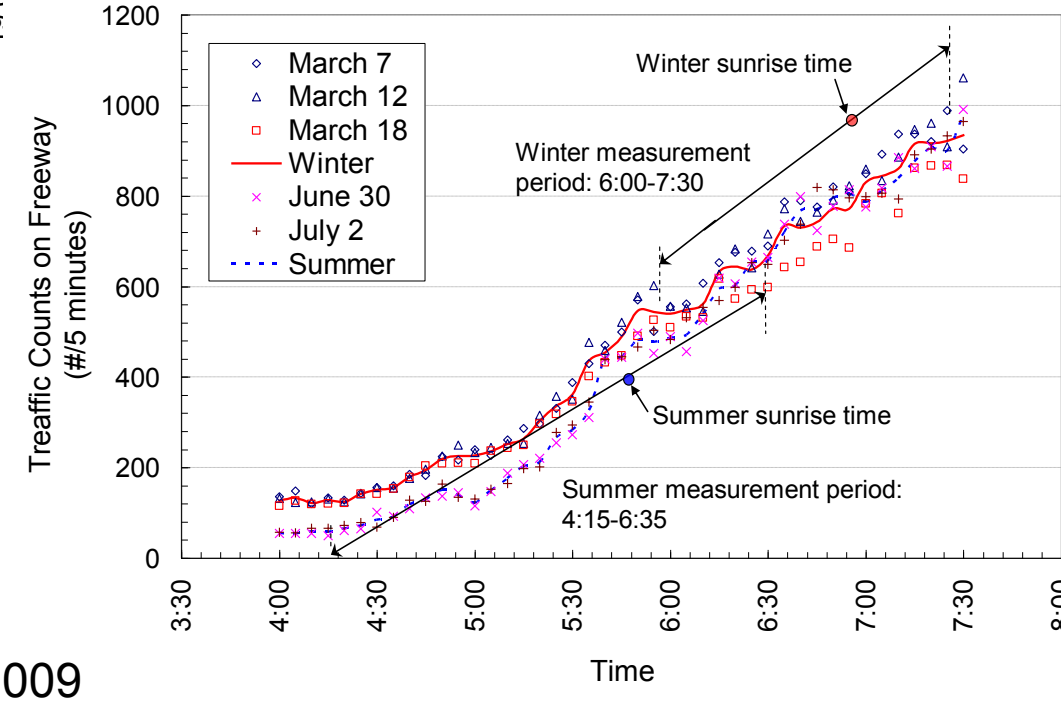
Santa Monica: Summer is Cleaner; why?



Hu et al., 2009

Traffic Counts Increase Rapidly in the Early AM

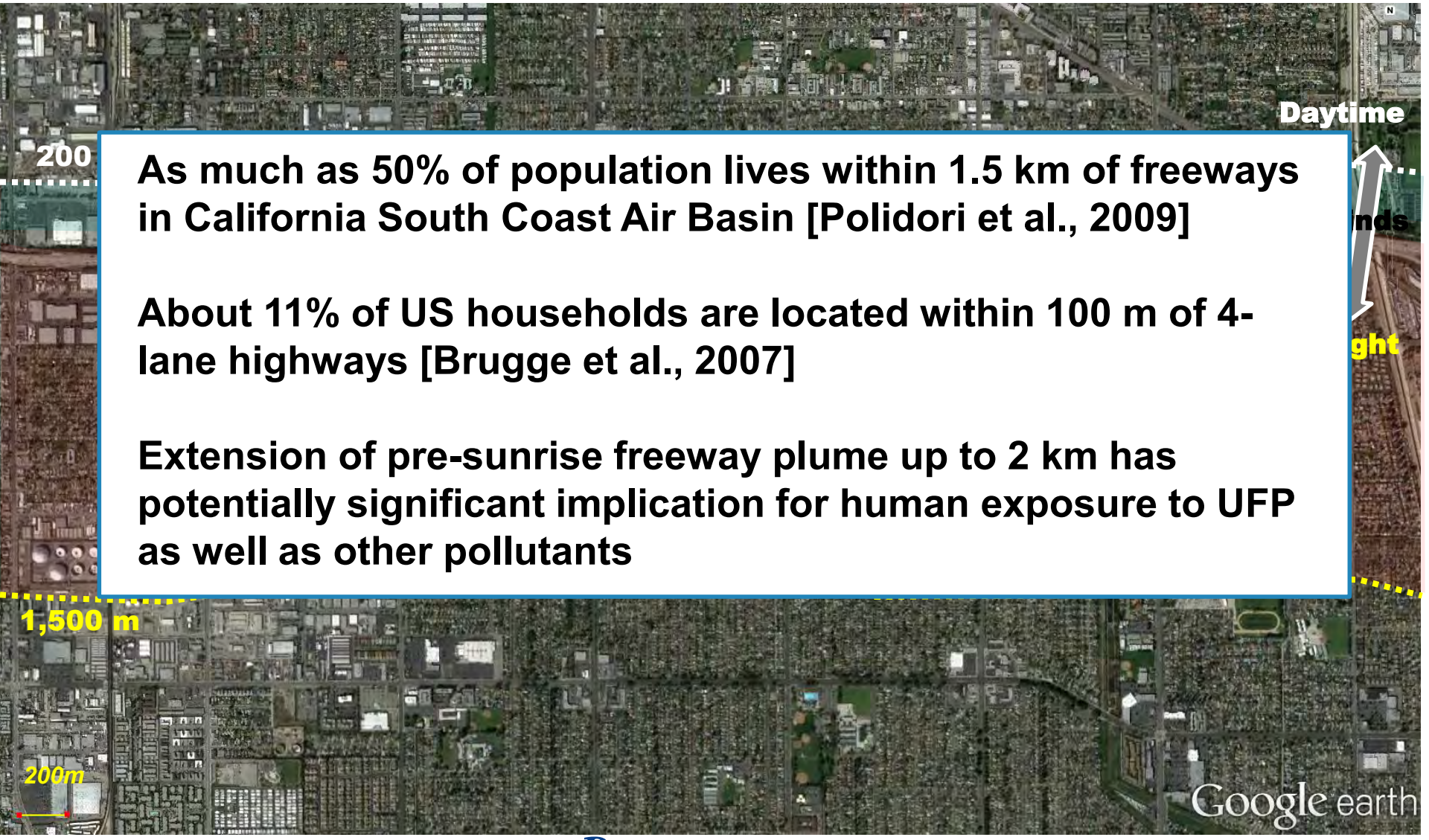




Summer is cleaner because there is less traffic during the pre-sunrise period

Hu et al., 2009

Night and Day



As much as 50% of population lives within 1.5 km of freeways in California South Coast Air Basin [Polidori et al., 2009]

About 11% of US households are located within 100 m of 4-lane highways [Brugge et al., 2007]

Extension of pre-sunrise freeway plume up to 2 km has potentially significant implication for human exposure to UFP as well as other pollutants

Paramount

CHALLENGES FINDING GOOD SITES

- Almost all residential areas in the South Coast Air Basin have a soundwall.
- Older freeway construction often has low barriers, newer construction taller barriers. Sometimes these are right next to each other.
- Almost all areas without a barrier are located near an interchange. Not good!
- Logistically, it is much easier to deploy stationary monitors in residential neighborhoods. Also need upwind stationary sites.
- But these almost always have walls—no controls!

OVERVIEW OF CARB 13-306

- We have closely examined over 100 miles of freeway and considered about 15 sites so far. We finally have 3 sites that seem viable.
- 1. Santa Monica
- 2. El Monte
- 3. Sacramento

Stationary Monitoring Instrumentation

Instrument and manufacturer	Time Resolution	Research Group
UFP/Fine Particle Size Distribution		
SMPSs (TSI) (3)	1 min	Zhu/Paulson
Particle Number Concentration		
Testo Discmini (4)	1 sec	Paulson
**CPC 3007	1 sec.	Zhu
WCPC 3785	1 sec.	Zhu
PM2.5		
DustTrak (2)	1 min	Zhu
Dylos (4)		Paulson/Zhu
NO_x and NO_2		
Ogawa Passive Samplers (70)	1 day - few weeks	Zhu
Noise		
Quest 2900/MicroDaQ (3)	1 min	Paulson/Zhu
Micro met		
Sonic Anemometer CSAT3 (3)	1 – 60 Hz	Venkatram

Pollutants & Measurements

Measurement Parameter
Particle Number (10 nm ~ 1μm), but dominated by ultrafine particles
Particle size distribution (5.6~560 nm)
$PM_{2.5}$ and PM_{10} mass
Particle bound PAHs
Black Carbon
CO_2
CO
NO, NO_2
Temperature, Relative humidity, Wind speed/direction
GPS
Vertical profiles of temperature, *RH*, wind speed/direction
Video record
-------- Wish List ----------
Speciated Volatile Organics
Particle Chemical Composition

ARB's electric vehicle

SmartTether™

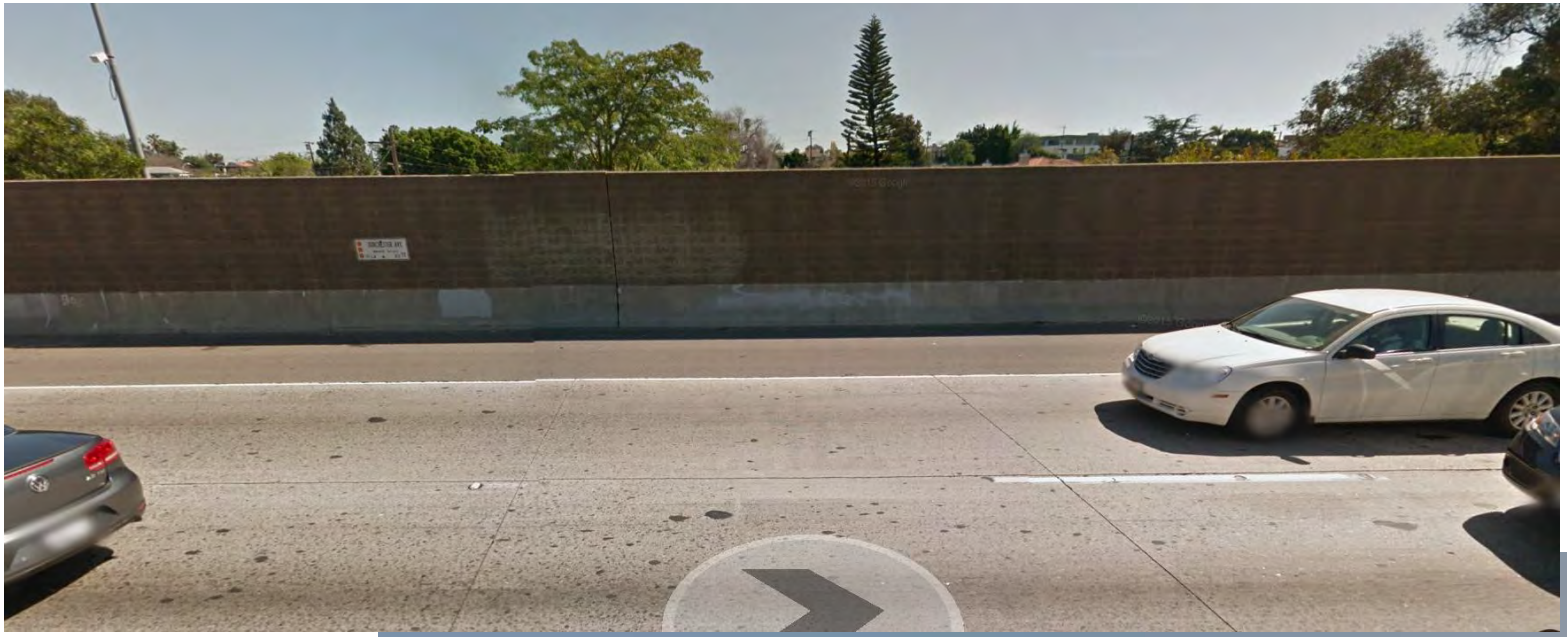
VEGETATION

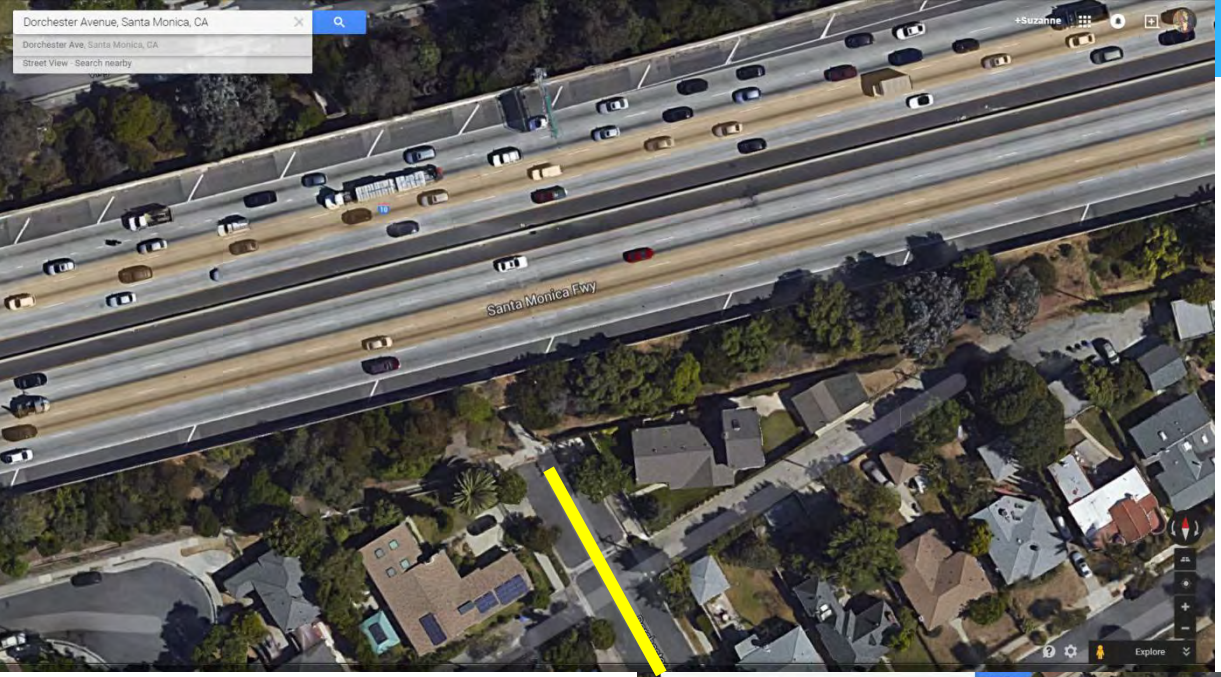
- With only three sites and so many other requirements in site selection we are not be able to find sites with an ideal selection of vegetation variables (i.e. control for height and geometry, vary leaf area index).
- Nonetheless, we hope to contribute to the understanding of the effectiveness of vegetation at mitigating pollution.

Characterize the vegetation

- Physical characteristics control deposition and barrier activity:
  - genus and species, height, width, spacing,
  - optical porosity, leaf shape and clumping, leaf area index
  - Leaf area index is likely the dominant parameter governing particle deposition
- Activity characteristics:
  - genus and species, height, width, spacing,
  - leaf area index
  - stomatal conductance: presumably most important characteristic controlling impacts on gaseous pollutants

SANTA MONICA:
WALL + VEGETATION VS. VEGETATION "MORNING SIDE"

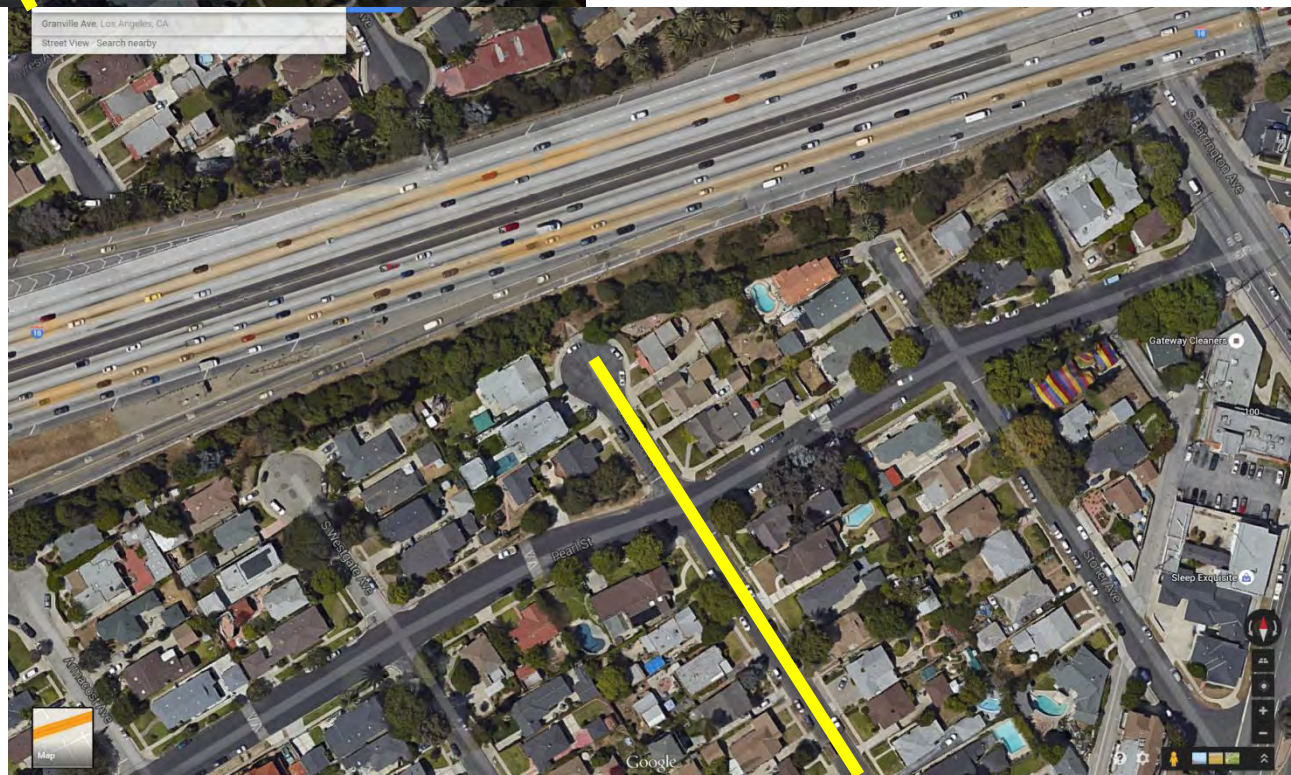




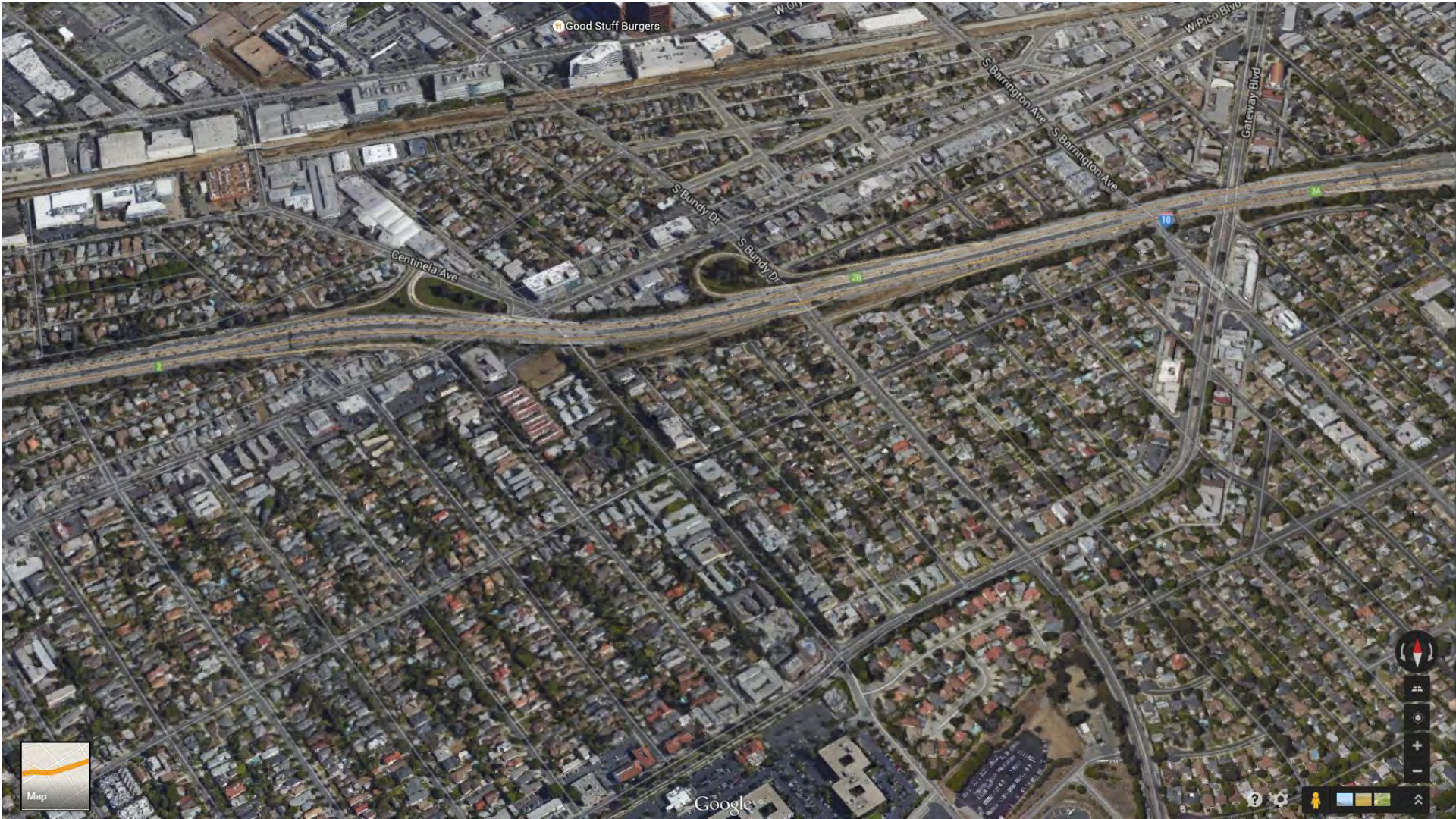
Santa Monica Site: Freeway is elevated 5-6 m

Similar Vegetation

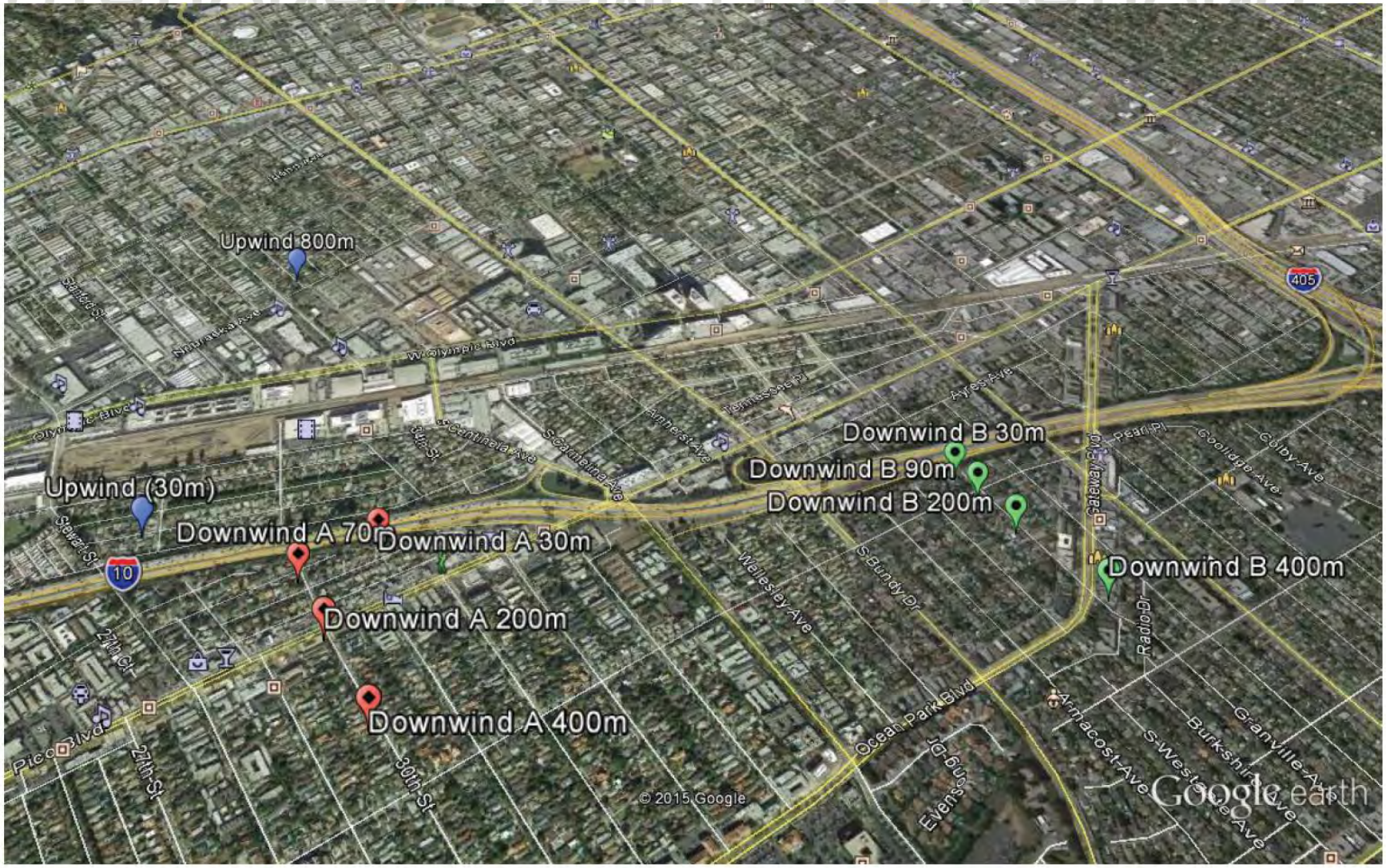
Similar but not identical elevation profile



Santa Monica Site:
Both have vegetation, one has soundwall



STATIONARY SAMPLER LOCATIONS



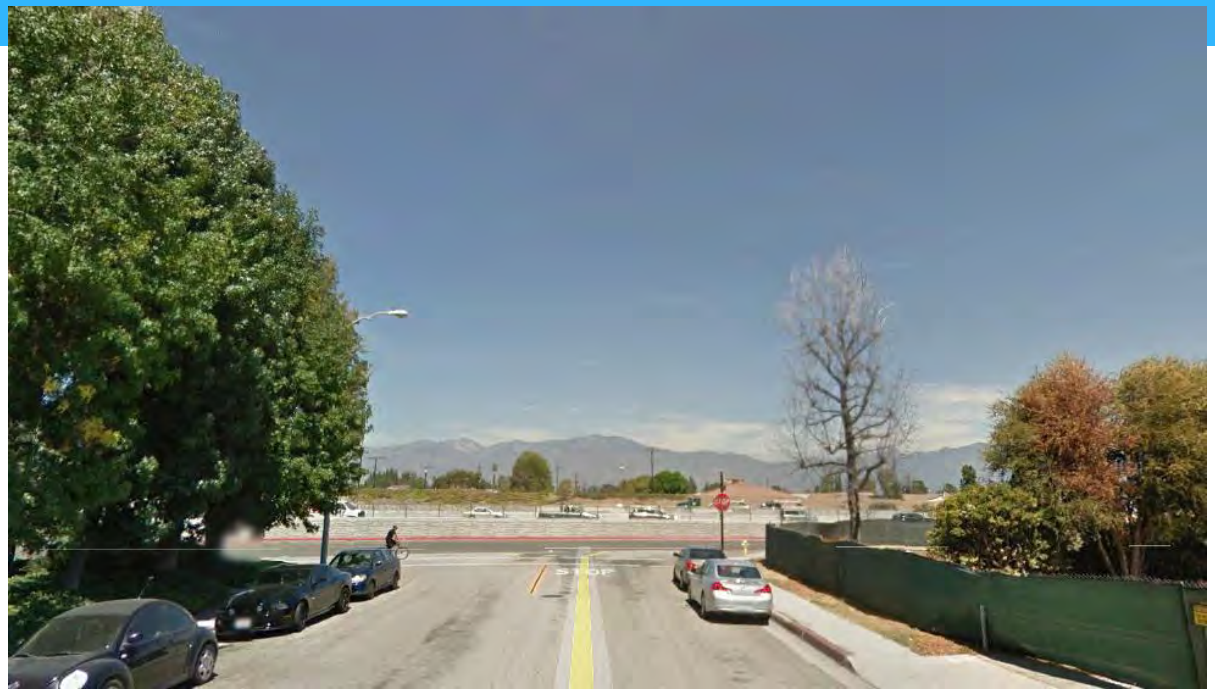
Google earth

feet 3000

km 1

EL MONTE:
WALL
VS. NO WALL
PRIMARILY AM

EL MONTE WALL/NO WALL AM SITE



No-Wall Site

Wall Site

SACRAMENTO:
WALL + VEGETATION VS. NO WALL DAYTIME

Wall only site
Vegetation
26th Ave.
27th Ave.
27th Ave
Strawberry Ln
10m
40m
100m
150m
250m
Distances perpendicular to the freeway
28th Ave
34th St
35th St
Golden State Hwy
S Sacramento Fwy
Strawberry Ln
Mascot Ave
26th Ave
Martin Luther King Jr Blvd
99
© 2015 Google
Google earth
1993
Imagery Date: 7/2/2014 38°31'38.66" N 121°28'01.62" W elev 8 m eye alt 464 m

Vege+Wall site

Thank you for your attention

The Credit is Really Due to:

Wonsik Choi
Dilhara Ranasinghe
Eon Lee
Yifang Zhu
Arthur Winer

***California Air Resources Board**

With assistance from Walter Ham, Kathleen Kozawa, Steve Mara, Walter Ham, And UCR M. Amini, F, Ahangar and A. Venkatram

Near-Roadway Risk Screening
Tools for Urban Planners

David Holstius[1], Edmund Seto[2], Phil Martien[1], Virginia Lau[1], Amir Fanai[1], David Vintze[1], Henry Hilken[1], Stephen Reid[3]

[1] Bay Area Air Quality Management District
[2] UC Berkeley (now Univ. Washington) [3] Sonoma Technology, Inc.

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

➢ Regional Air Pollution Control Agency

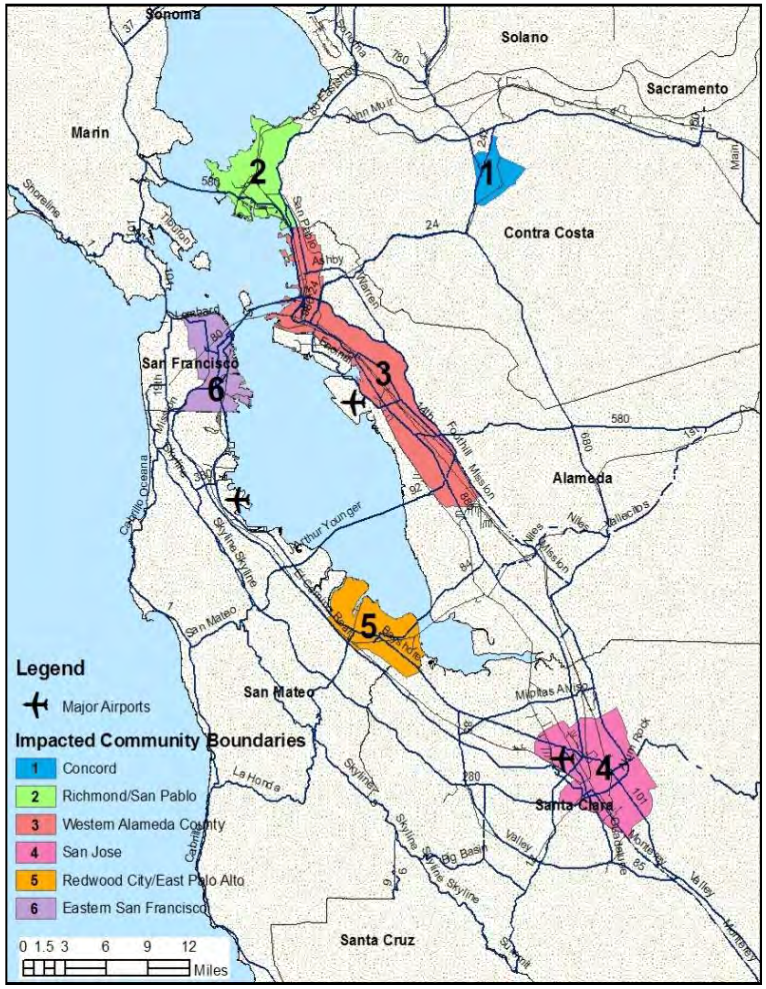
- Jurisdiction over air quality in San Francisco Bay Area
- 9 counties, 101 cities, population > 7 million
- 170+ million vehicle-miles per day
- 22 member Board of Directors

➢ Responsibilities

- Stationary source regulations & permits
- Compliance assistance/enforcement
- Air quality monitoring
- Plans for attaining/maintaining air quality standards
- Incentive programs (reduce emissions from motor vehicles)
- Coordinate with regional agencies, cities and counties on transportation and land use programs to reduce motor vehicle emissions

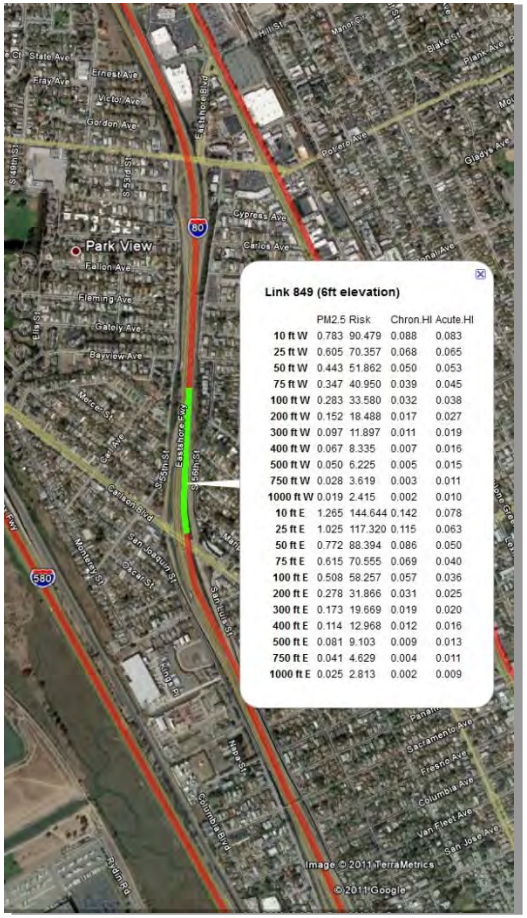
Community Air Risk Evaluation (CARE)

- CARE program identifies 6 priority communities in Bay Area (2009)
  - Exposure of vulnerable populations (youth, seniors, low income) to air toxics
  - High emissions of air toxics
  - Roadways as primary boundaries
- Focus comprehensive emission reduction strategies through Clean Air Communities Initiative
- Seek to reduce impacts from land use and transportation decisions
- Promote infill, while protecting residents
- Impacted communities currently being updated to include PM, other factors



Technical Assistance for Planners

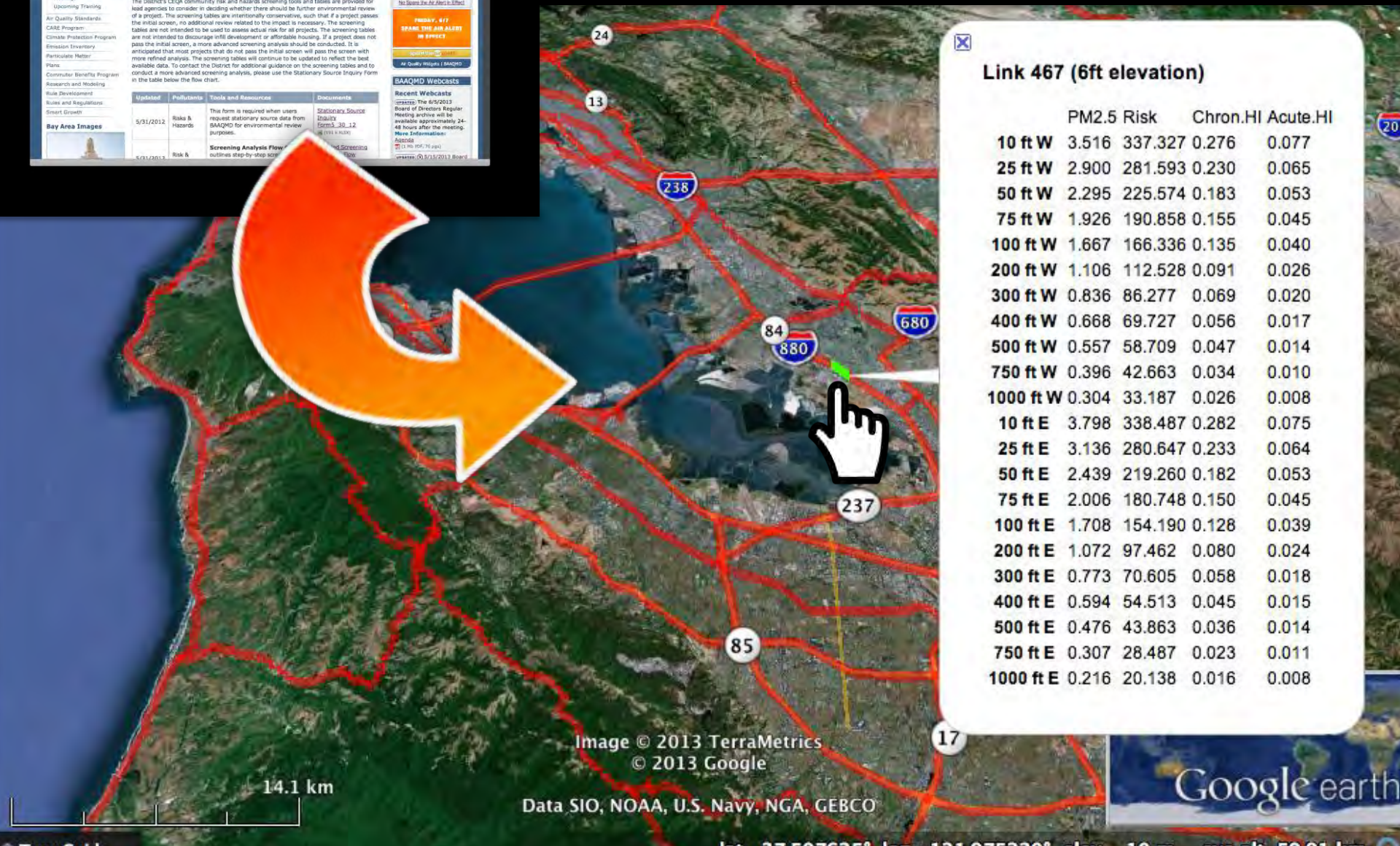
- **Guidance for environmental review processes**
  - Estimating and mitigation AQ impacts
- **State Highways Screening Tables**
  - PM and risk values for all links along every state highway, at varying distances from roadway
  - Local traffic volumes and meteorology
  - Google Earth application
- **Surface Street Screening Tables**
  - County specific meteorology and truck percentages
- **Stationary Source Screening Tables**
  - PM and risk values for permitted stationary sources
- **Planning Guidance**
  - How to address healthy infill in local plans & programs
  - Recommend best practices - air filtration, setbacks, site design, project phasing, etc.



	PM2.5	Risk	Chron.HI	Acute.HI
10 ft W	0.783	90.479	0.088	0.083
25 ft W	0.605	70.357	0.068	0.065
50 ft W	0.443	51.862	0.050	0.053
75 ft W	0.347	40.950	0.039	0.045
100 ft W	0.283	33.580	0.032	0.038
200 ft W	0.152	18.488	0.017	0.027
300 ft W	0.097	11.897	0.011	0.019
400 ft W	0.067	8.335	0.007	0.016
500 ft W	0.050	6.225	0.005	0.015
750 ft W	0.028	3.619	0.003	0.011
1000 ft W	0.019	2.415	0.002	0.010
10 ft E	1.265	144.644	0.142	0.078
25 ft E	1.025	117.320	0.115	0.063
50 ft E	0.772	88.394	0.086	0.050
75 ft E	0.615	70.555	0.069	0.040
100 ft E	0.508	58.257	0.057	0.036
200 ft E	0.278	31.866	0.031	0.025
300 ft E	0.173	19.669	0.019	0.020
400 ft E	0.114	12.968	0.012	0.016
500 ft E	0.081	9.103	0.009	0.013
750 ft E	0.041	4.629	0.004	0.011
1000 ft E	0.025	2.813	0.002	0.009

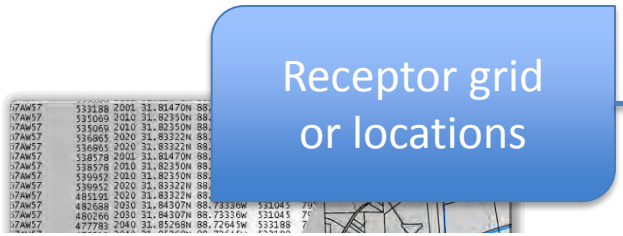
Highway Screening Analysis Tool

http://tinyurl.com/**BAAQMD-HSAT**



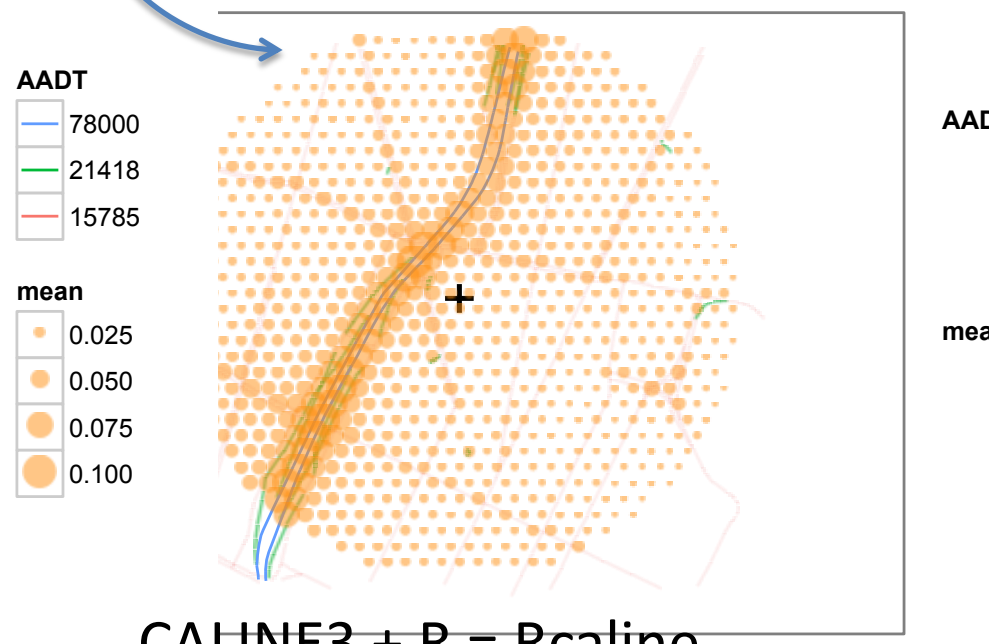
	PM2.5	Risk	Chron.HI	Acute.HI
10 ft W	3.516	337.327	0.276	0.077
25 ft W	2.900	281.593	0.230	0.065
50 ft W	2.295	225.574	0.183	0.053
75 ft W	1.926	190.858	0.155	0.045
100 ft W	1.667	166.336	0.135	0.040
200 ft W	1.106	112.528	0.091	0.026
300 ft W	0.836	86.277	0.069	0.020
400 ft W	0.668	69.727	0.056	0.017
500 ft W	0.557	58.709	0.047	0.014
750 ft W	0.396	42.663	0.034	0.010
1000 ft W	0.304	33.187	0.026	0.008
10 ft E	3.798	338.487	0.282	0.075
25 ft E	3.136	280.647	0.233	0.064
50 ft E	2.439	219.260	0.182	0.053
75 ft E	2.006	180.748	0.150	0.045
100 ft E	1.708	154.190	0.128	0.039
200 ft E	1.072	97.462	0.080	0.024
300 ft E	0.773	70.605	0.058	0.018
400 ft E	0.594	54.513	0.045	0.015
500 ft E	0.476	43.863	0.036	0.014
750 ft E	0.307	28.487	0.023	0.011
1000 ft E	0.216	20.138	0.016	0.008

HSAT: Under the Hood



Receptor grid or locations

```
> library(Rcaline)
> ... # do stuff
> PM25 <- predict(my_model)
> plot(PM25)
> write.kml(PM25)
```



563 km 564 km 565 km

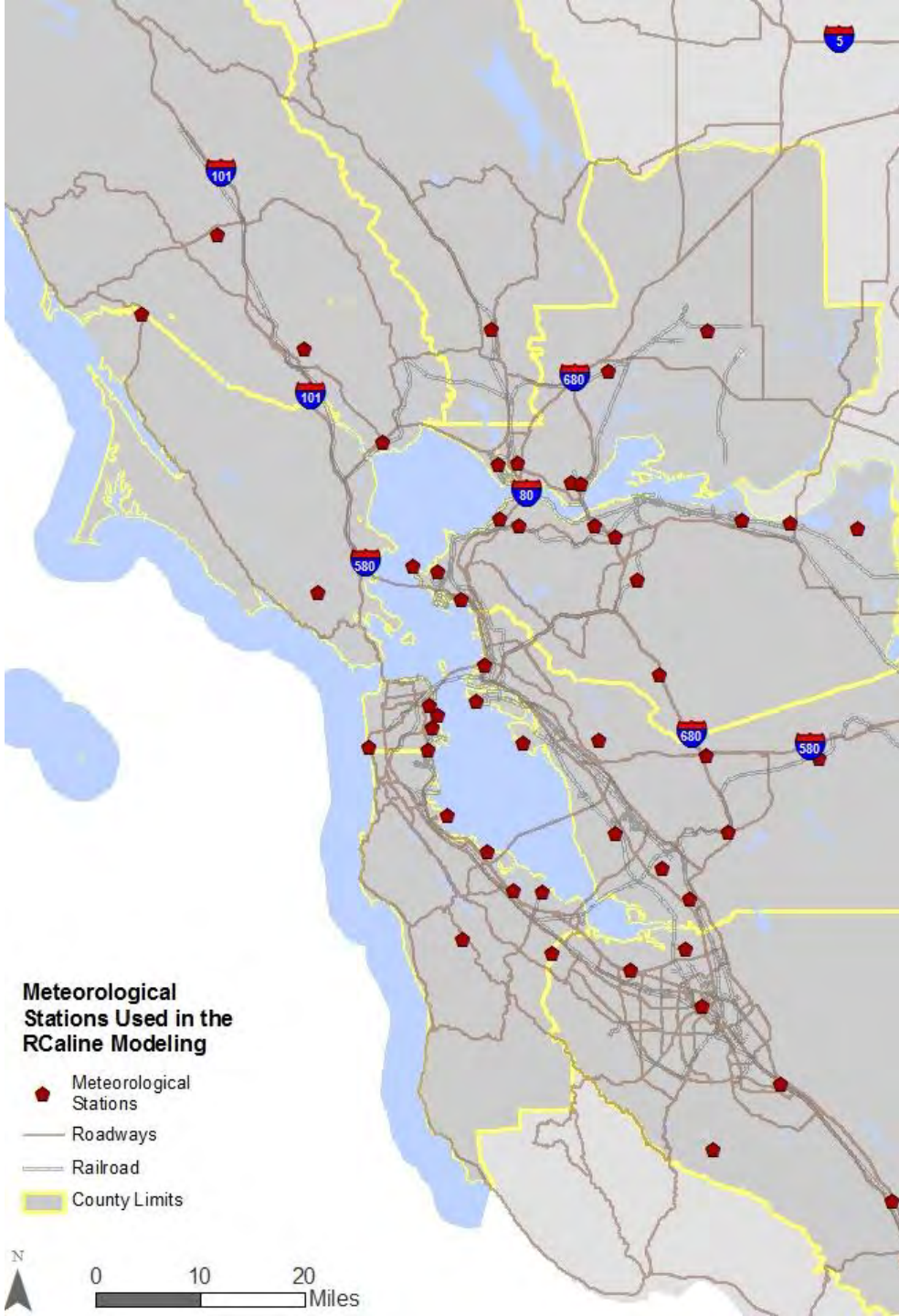
564 km 565 km

CALINE3 + R = Rcaline

HSAT Inputs

Meteorology

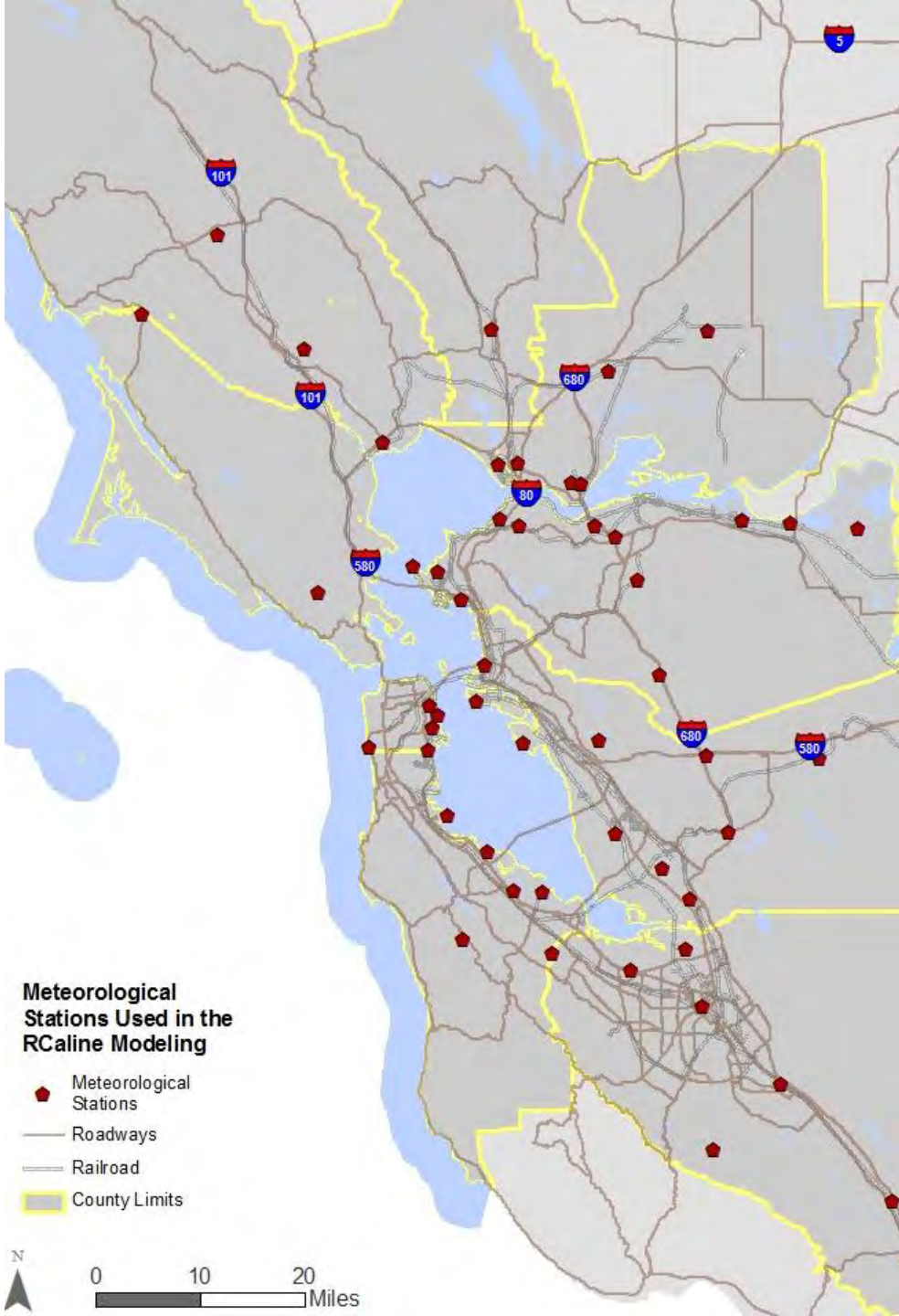
- BAAQMD-operated network of stations
- Used in support of many air quality programs
- Matched to highway links based on local knowledge
- Most recent year available was used



HSAT Inputs

Road Network & Traffic

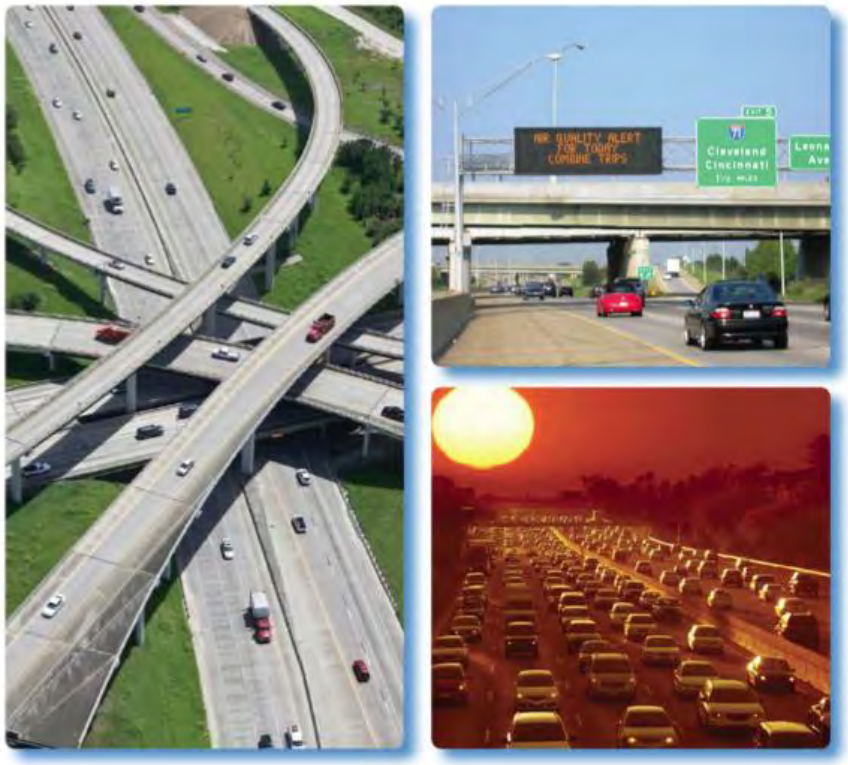
- Geometry: FHWA NHPM + 2008 TIGER
- AADTs: Caltrans (2009), joined via milepost ID
- Avg speed = weighted sum of AM/midday/PM speeds from MTC BAYCAST-90 model

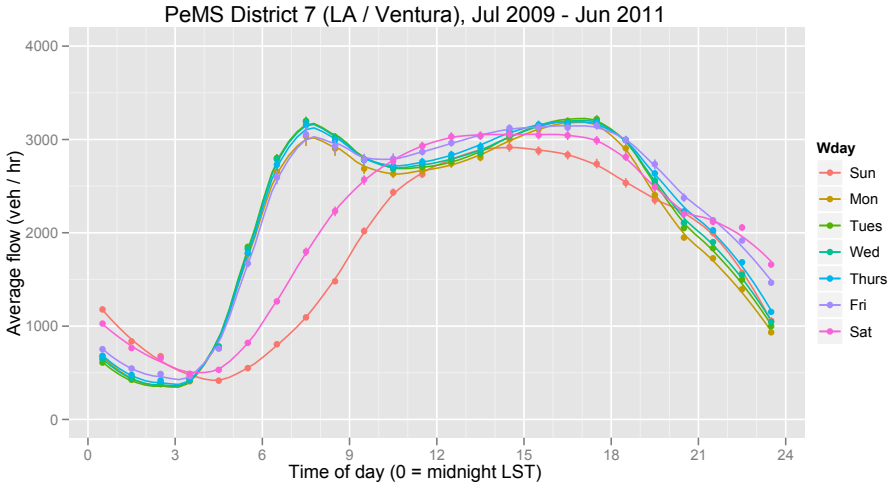


HSAT Inputs

Emission Factors

- EMFAC (CARB 2011)
- Truck/non-truck
- Scaled by diurnal profile
- Joined to ~1200 links
- Total organic gases (TOG)
- $PM_{2.5}$ (exhaust + brake/tire)
- PM_{10} (exhaust + brake/tire)
- Diesel fractions

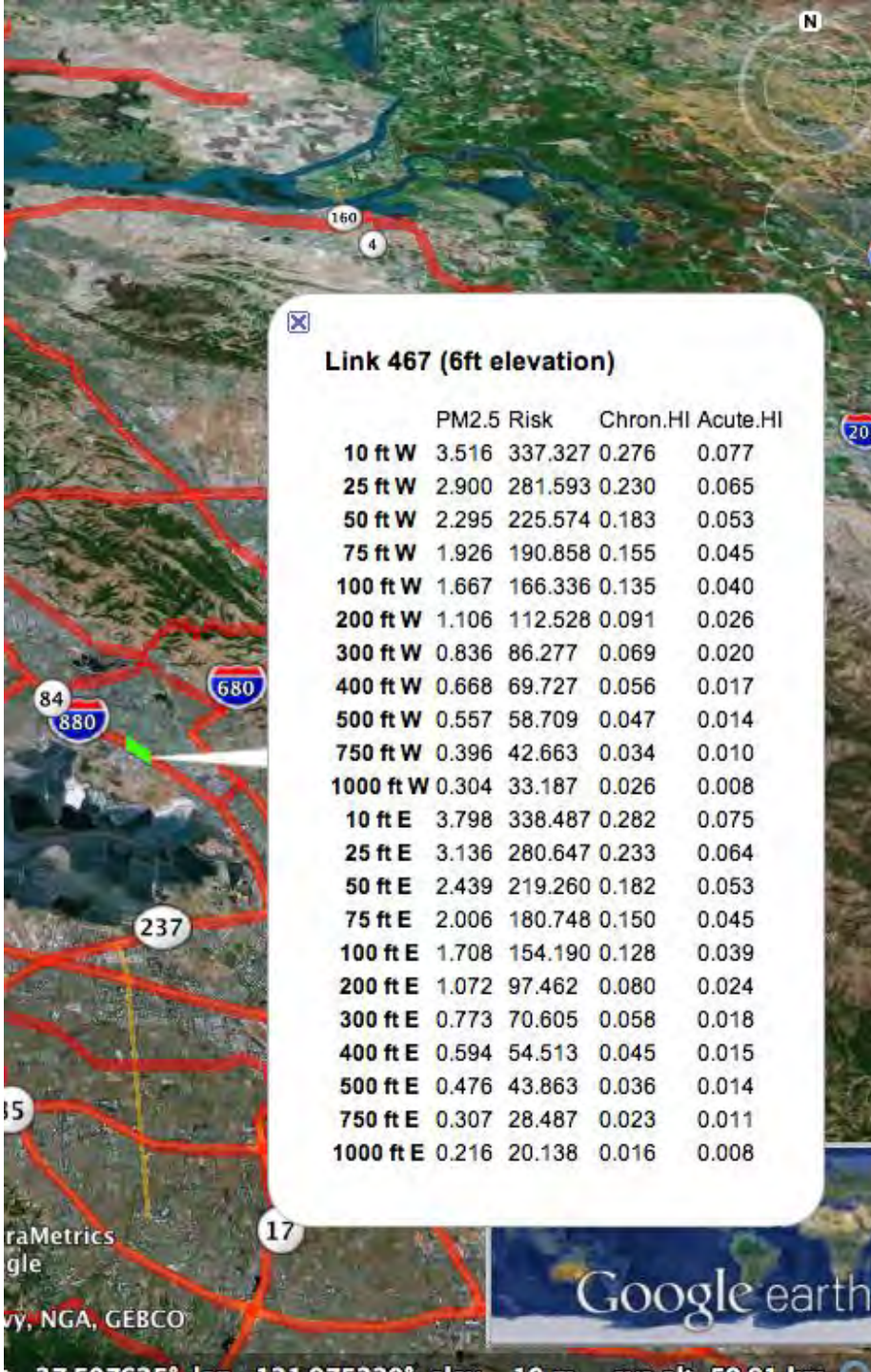




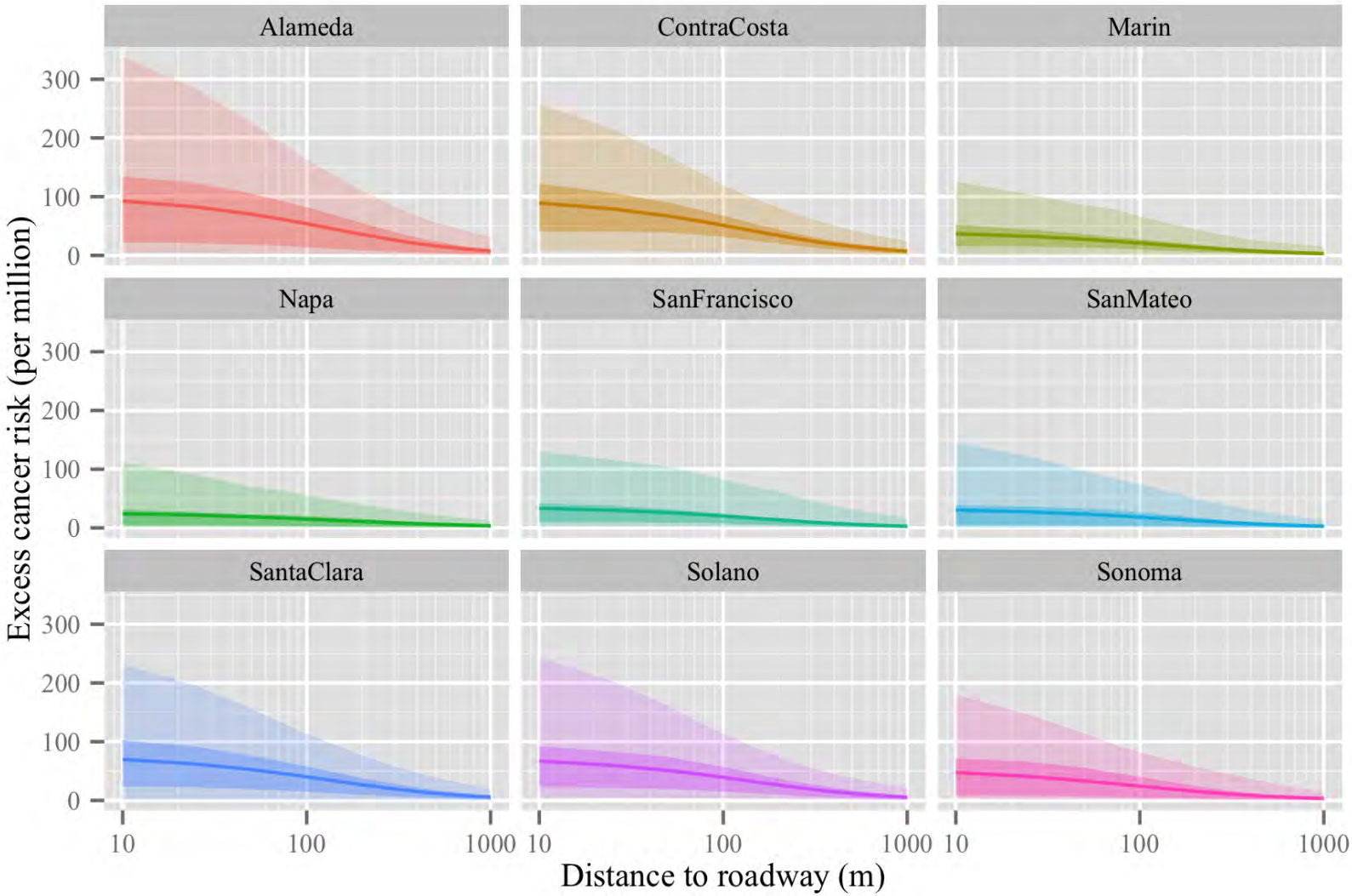
HSAT Model

Approach (pseudocode)

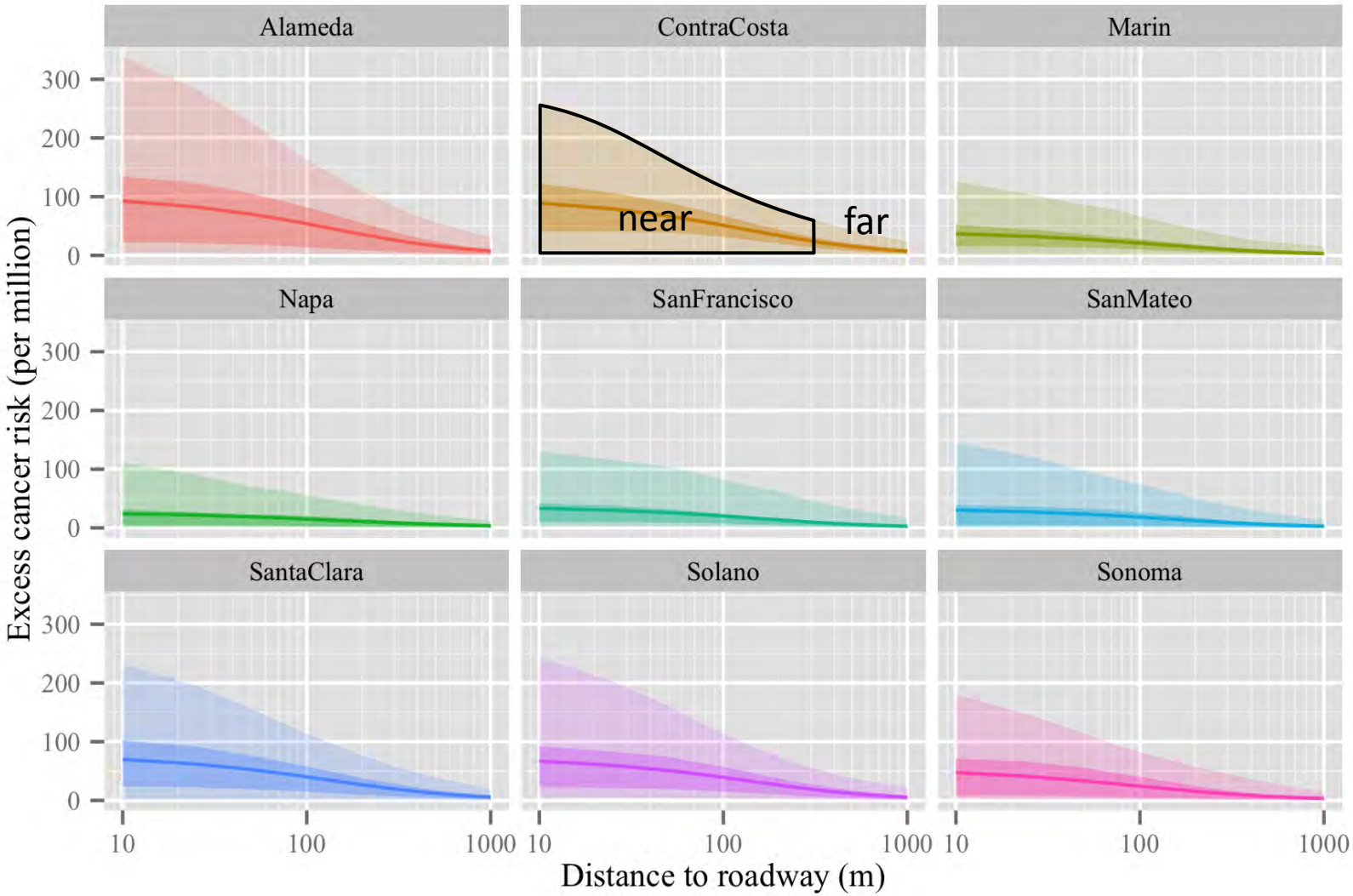
```
# For each transect location
distances = [10, 25, 50, …, 750, 1000]
for each L in highway_links:
  for each R in transect(L, distances):

    # Model annual "unit emissions" result
    for each M in nearest(meteorology, R):
      X_RLM = Rcaline(M, R, AADT_L, EF_L = 1.0)
    X_RL = apply(mean, C_RLM, M)

    # Scale by emission factors
    for each P, Y in pollutants, years:
      C_RPY = X_R x EF_L x EF_PY

    # Summarize 70-year risk profile
    Cancer_R = f(DPM_RY1, …)
```



Extended Analyses



Extended Analyses

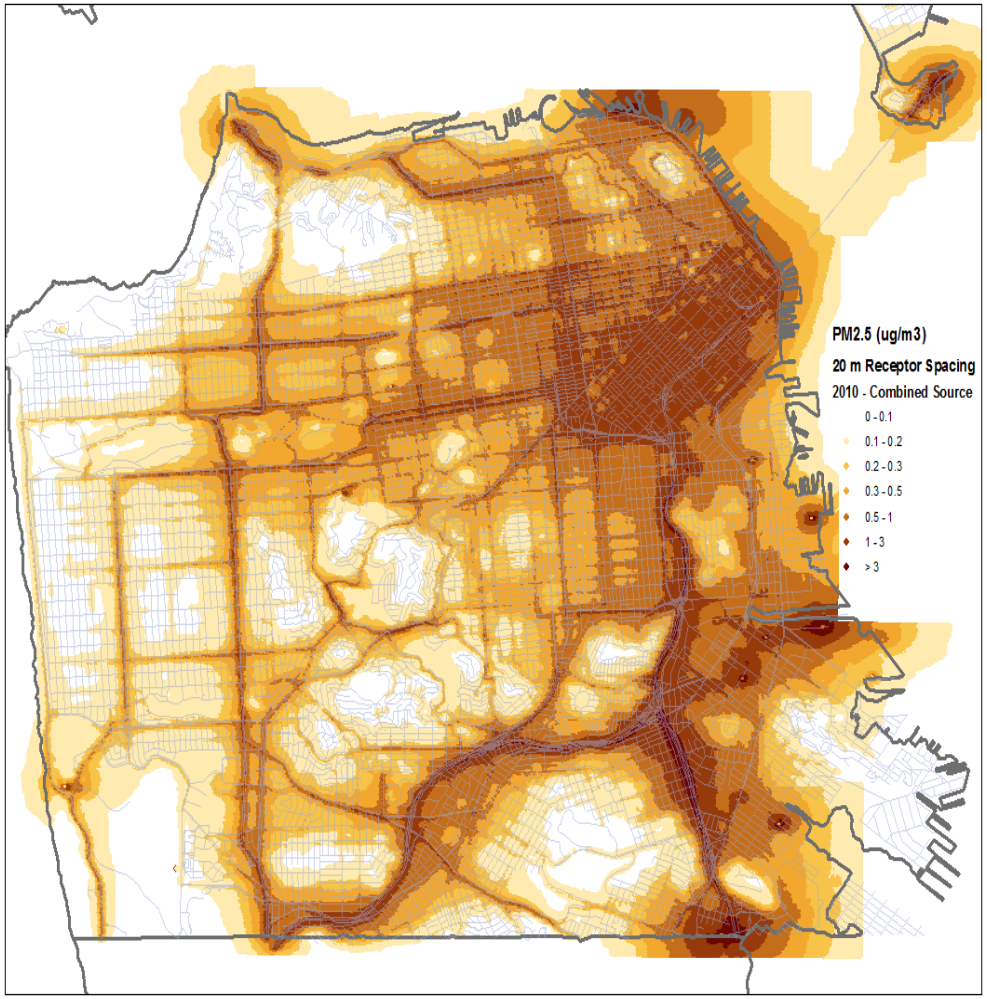


Extended Analyses

	$PM_{2.5}$, mean (sd), μg/m^3		Cancer risk, mean (sd), x10^{-6}	
County	**Near**	**Far**	**Near**	**Far**
Contra Costa	0.61 (0.36)	0.15 (0.12)	45.5 (24.7)	11.7 (8.6)
Alameda	0.57 (0.42)	0.14 (0.13)	47.8 (39.6)	12.3 (12.6)
Santa Clara	0.55 (0.35)	0.14 (0.11)	35.7 (26.2)	9.3 (8.2)
San Francisco	0.39 (0.29)	0.09 (0.10)	17.9 (19.8)	4.7 (7.6)
Solano	0.38 (0.28)	0.09 (0.08)	34.8 (25.7)	9.0 (7.9)
Marin	0.35 (0.28)	0.09 (0.10)	18.7 (14.1)	4.9 (5.0)
San Mateo	0.34 (0.33)	0.09 (0.11)	16.3 (18.4)	4.5 (5.9)
Sonoma	0.29 (0.25)	0.07 (0.07)	21.8 (21.5)	5.3 (6.2)
Napa	0.18 (0.17)	0.07 (0.06)	13.6 (15.7)	5.1 (5.9)
(All)	0.48 (0.37)	0.12 (0.11)	34.1 (30.6)	8.8 (9.5)

Near := 10–300m Far := 300–1000m

Local Plans to Address Health Risks: SF Community Risk Reduction Plan



- Address local AQ exposures and health effects in long-range community plans
- Model AQ conditions in expected growth areas, adjust development plans and mitigations as needed
- Pilot programs in San Francisco and San Jose
- District modeled 2014 and 2025 emissions and exposure, including:
  - Freeways, surface streets
  - Permitted stationary sources
  - Ships and trains
- Pollution highest near freeways, ship terminals, certain stationary sources
- Identifies strategies to reduce exposure
  - E.g., expand SF's ordinance requiring air filters in housing near freeways

Acknowledgments

- Bay Area AQMD
- UC Berkeley School of Public Health
- Sonoma Technology, Inc.

Mitigation of Roadside Aerosols:

New data, new challenges, new opportunities

A presentation for Vegetation for Mitigation

June 2, 2015

Programs of the Breathe California/ Health Effects Task Force and UC Davis DELTA Group;

Thomas A. Cahill,

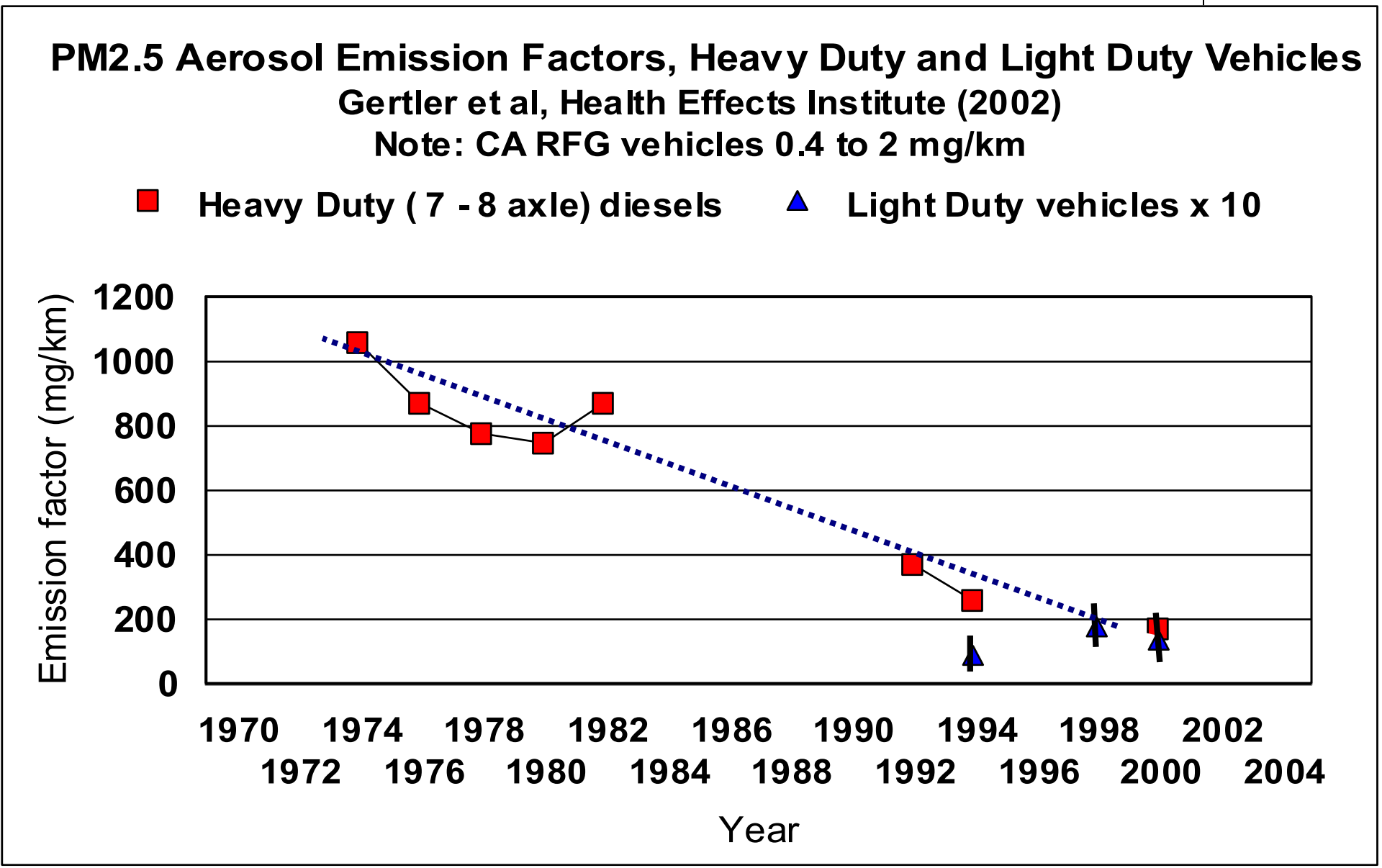
Professor of Physics and Atmospheric Sciences and Head, DELTA Group, University of California, Davis

HETF assessment (circa 2005) of problems to be addressed for effective mitigation:

- Problem #1 What are we trying to mitigate, and why are we doing it?
- Problem # 2 Despite greatly reduced roadway emissions, health impacts continue to be observed.
- Problem #3 The health effects seen near roadways extend much farther out than models and data predict.
- Problem #4 The growing important of ultra fine metallic “wear” aerosols that lack data and are hard to model with vegetation.

Why do we still need to mitigate roadways?

We have achieved massive reductions in source emissions!



How are lower emission rates reflected in roadway aerosol measurements?

- **Assumptions**: Freeways, ≅ 5,000 v/hr, at grade, no obstructions, lateral winds 2 to 5 m/sec, freely moving vehicles circa 100 km/hr., 7% ± 3% heavy diesels.
- **Data** – $PM_{2.5}$ mass, size resolved and speciated aerosols, measured at downwind edge circa 10 m
  - 1973 Los Angeles 25 ± 3 μg/m^3 measured + modeled 1972 emission data

    (included 4.0 ± 0.3 μg/m^3 of ultra fine lead in the form PbBrCl) measured and modeled from emissions

How are lower emission rates reflected in roadway aerosol measurements?

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- **Data** – $PM_{2.5}$ mass, size resolved and speciated aerosols, measured at downwind edge circa 10 m
  - 1973 Los Angeles 25 ± 3 μg/m^3 measured + modeled 1972 emission data
  - 2008 Europe 5.0 ± 1 μg/m^3 measured
  - 2010 Michigan 2.7 ± 0.5 μg/m^3 modeled from 2002 emission data
  - 2010 Michigan 2.0 ± 0.7 μg/m^3 measured

How are lower emission rates reflected in roadway aerosol measurements?

- **Assumptions**: Freeways, ≅ 5,000 v/hr, at grade, no obstructions, lateral winds 2 to 5 m/sec, freely moving vehicles circa 100 km/hr., 7% ± 3% heavy diesels.
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Despite lower emission rates, there are still well documented health impacts:

- For children,
  - Cancer (x6), leukemia (x8), asthma, and general respiratory distress, etc, etc. (Zhu et al 2009) including "Lung function in children living near freeways", Gauderman et al 2007 -

- For adults,
  - **Diesel exhaust and cancer**
    - Prop 65 Toxic Air Contaminant – ~ 2/3 of total cancer risk,
  - **Cardio-vascular disease**
    - HEI summary, 2009, HETF Central Valley Studies, (Cahill et al 2011), EPA ufp Meeting, ultra fine particles (Feb, 2015)
  - **Increased chance for strokes and decreased brain volume**

    Long-Term Exposure to Fine Particulate Matter, Residential Proximity to Major Roads and Measures of Brain Structure Wilke et al, **Stroke (2014)**

Despite lower emission rates, there are still well documented health impacts: possible causal agents?

- For children,
  - Cancer (x6), leukemia (x8), asthma, and general respiratory distress, etc, etc. (Zhu et al 2009) including "Lung function in children living near freeways", Gauderman et al 2007 -Very fine (< 0.25 µm) iron ?

- For adults,
  - **Diesel exhaust and cancer** (< 0.25 µm ultra fine PAHs)
    - Prop 65 Toxic Air Contaminant – ~ 2/3 of total cancer risk,
  - **Cardio-vascular disease** – (ultra fine metals)
    - HEI summary, 2009, HETF Central Valley Studies, (Cahill et al 2011), EPA ufp Meeting, ultra fine particles (Feb, 2015)
  - **Increased chance for strokes and decreased brain volume** (Only PM2.5 measured)
    - Long-Term Exposure to Fine Particulate Matter, Residential Proximity to Major Roads and Measures of Brain Structure Wilke et al, **Stroke (2014)**

HETF assessment (circa 2005) of problems to be addressed for effective mitigation:

- Problem #1 What are we trying to mitigate, and why are we doing it?
- Problem # 2 Despite greatly reduced roadway emissions, health impacts continue to be observed.
- Problem #3 The health effects seen near roadways extend much farther out than models and data predict.
- Problem #4 The growing important of ultra fine metallic “wear” aerosols that lack data and are hard to model with vegetation.

Problem # 3 Distances all wrong, and causal source(s) of the problem unknown.

Gauderman et al 2007

The Sacramento Bee

FRIDAY, JANUARY 26, 2007 www.sacbee.com FINAL EDITION 50 CENTS

Living near busy roads tied to kids' lung risk

Impact on breathing is long-term health threat, study says

Distances for loss of lung function

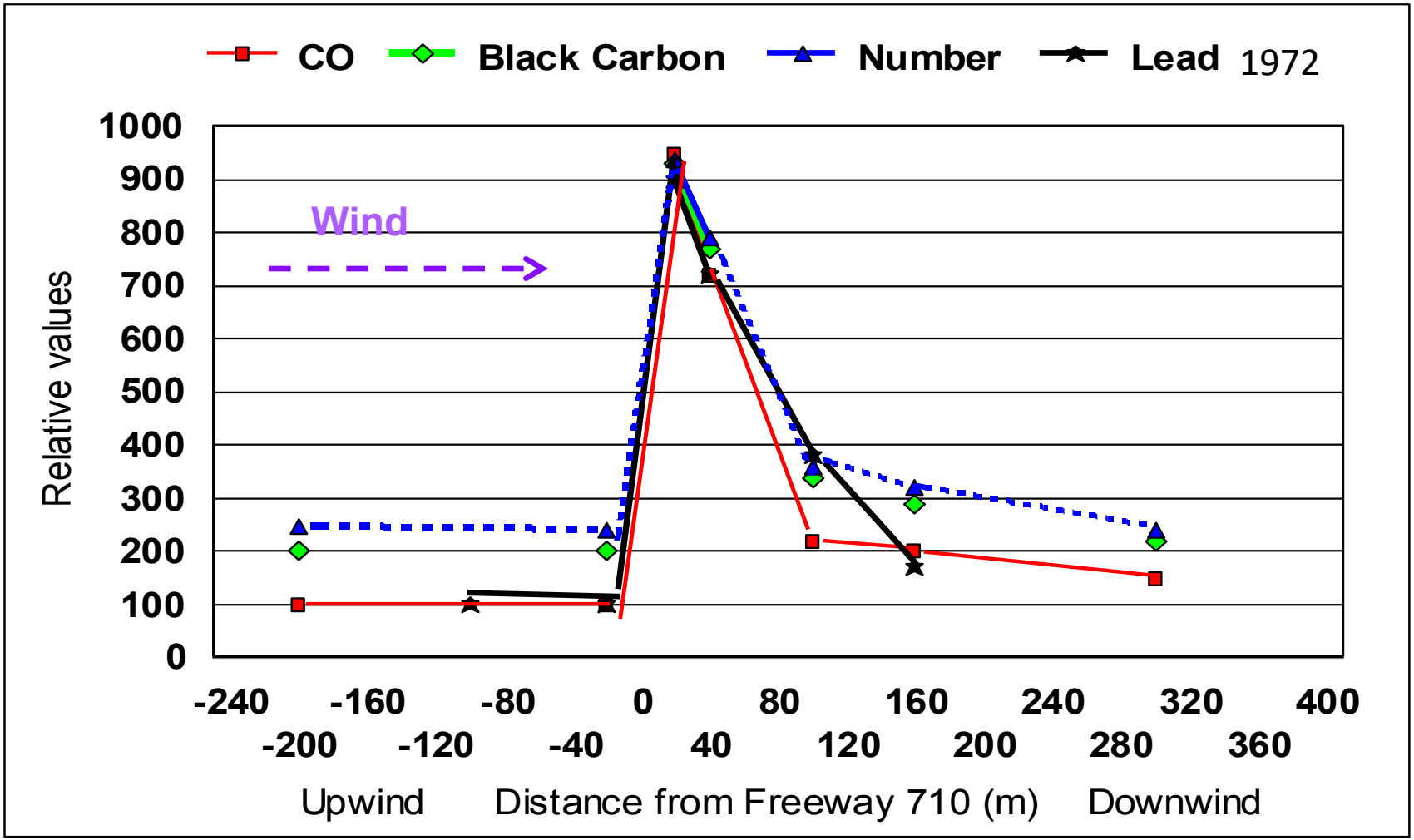
< 530 m,

<1060 m,

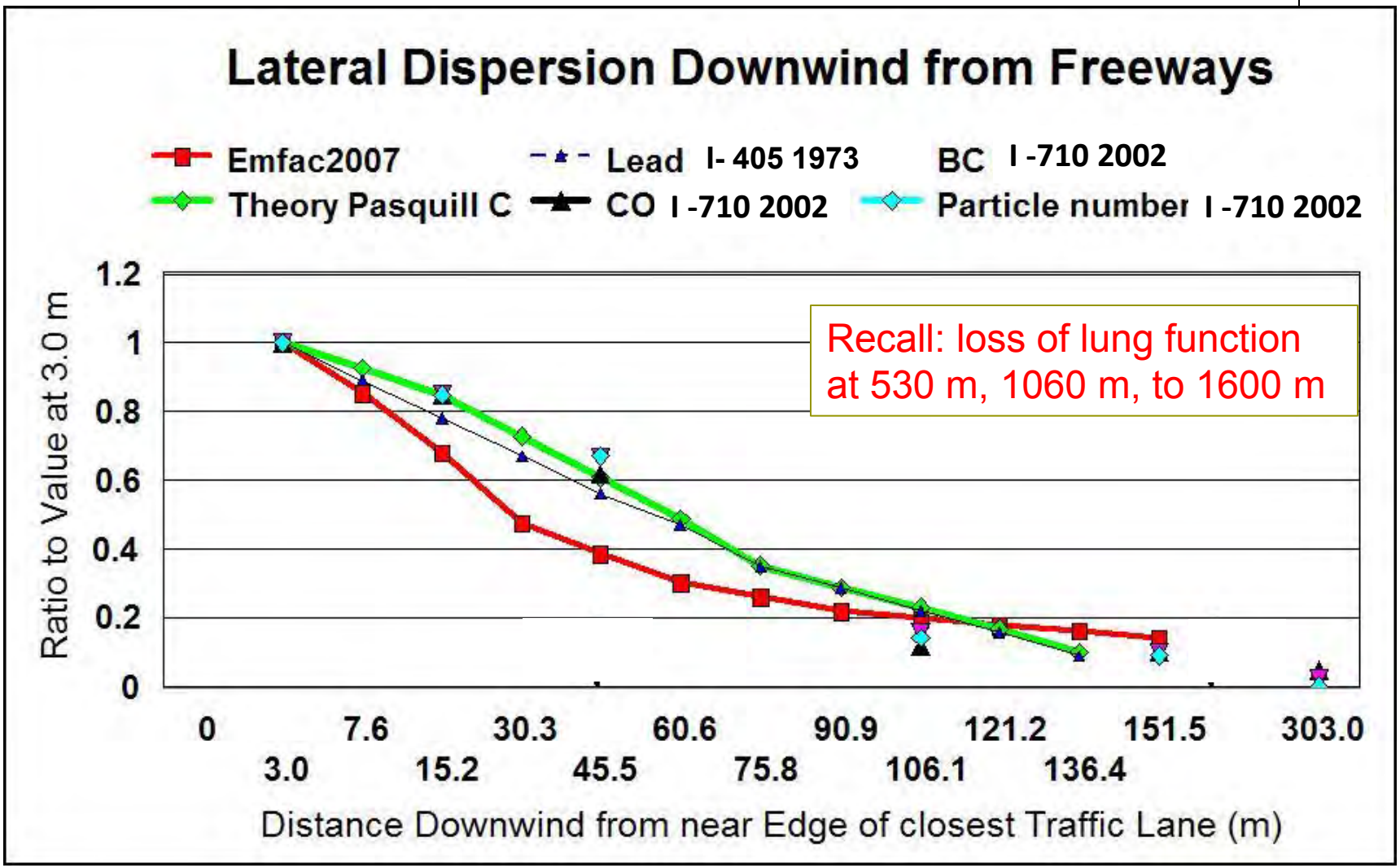
1060 m to 1600 m,

> 1600 m

Profile of gaseous and ultra fine pollutants near at-grade freeways (Zhu et al, 2002, I-710) and 1972 lead data (Cahill et al, 1973)



Comparison of line source diffusion models and pollutants downwind of an at-grade freeway



HETF assessment (circa 2005) of problems to be addressed for effective mitigation:

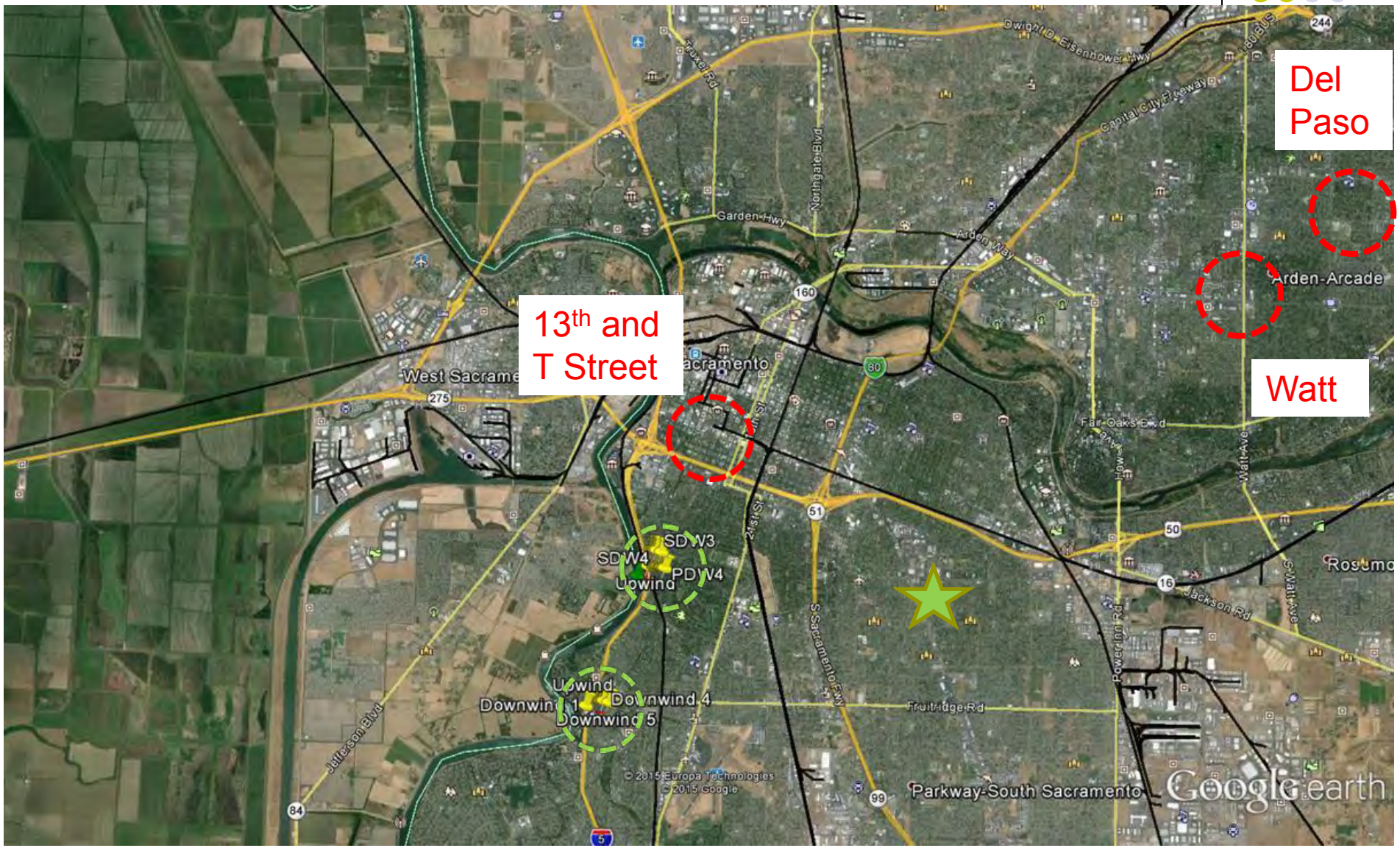
- Problem #1 What are we trying to mitigate, and why are we doing it?
- Problem # 2 Despite greatly reduced roadway emissions, health impacts continue to be observed.
- Problem #3 The health effects seen near roadways extend much farther out than models and data predict.
- Problem #4 The growing important of ultra fine metallic “wear” aerosols that lack data and are hard to model with vegetation.

Problem #4: Europe – "wear" aerosols will soon equal tailpipe aerosols. What do we know?

- **PM_{10} "wear" aerosols**
  - Good theoretical and experimental data on concrete roadbeds (Typically about 0.8 ± 0.4 μg/m^3 but no asphalt data) and non-soil iron (Typically 1.0 ± 0.5 μg/m^3 , often > 10 x what is in soil).
  - Fair data on zinc (tire wear) (Widely varying from 0.02 μg/m^3 to 0.22 μg/m^3)
- **Ultra fine (uf) tailpipe aerosols < 0.25 μm**
  - Good experimental and theoretical data on zinc, sulfur, and phosphorus from diesels (Zielinska et al 2004)
  - Little if any data on metals in uf "wear" aerosols

While doing a Sacramento Valley transect of aerosols from I-5 and Hwy 99, the HETF/UCD developed ultra-fine "wear" data as an unexpected benefit of helping Arden Middle School, which was directly downwind of Watt Avenue

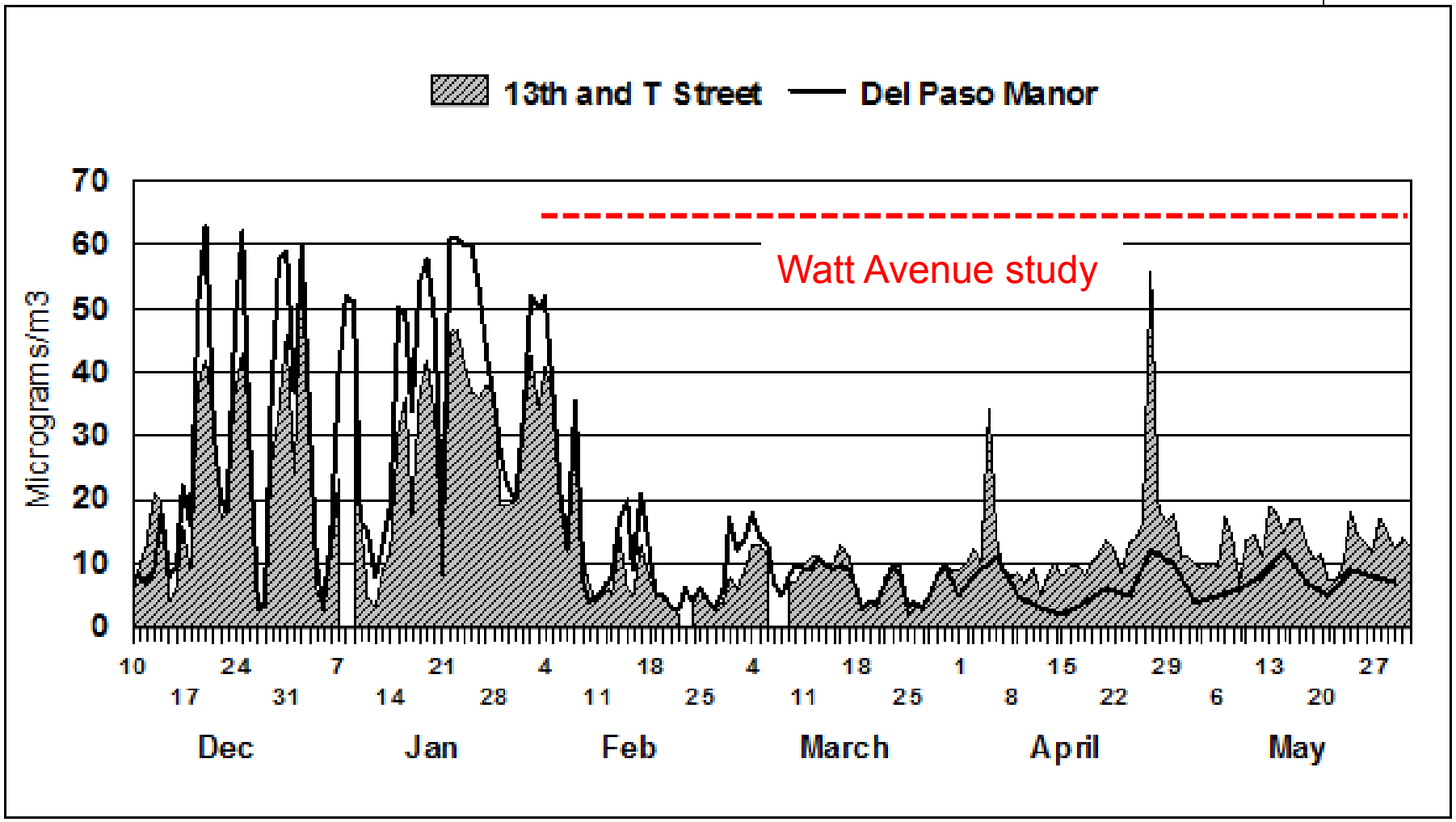
Sacramento; 13th and T St. , Watt and Arden, Del Paso Manor; I-5 Transects



Watt Ave Traffic – 15 m from school: 9 lanes of traffic, 65,000 v/day (1.5% diesels), and a stop light

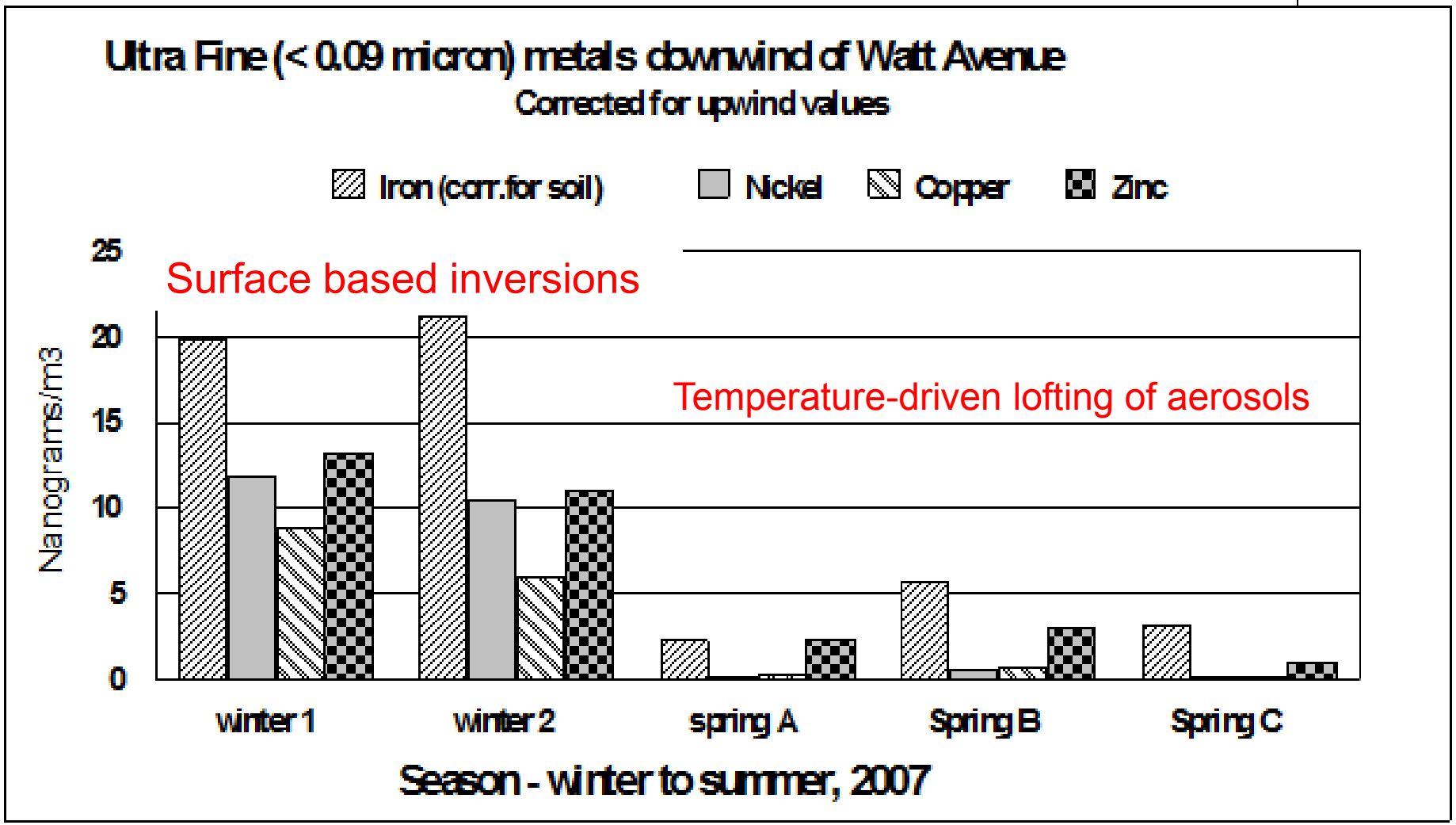
≅ $PM_{2.5}$ mass as 165,000 v/day, (12% diesels) on I-5!

Pattern of $PM_{2.5}$ from winter (strong inversions) to spring and summer. The Del Paso Manor site is near Watt Avenue



Good news: The site 500 m upwind **had almost no ultrafine metals** (few % of the downwind values)

Bad news: Significant **ultra fine (< 0.09 µm) transition metals downwind of Watt Avenue**



Composition of brake pads. Brake drums also erode from a "grey iron" with a graphite admixture.

(Also must add uf zinc from zinc thio-phosphate in motor oil).

(Zielinska et al 2004)

Element (ppm)	10th percentile	median	90th percentile
Iron	**11,700**	**18,300**	**190,000**
Copper	**29**	**5,000**	**116,000**
Zinc	**127**	**1630**	**37,400**
Nickel	**44**	**342**	**652**
Manganese	**143**	**315**	**1088**
Lead	6	50	949
Barium	558	3195	6144

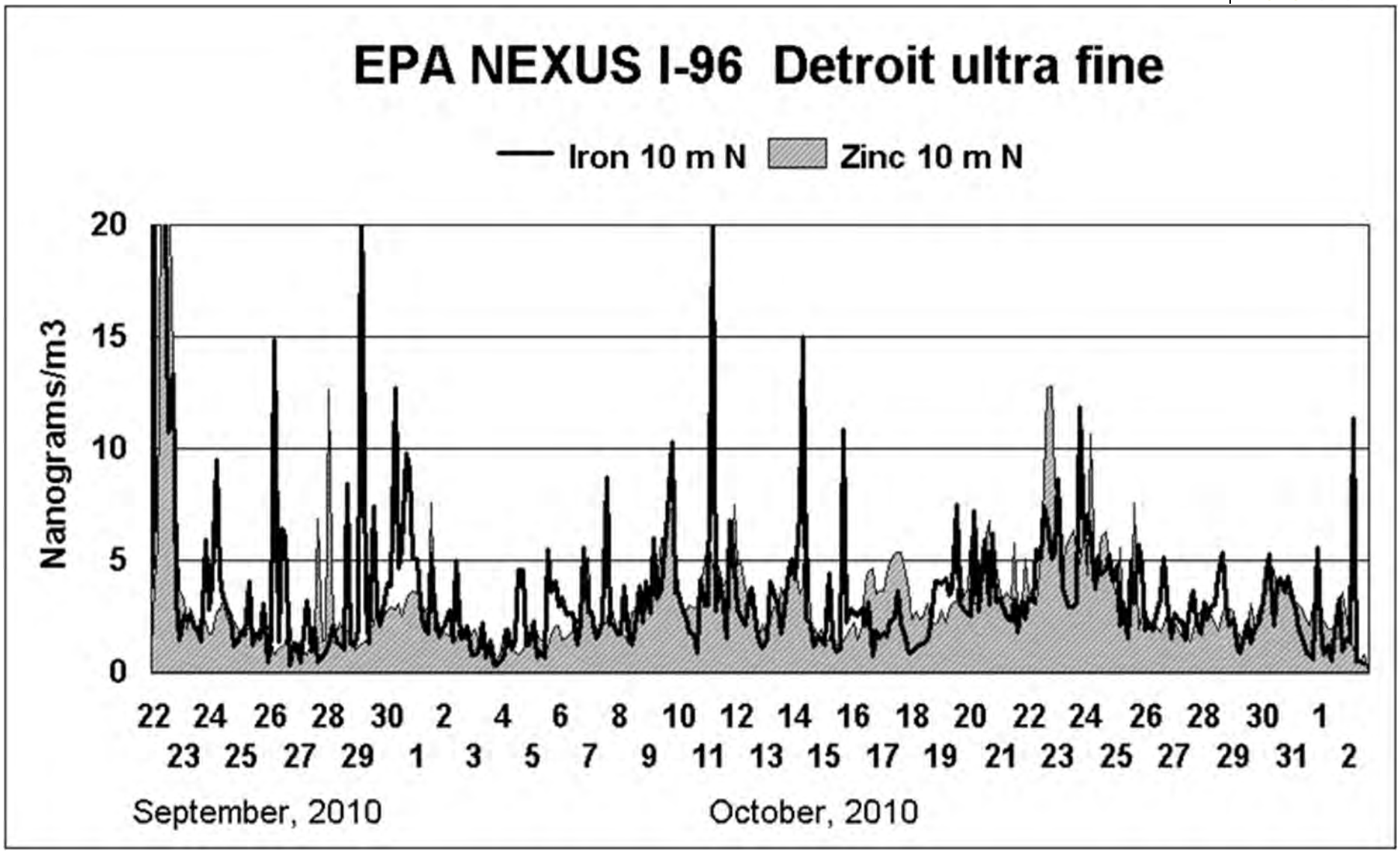
- Cahill, Thomas A., David E. Barnes, Nicholas J. Spada, **Seasonal variability of ultra-fine metals downwind of a heavily traveled secondary road**, Atmospheric Environment 94 173 - 179 (2014)

Table 4. Summary of concentrations of elements in New Zealand brake pads (Kennedy et al (2002), from largest to smallest concentrations of transition metals plus heavier elements

EPA/U. Michigan/UC Davis NEXUS study 9 miles west of Detroit

Figure 2. NEXUS transect array across I-96 west of Detroit.

Ultra-fine (< 0.09 µm) iron and zinc, the two largest elements see heavier than calcium



Comparison – Ultra fine metals , Watt Avenue to NEXUS Detroit

The four largest ultra-fine elements heavier than calcium		HETF/UCD Watt Avenue (Spring, 2007) 15 m east		EPA/U. Mich./UCD NEXUS I-96 (October 2010) 10 m north	
		ng/m^3		ng/m^3	
Iron (small correction for soil)		3.7		3.3	
Nickel		0.43		0.40	
Copper		0.5		1.9	
Zinc		2.2		3.2	

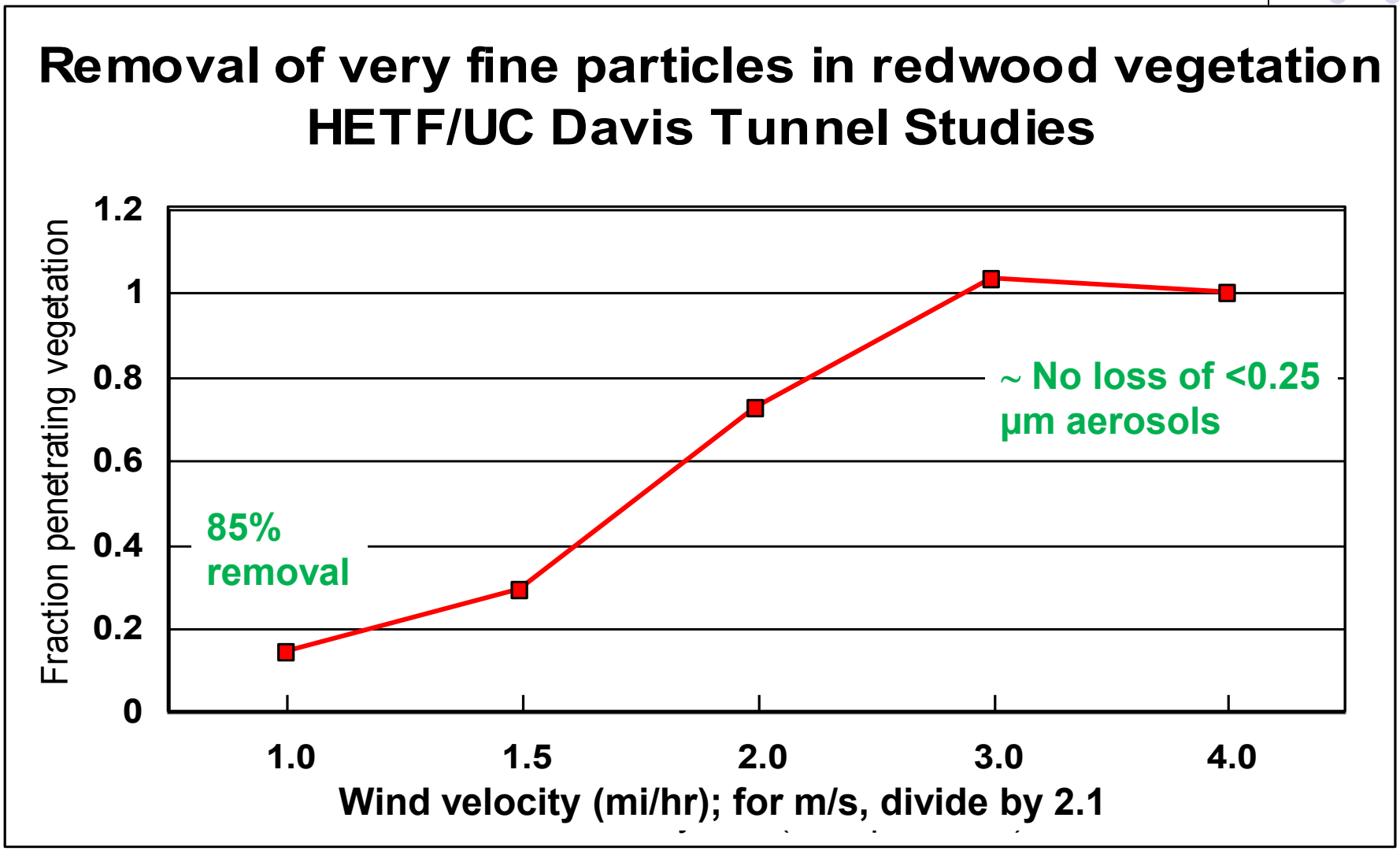
To measure the impact of vegetation, we need transects. Since we no longer have lead as a tracer, highway flares can serve as a unique very fine/ultra fine (< 0.25 µm) aerosol source

Typically strontium and potassium nitrate, potassium perchlorate, sulfur, aluminum, magnesium charcoal, sawdust

K	187,
Sr	131,
Cl	90,
S	68,
Si	38,
Mg	22,
P	5,
rest	< 0.1

UC Davis Mechanical Engineering 20 m wind tunnel – redwood branches in place

Removal of very fine (< 0.25 µm) and ultra fine (< 0.1 µm) particles in vegetation as a function of wind velocity



Applying flare tracer to ambient conditions: Transects of I-5 at 10th and 13th Avenues

UC Davis DELTA Group/HETF/USEPA highway transect studies

Purple indicates data from artificial tracers

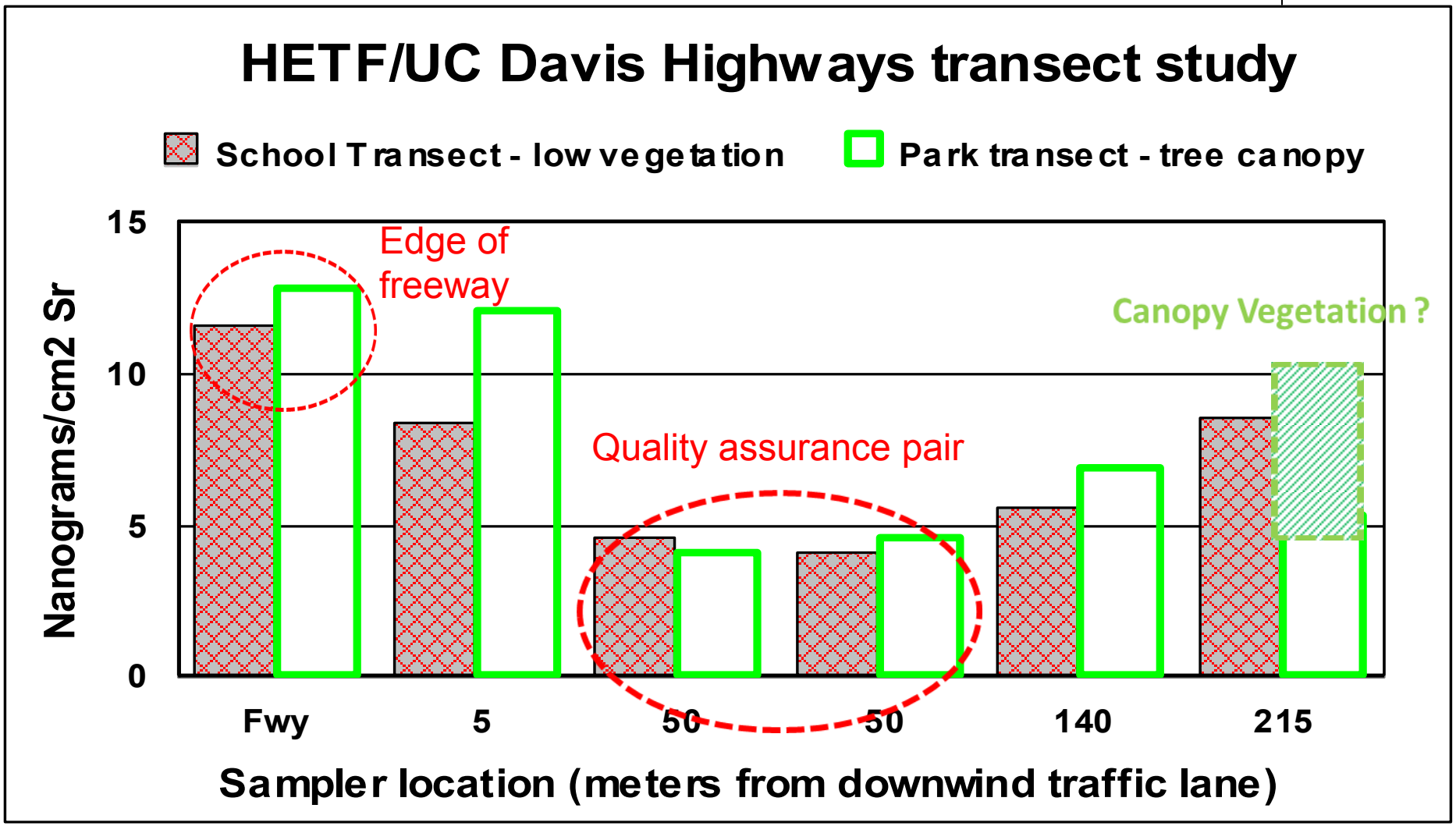
Freeway configuration			Vegetation	Vegetation	Season			Transect site
	Traffic braking?	Sound wall?	Barrier + sound wall	Downwind canopy	Summer	Spring, Fall	Winter	
Raised 5 ft	No	Yes	~ 0.3	~ 0.2	Yes	Yes	Yes	10th Ave
At Grade	No	Yes	~ 0.5	~ 0.8	Yes	Yes		13 th Ave
Raised 30 ft	No	Yes	~ 1.0	~ 0.3	Yes		Yes	35th Ave
At Grade	Yes	No	No	No	Yes	Yes	Yes	Watt Ave
At Grade	No	No	No	No		Yes		Detroit* 2010

Rolling cart with flares on the upwind bike path, used for 10th Ave and 13th Ave studies

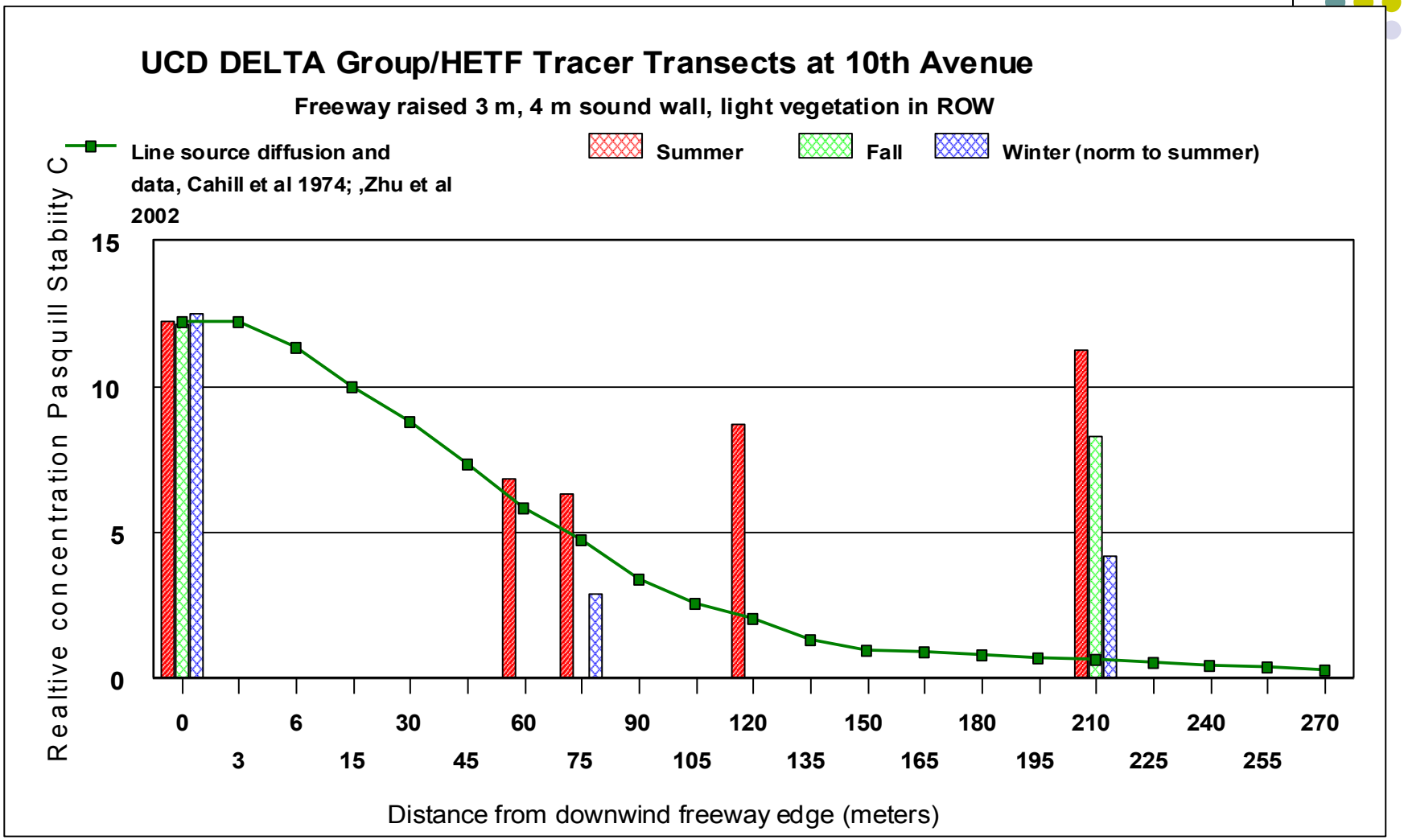
10th Avenue transect, SDW1 at top of ROW wall

At 50 m downwind, paired samplers for quality assurance checks; Camille guarding her QA site

Transect sites #2 10th Avenue (little vegetation), and #3 13th Avenue, (freeway screen, and tree canopy downwind); Vw = 5 mph

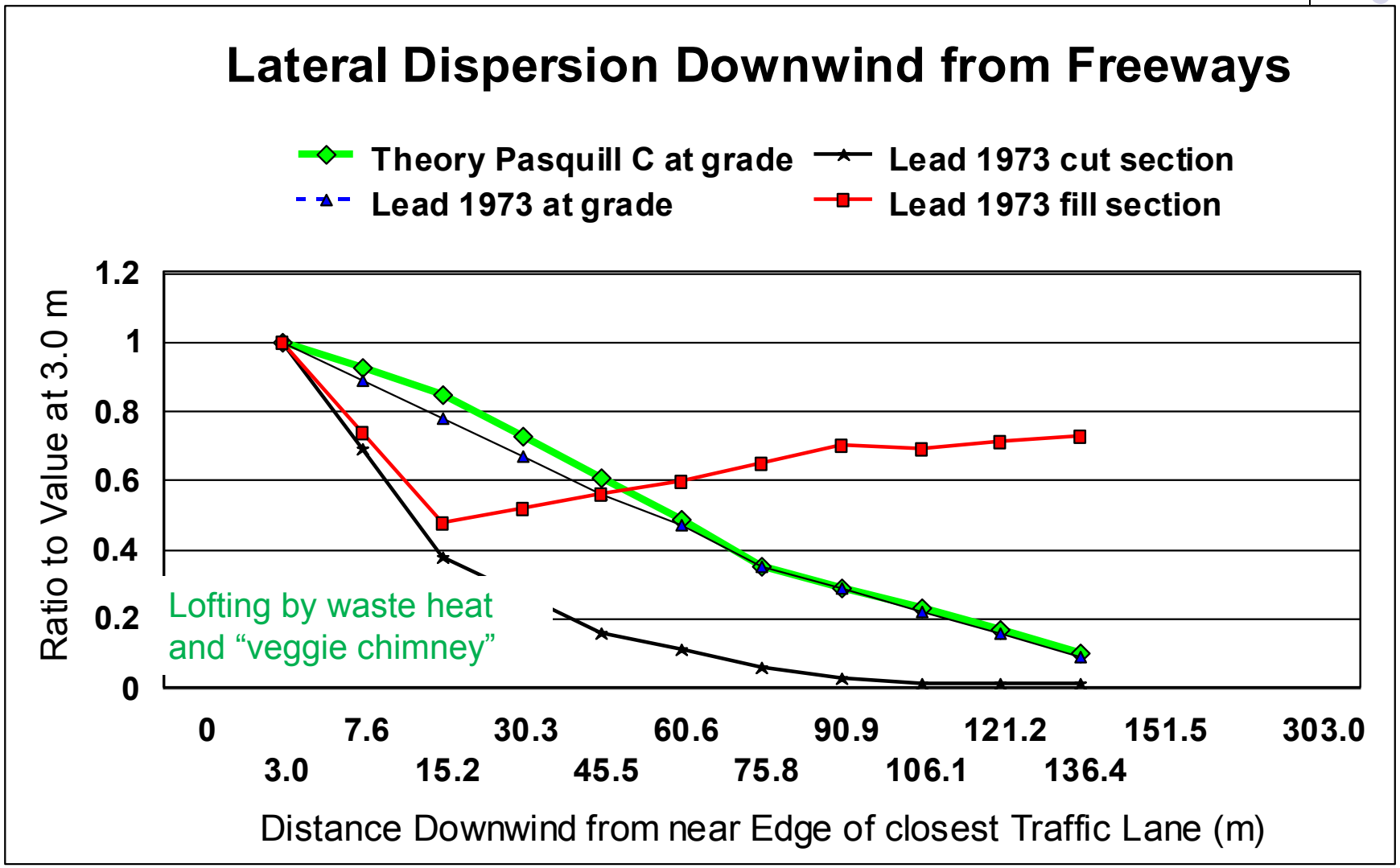


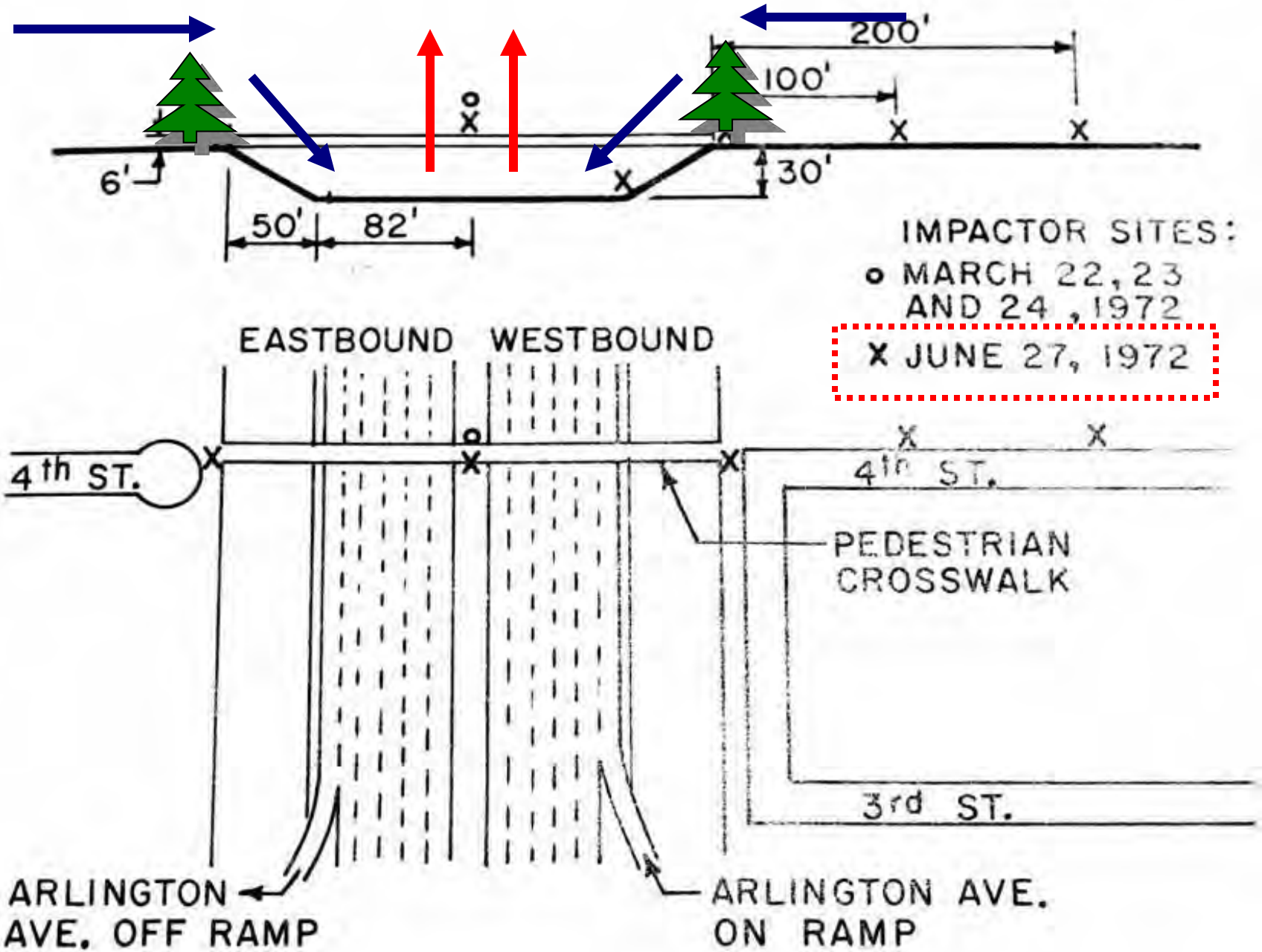
Applying flare tracer to ambient conditions: Transect of I-5 at 10th Avenue



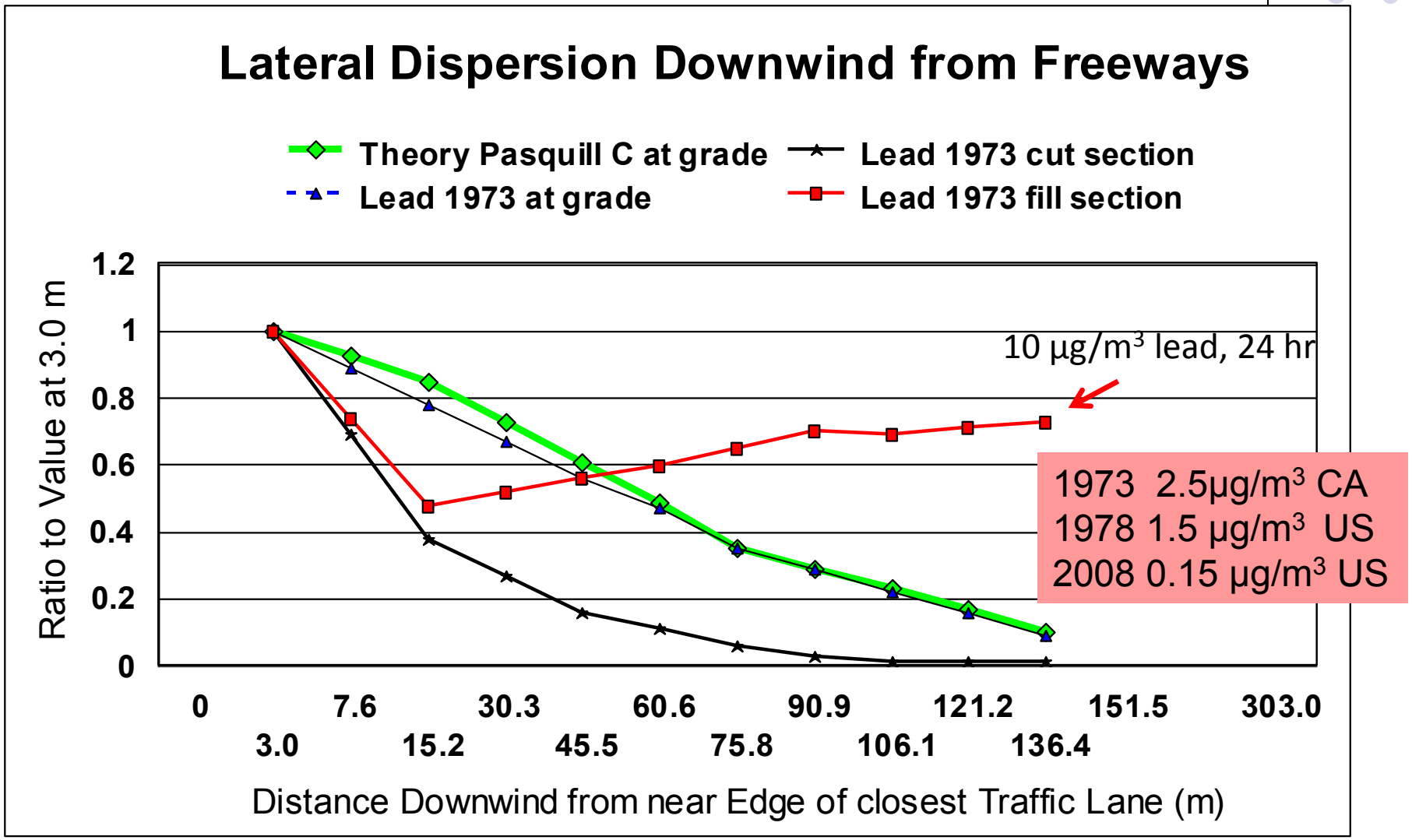
At-grade freeway with 4 meter sound wall

Results for 5 transects (2 cut, 2 fill) downwind with ultra fine lead (Cahill et al 1973; Feeney et al, 1975.)

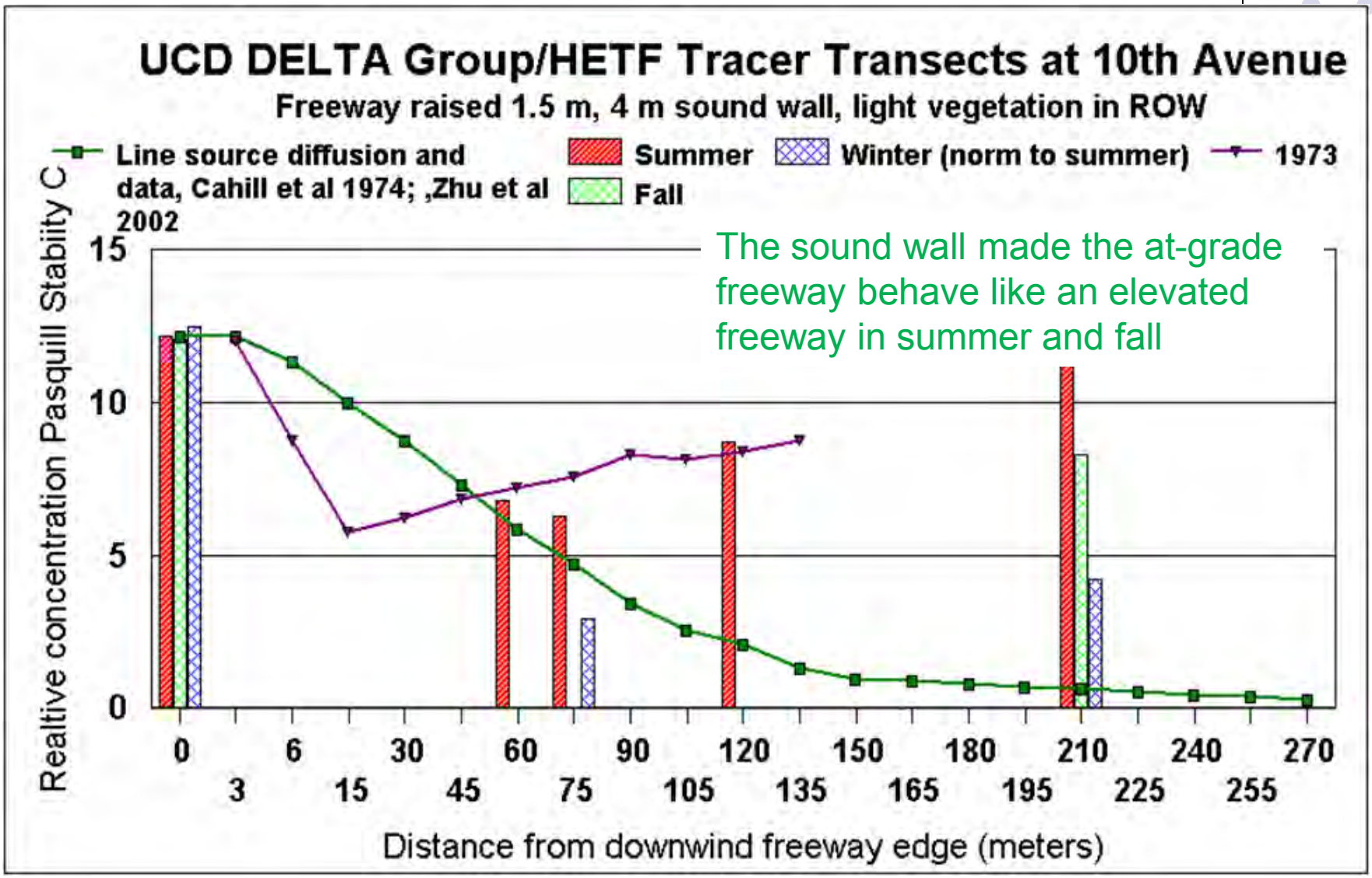



200'
100'
6'
30'
50'
82'
IMPACTOR SITES:
o MARCH 22, 23 AND 24, 1972
X JUNE 27, 1972
EASTBOUND
WESTBOUND
4th ST.
4th ST.
PEDESTRIAN CROSSWALK
3rd ST.
ARLINGTON AVE. OFF RAMP
ARLINGTON AVE. ON RAMP

Results for 5 transects (2 cut, 2 fill) downwind with ultra fine lead (Cahill et al 1973; Feeney et al, 1975.)



Adding 1972 lead data from 2 raised section Los Angeles freeways (Cahill et al, 1973), 10th Avenue



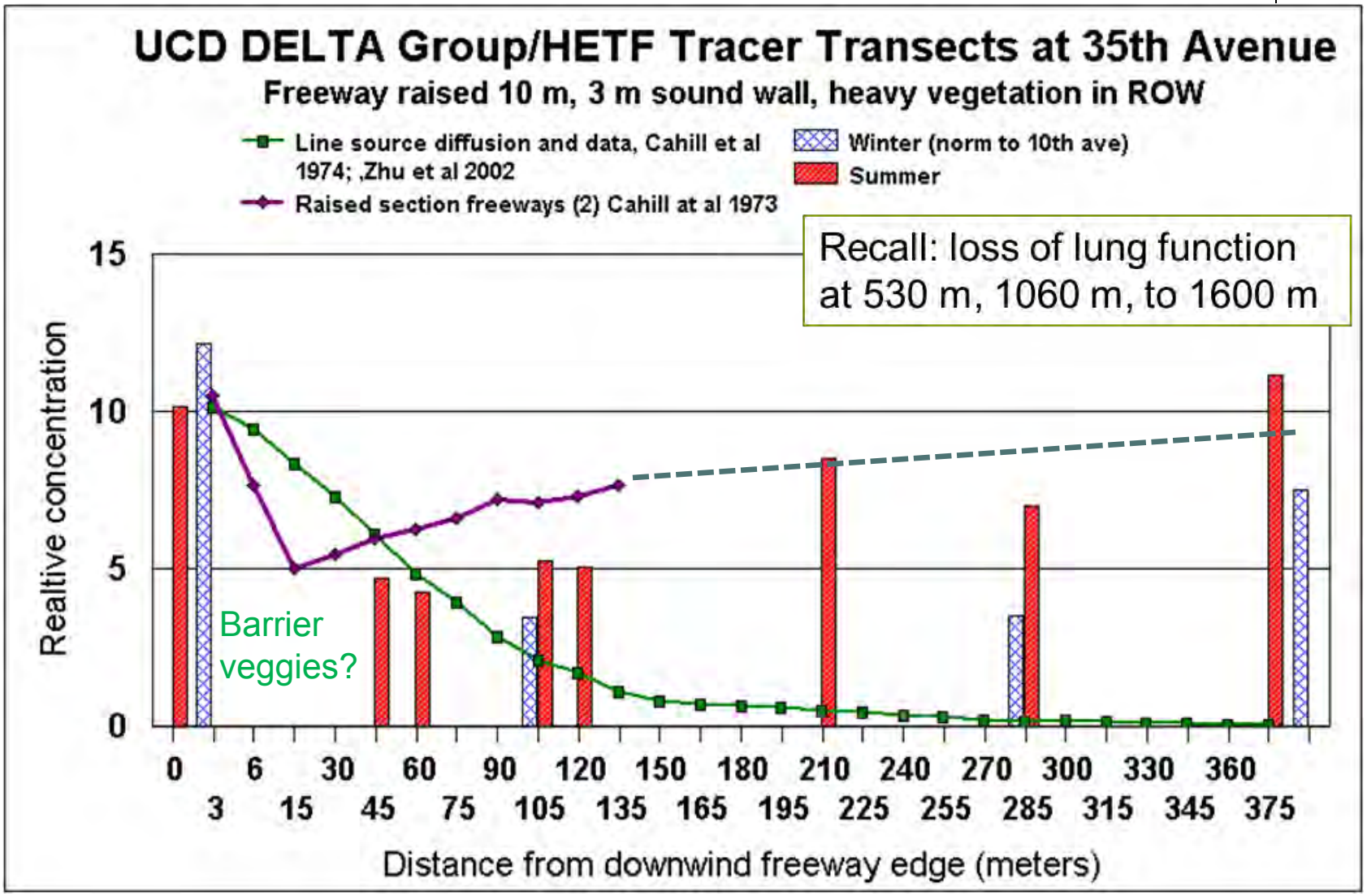
Applying flare tracer to ambient conditions: Transects of I-5 at 35th Avenue

The winds in this transect were from the southwest

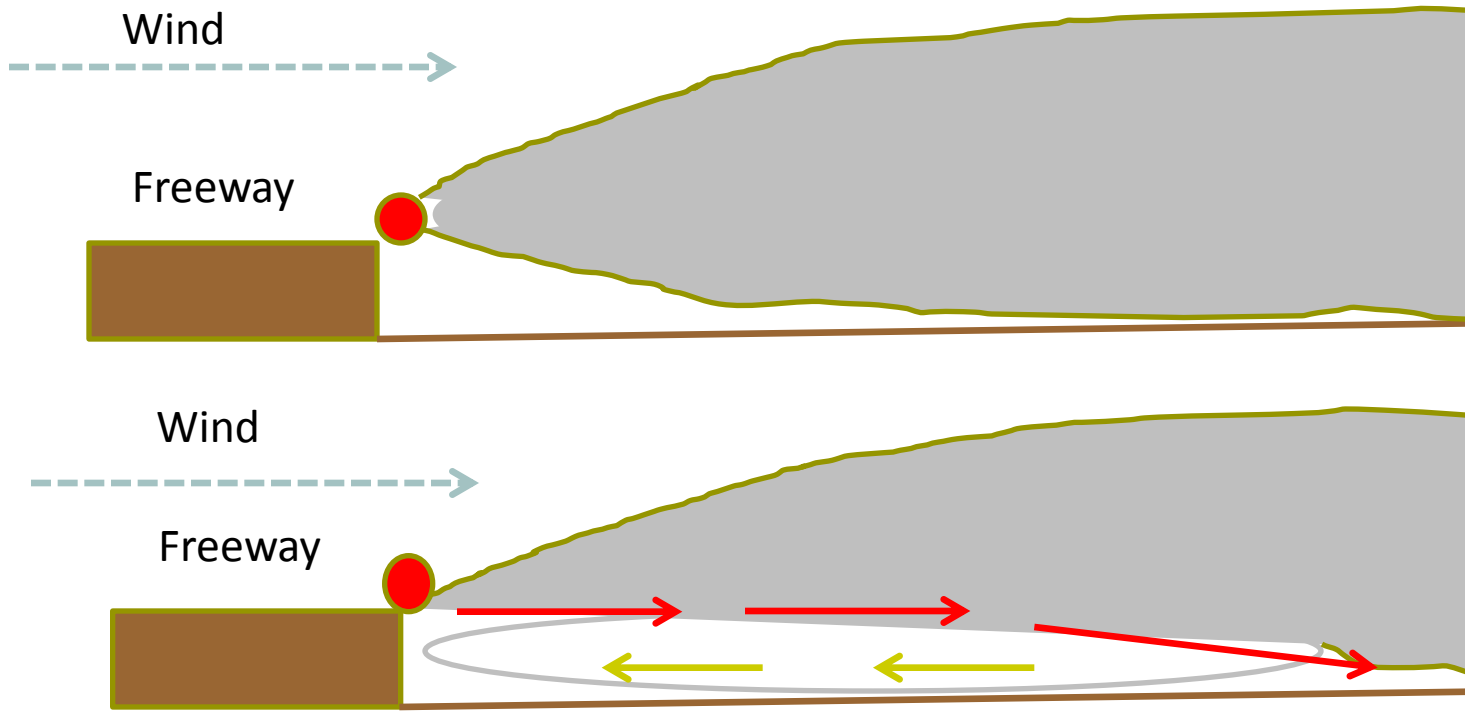
Redwood barrier on Interstate 5 near 35th Avenue

Downwind distribution of very fine and ultra fine aerosols – 1973 and 2010.

- **The raised freeway trumped the vegetation!**



Line source dispersion modeling - elevated source



Top – model used in Cahill, Myrup, and Dunn in 1973 Final Report, ARB

Bottom – model used be Baldauf et al US EPA, current

Mitigation must occur at all levels
(vegetation options in green)

- Source mitigation - federal and state responsibilities
  - Tailpipe - Fuels, engines; but also lubricating oil
  - "Wear" aerosols - Brake pads, brake drums, disks, roads (~ ½ of total)
- Roadway to right-of-way fence – transportation agencies
  - Roadway design (Complete streets; avoid elevated freeways)
  - Distance
  - Traffic volume and type mitigation
  - Barrier vegetation
- Right-of-Way fence to receptors – regional and local planners
  - Distance (but this conflicts with in-fill emphasis)
  - Traffic volume and type mitigation
  - Barrier vegetation
- Receptors – local planners, receptor responsibility
  - Canopy vegetation
  - Indoor mitigation – indoor vegetation, ultra filtration

…..and acknowledgements

- To Sac Met AQMD, long time supporter of BC/SET
- To the HTEF and BC/SET, for encouraging and guiding these studies
- To the Arden Middle School principal and staff
- To the crew of the UC Davis DELTA Group, Dr. David Barnes and many students, and Camille, our French intern,
- To EPA Region IX and the Resource Legacy for funding
- To the US EPA, who helped develop these technique and are using them in Detroit
- To Dr. Steve Cliff, Dr. Yongjing Zhao, and Prof. Kevin Perry, who achieved amazing Synchrotron induced –X-ray Fluorescence Analysis (S-XRF) analytical sensitivity of these very clean filters
- The Sacramento Police, who didn't arrest us even after a bomb threat was phoned in. After that, we always had people at sites.

Recent relevant HETF/UC Davis publications….

- Cahill, Thomas A., David E. Barnes, Nicholas J. Spada, **Seasonal variability of ultra-fine metals downwind of a heavily traveled secondary road**, Atmospheric Environment 94 173 - 179 (2014)
- Baldauf, Richard, Greg McPherson, Linda Wheaton, Max Zhang, Tom Cahill, Chad Bailey, Christina Hemphill-Fuller, Earl Withycombe, and Kori Titus, **Integrating Vegetation and Green Infrastructure into Sustainable Transportation Planning,** Transportation Research Bulletin, National Academy of Sciences (2013)
- Cahill, Thomas M, and Thomas A. Cahill, **Seasonal variability of particle-associated organic compounds near a heavily traveled secondary road**. *Aerosol Science and Technology*, (2013) doi: 10.1080/02786826.2013.857757
- Thomas A. Cahill, David E. Barnes, Earl Withycombe, and Mitchell Watnik. **Very fine and ultra-fine metals and ischemic heart disease in the California Central Valley 2: 1974 – 1991**. *Aerosol Science and Technology* 45:1135-1142 (2011) doi:10.1080/02786826.2011.582196
- Thomas A. Cahill, David E. Barnes, Nicholas J. Spada, Jonathan A. Lawton and Thomas M. Cahill. **Very fine and ultra-fine metals and ischemic heart disease in the California Central Valley 1: 2003 – 2007**. *Aerosol Science and Technology* 45:1125-1134 (2011) doi:10.1080/02786826.2011.582194
- Cahill, TM, Size-Resolved **Size-resolved organic speciation of wintertime aerosols in California's Central Valley**. *Environmental Science and Technology* 44:2315 - 2321 (2010) doi 10.1021/es902936v

- Thomas A. Cahill, Thomas M. Cahill, David E. Barnes, Nicholas J. Spada and Roger Miller. **Inorganic and organic aerosols downwind of California's Roseville Railyard.** Aerosol Science and Technology 45:1049-1059 (2011) doi:10.1080/02786826.2011.580796

- Plus 2 from EPA NEXUS….
- Robert Willis[1], Thomas A. Cahill[2], David E. Barnes[2], Jonathan A Lawton[2], Roger S. Miller[2], and Nicholas J. Spada[3] **Relationships between Indoor and Outdoor PM in a downtown Detroit school by size, time, and compositionally resolved aerosols** (under EPA review)
- Thomas A. Cahill[1], David E. Barnes[1], Jonathan A Lawton[1], Roger Miller[1], Nicholas Spada[2], and Robert D. Willis[3,] **Coarse, fine, very fine, and ultra-fine transition metals from the NEXUS I-96 Transect near Detroit** (under EPA Review)

United States Environmental Protection Agency

Examining the Effects of Roadside Vegetation on Near-Road Air Pollution

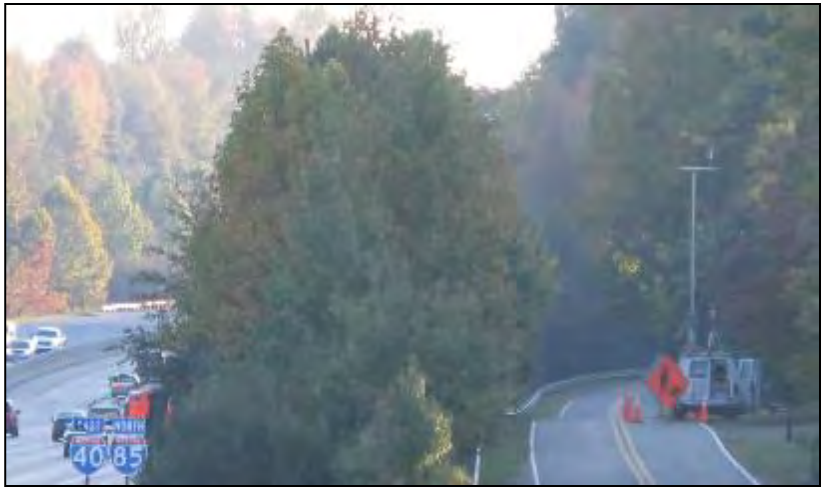
Rich Baldauf
U.S. Environmental Protection Agency
June 2, 2015
Sacramento, CA

Presentation Overview

- Interest in Roadside Vegetation
- Research Results
- Summary/Recommendations

Why study roadside vegetation?

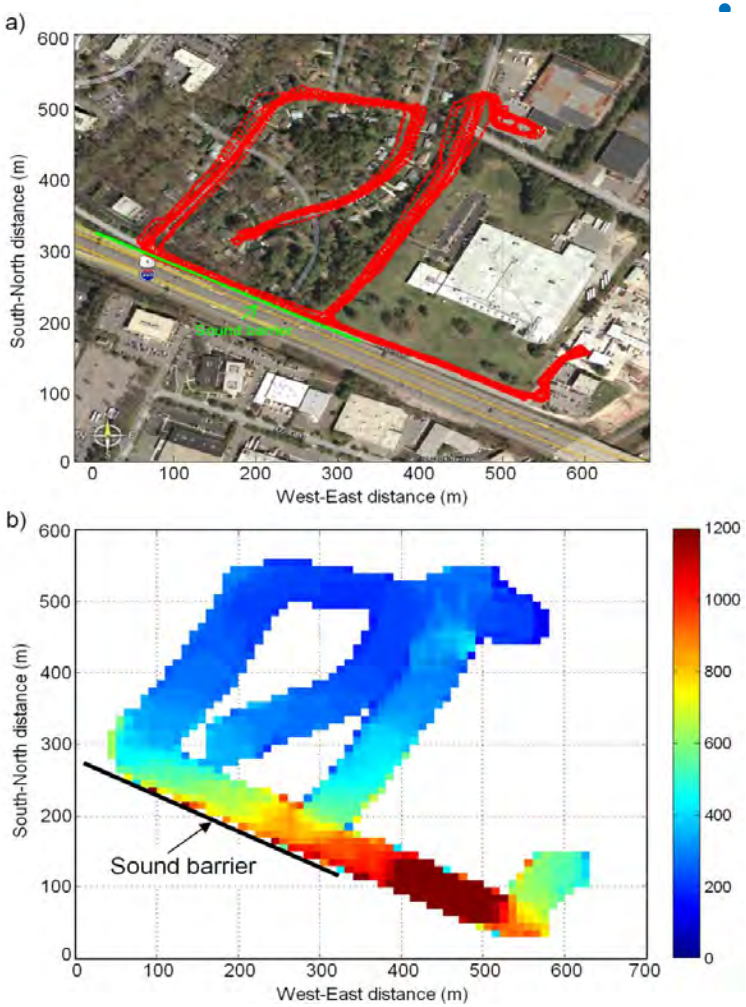
- Few “short-term” mitigation options for near-road air quality concerns
  - Emission reductions take long to implement (fleet turnover required)
  - Planning and zoning involved in rerouting/VMT reduction programs
  - Buffer/exclusion zones may not be feasible or effective
- Roadside vegetation may already be present
- Roadside vegetation has other positive benefits



Research Methodology

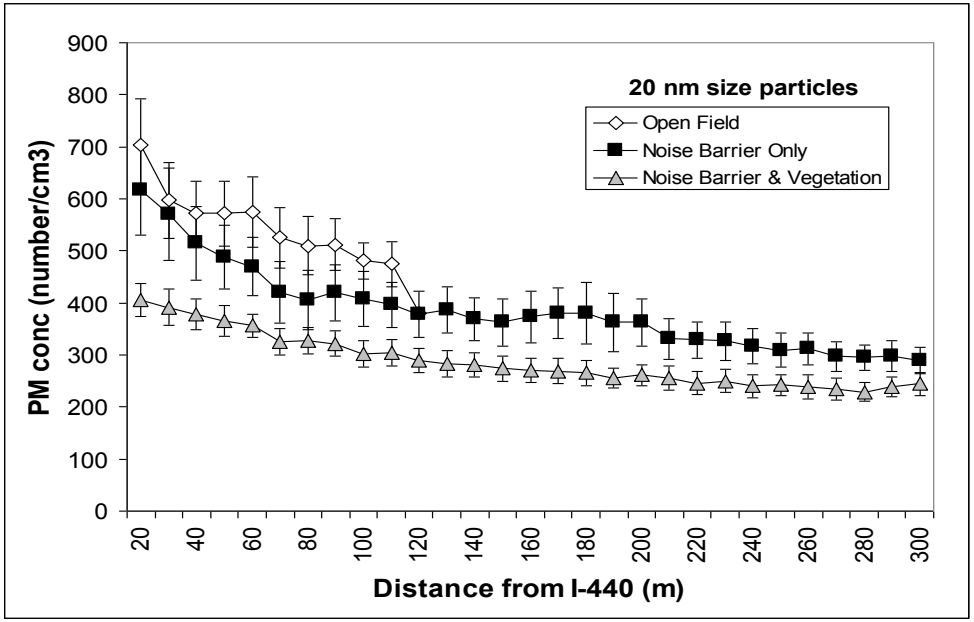
- EPA has initiated research to examine the role roadside vegetation may play in affecting near-road air pollution
  - Field studies
    - Research Triangle Park area (vegetation and noise barriers)
    - Detroit (vegetation)
    - San Francisco (vegetation)
  - Wind tunnel assessments
    - Vegetation removal processes
    - Site-specific configurations
  - Computational Fluid Dynamics (CFD) modeling
    - Generalized vegetative scenarios
    - Site-specific configurations

Noise Barrier & Vegetation Effects



- Noise barriers reduced PM levels compared with a clearing

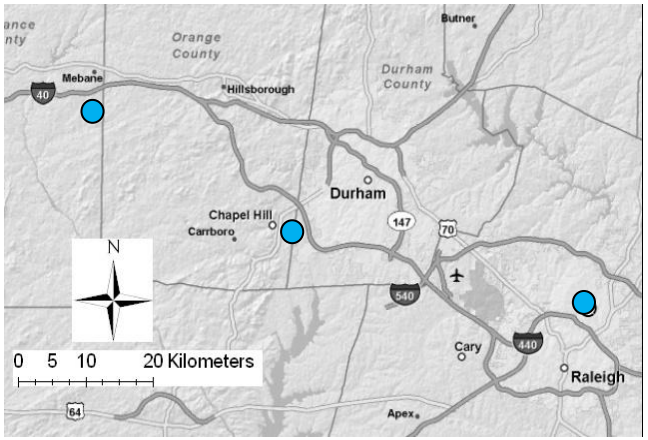
  Vegetation with noise barriers provided a further reduction of PM concentrations and gradients

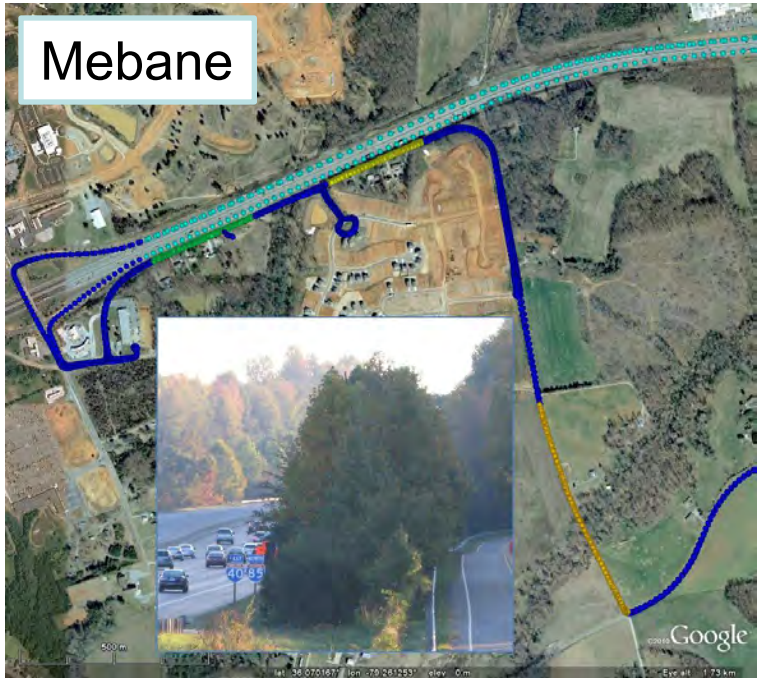


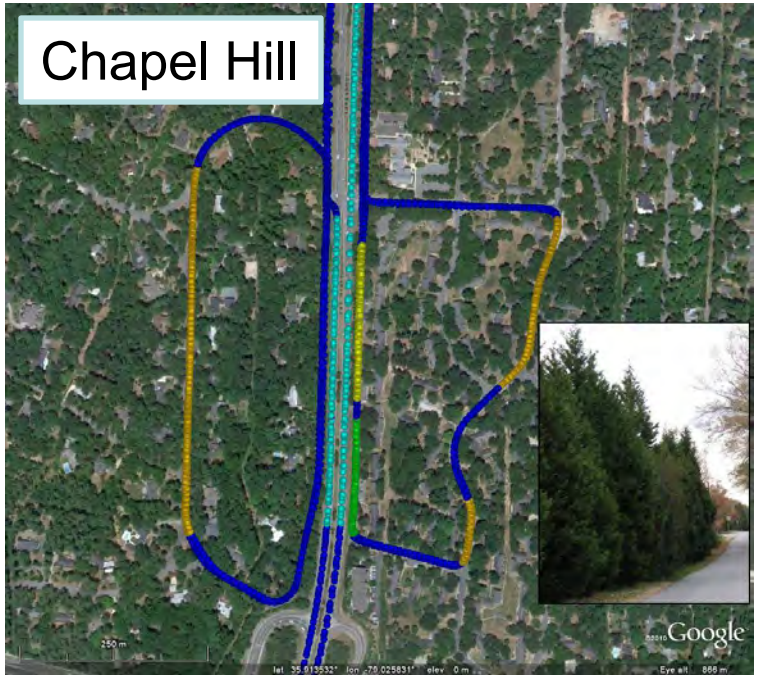
(Baldauf et al., 2008a; 2008b)

Vegetation Effects

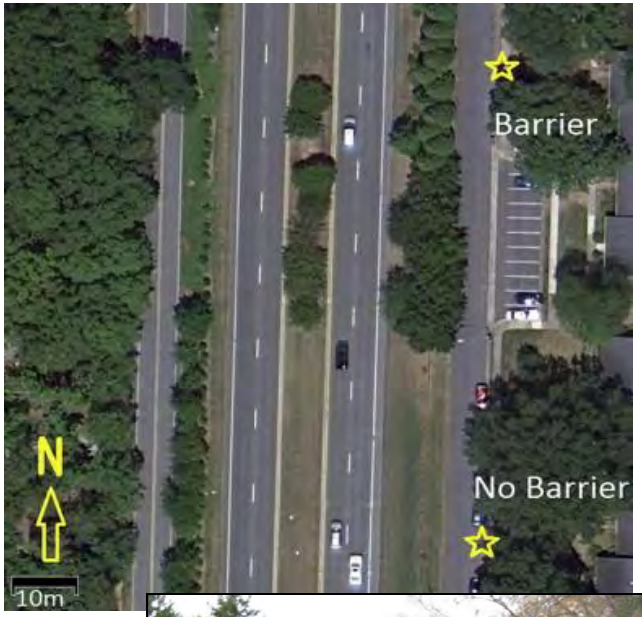
- Field data: Mobile and fixed site sampling study at two sites in North Carolina
  - One with primarily pine trees (Chapel Hill)
  - One with primarily hardwoods (Mebane)

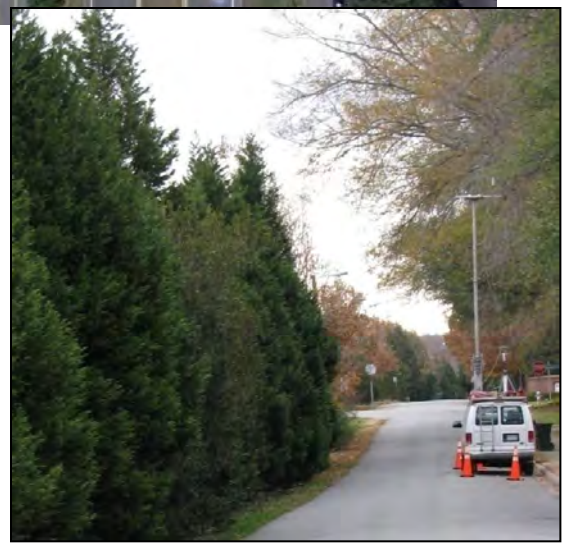




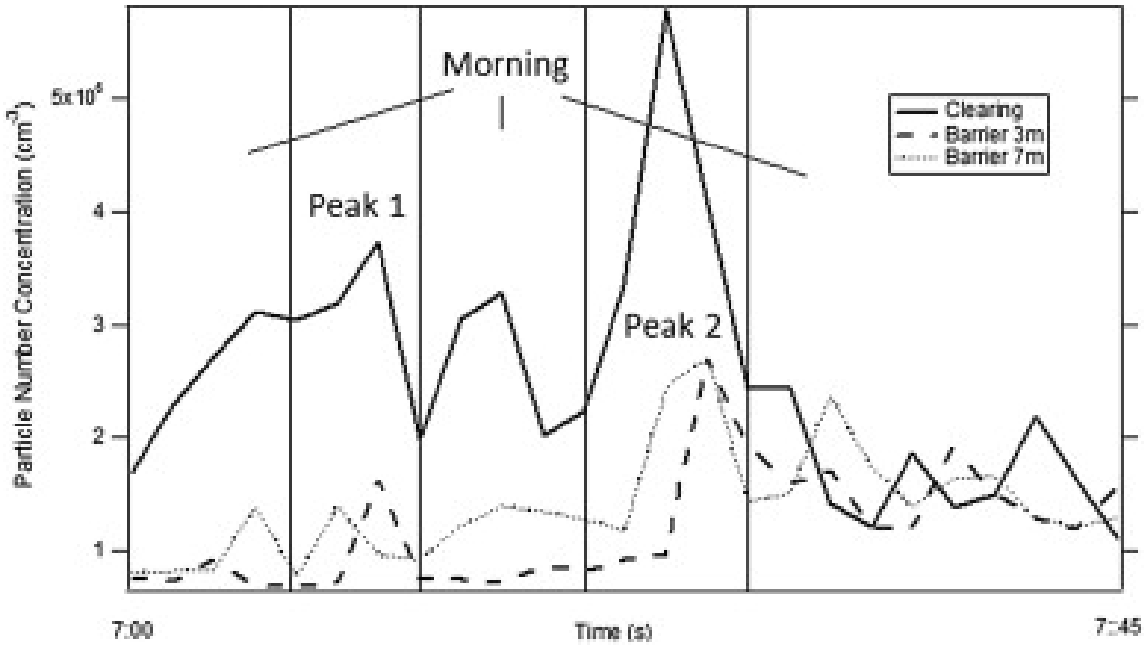


Vegetation Effects





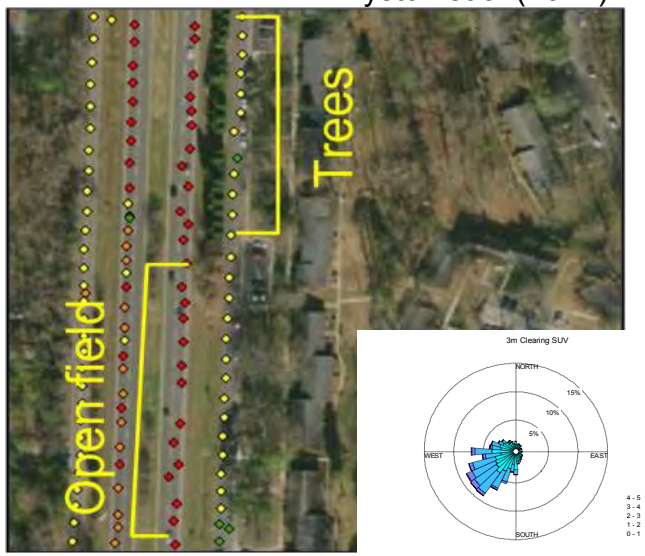
Steffans et al. (2011)

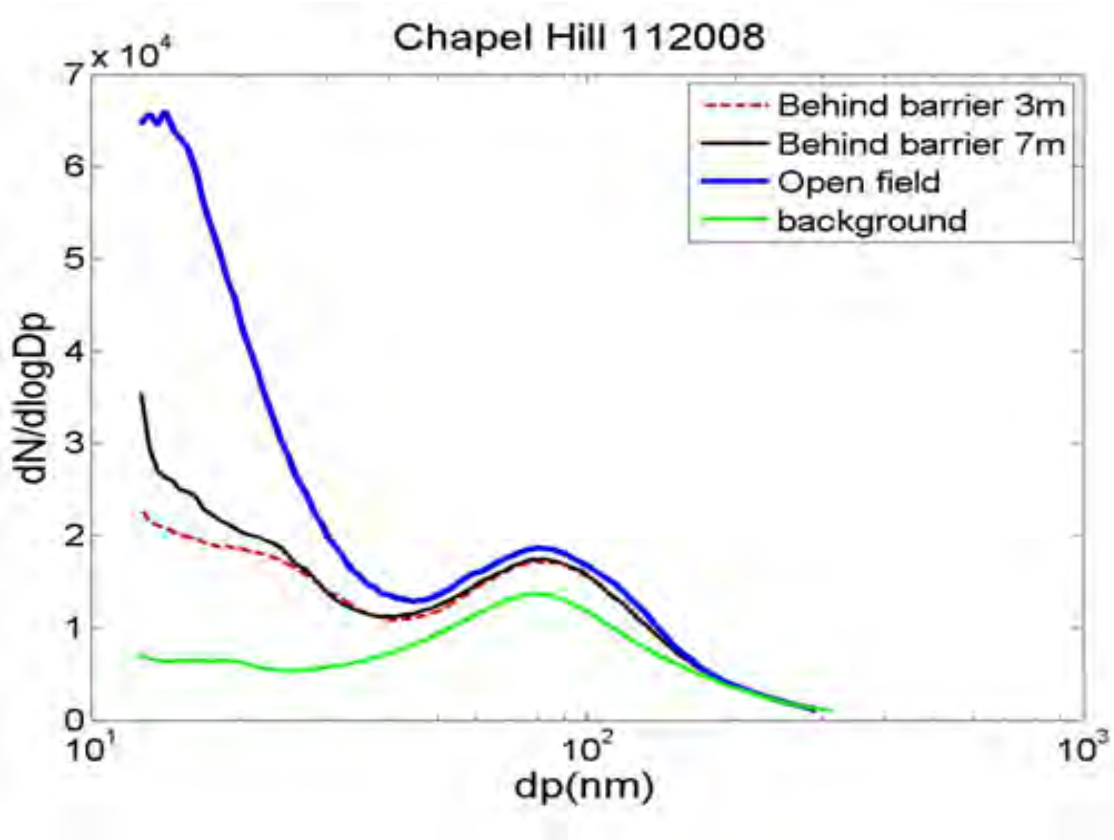


- Ultrafine PM number count generally reduced downwind of a vegetation stand
- Higher reductions most often occurred closer to ground-level
- Variable winds caused variable effects

Vegetation Effects

Khlystov et al (2012)

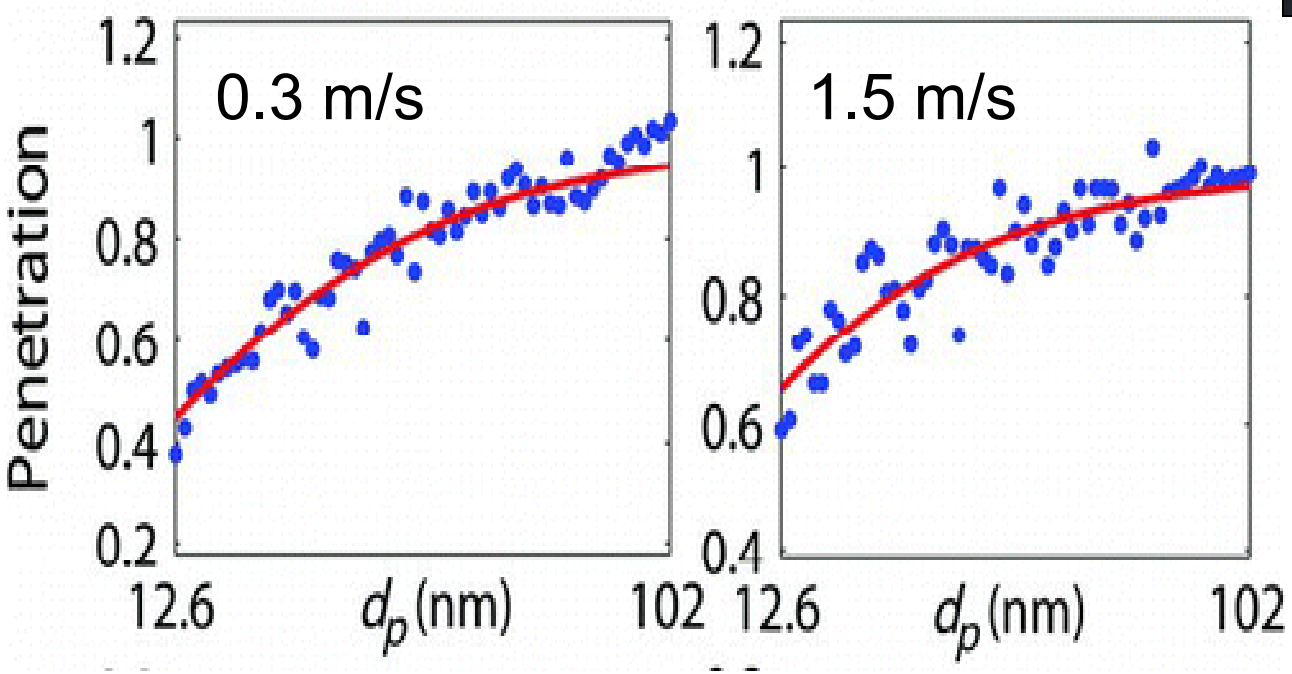


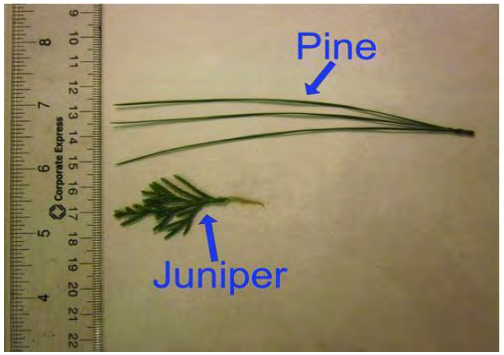


- Lower size fractions of PM most reduced downwind of the vegetation stand
- Effect most evident closer to ground-level

Vegetation Effects

- Smaller size PM have higher removal rate
- Removal increases at lower wind velocities
- Branch/leaf shape and size affects removal



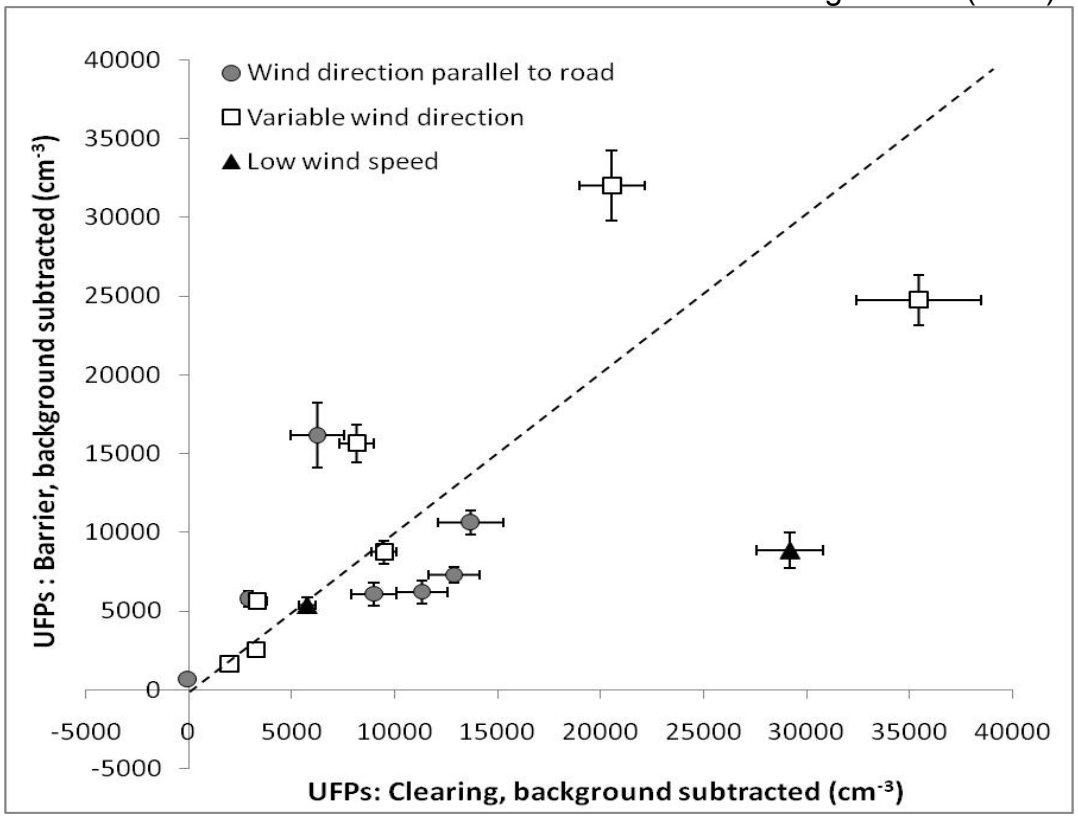


Cahill et al., (2010)

Vegetation Effects

- For thin tree stands, variable results seen under changing wind conditions (e.g. parallel to road, low winds) and larger spatial scales
- Future research looking into effects of lower porosity/wider tree stands

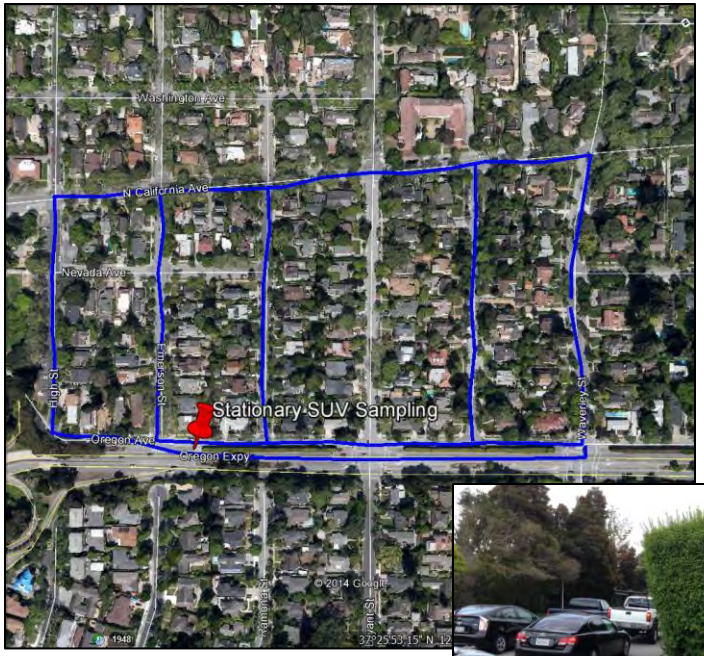
Hagler et al. (2011)

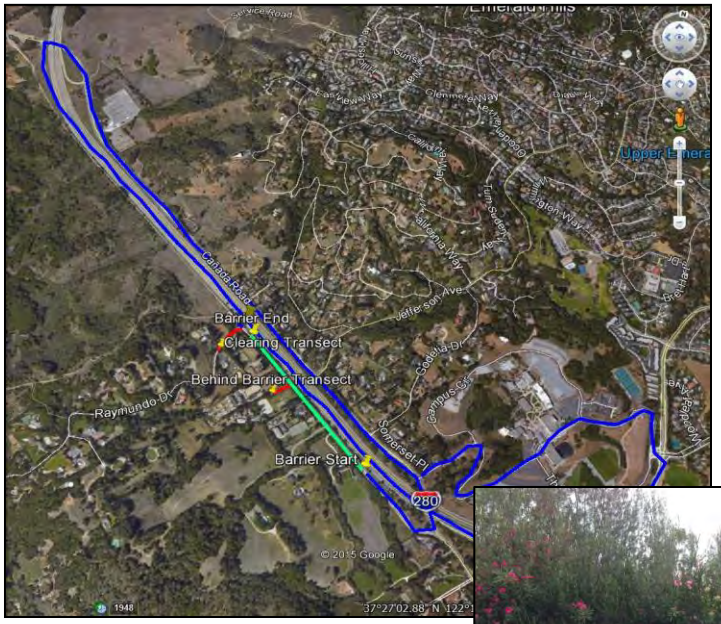


San Francisco Vegetation Study

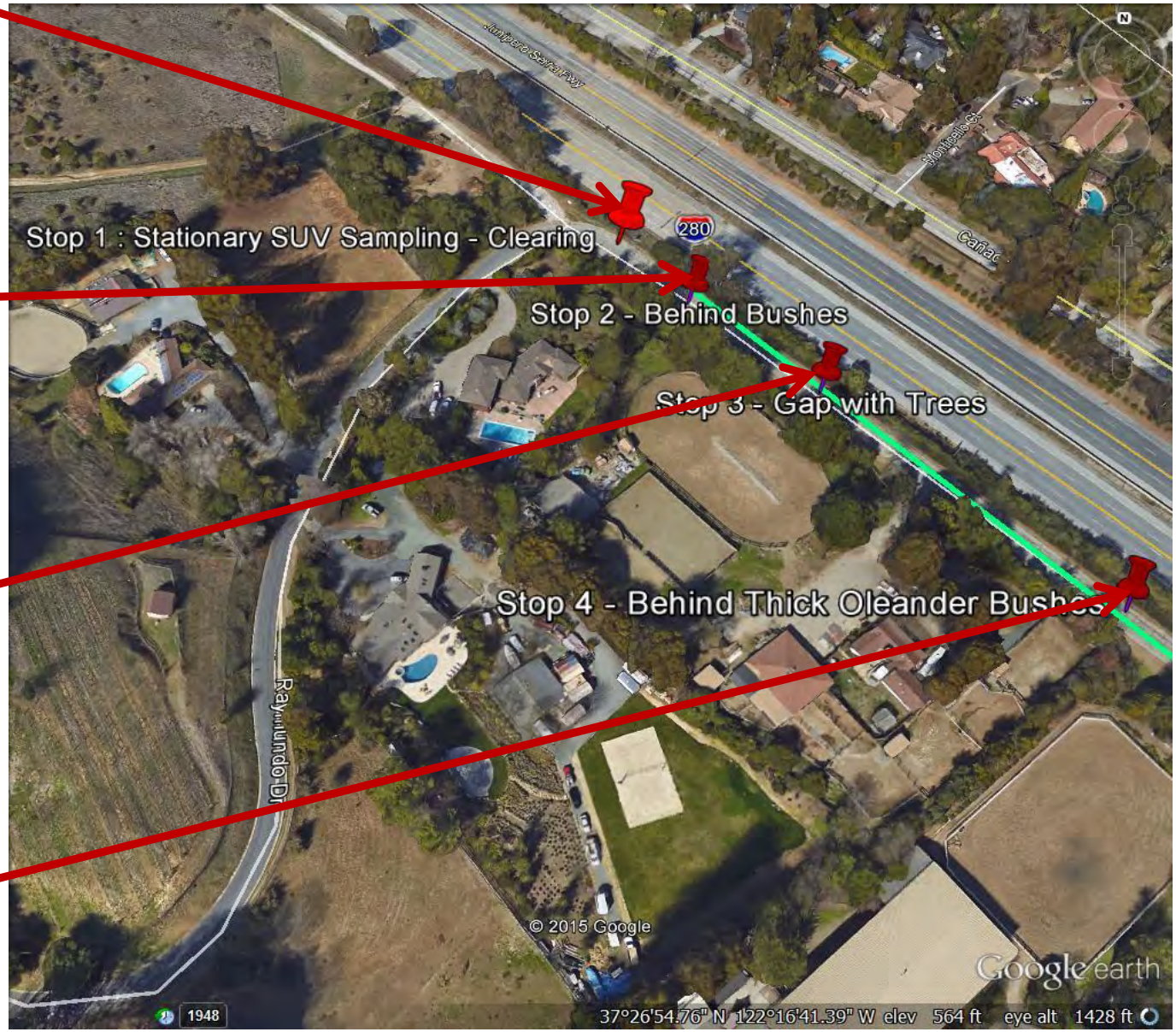
United States Environmental Protection Agency

- On-road and near-road mobile and fixed monitoring with varying vegetation types
  - Bush/tree combinations with varying porosity
  - Manicured hedges



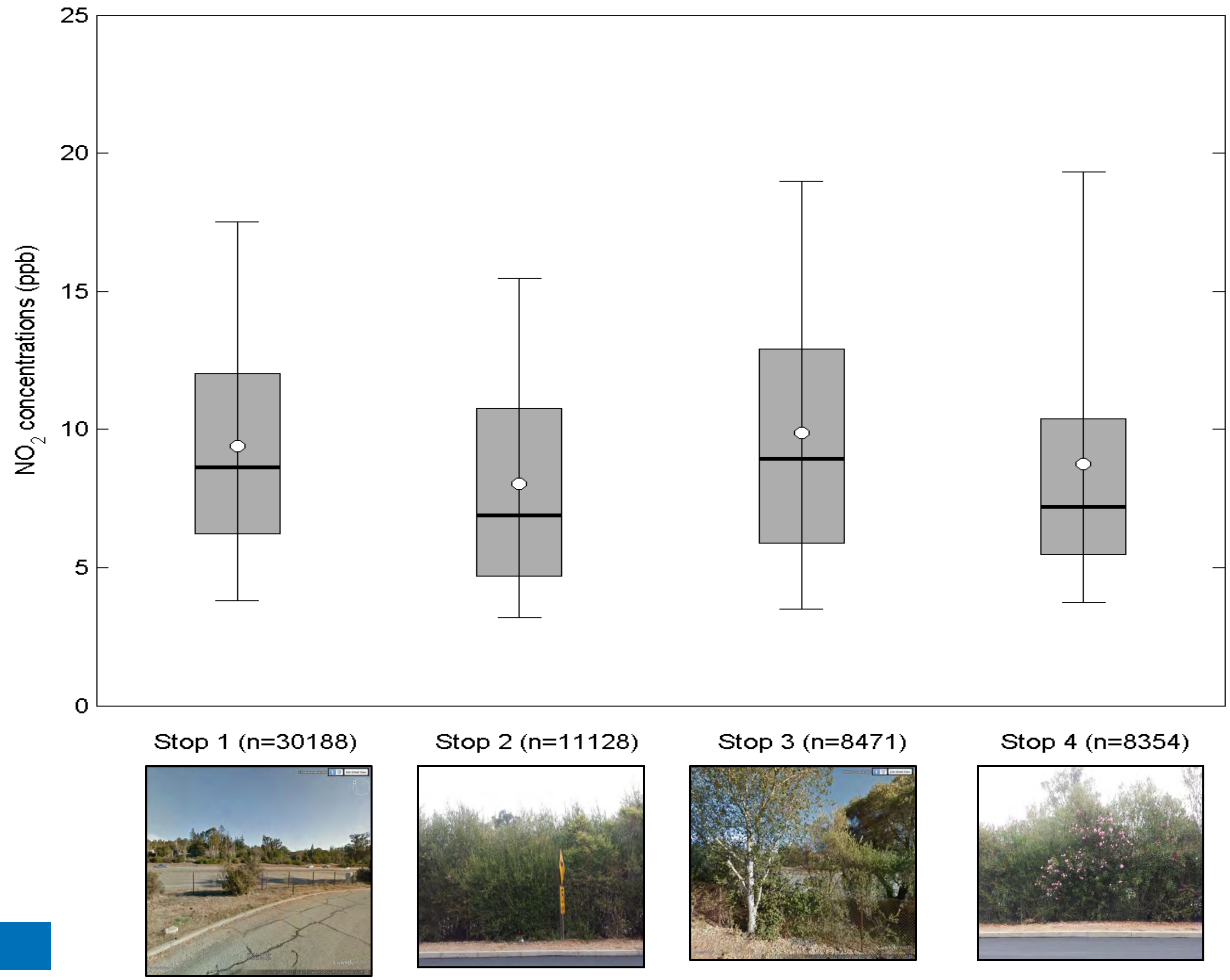


San Francisco Vegetation Study



San Francisco Vegetation Study

- Initial results suggest the importance of thickness, porosity and full coverage

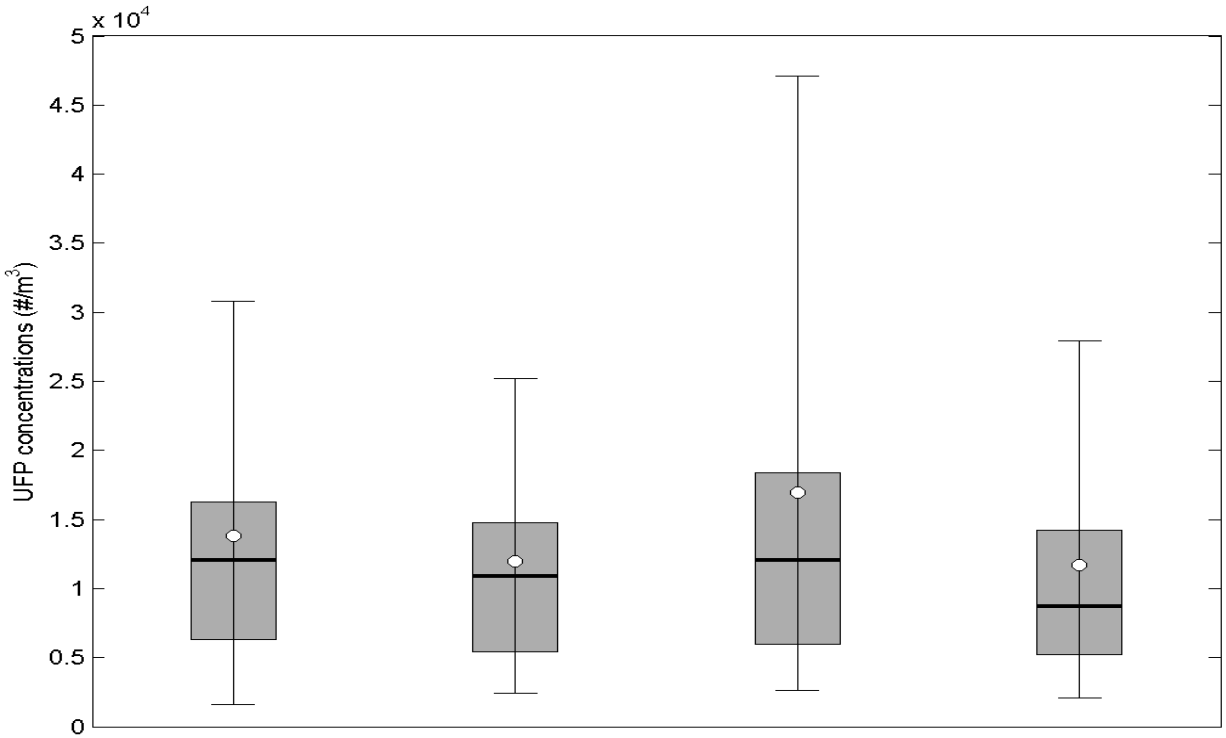


- All wind directions
- ~10k data pts/stop
- ~10min/stop/day

Preliminary data: do not cite or quote

San Francisco Vegetation Study

- Initial results suggest the importance of thickness, porosity and full coverage



Stop 1 (n=30188)

Stop 2 (n=11128)

Stop 3 (n=8471)

Stop 4 (n=8354)

- All wind directions
- ~10k data pts/stop
- ~10min/stop/day

Preliminary data: do not cite or quote

Summary - Vegetation

- Research shows the ability for roadside vegetation to reduce downwind pollutant concentrations near roads
- Design considerations are very important:
  - Generally, the higher and thicker the vegetation, the higher the pollution reduction
  - Pollutants can meander around edges or through gaps
    - Areas targeted for reductions should avoid edge effects
    - Existing vegetation with gaps may be increasing exposures
- Vegetation should be appropriate for the location of use
- Best practice guidance and case studies needed to fully evaluate potential effectiveness of roadside vegetation and avoid unintended consequences
- Models will be important in designing and evaluating vegetative barriers

Summary - Vegetation

- Areas desired for reduced concentrations should avoid gaps and edge effects
  - Vegetation barrier should provide coverage from the ground to the top of canopy
  - Barrier thickness should be adequate for complete coverage so gaps are avoided
- Pine/coniferous trees and thick bushes may be a good choice
  - No seasonal effects
  - Complex, rough, waxy surfaces

Examples of full coverage barriers

Summary - Vegetation

- Pollutants can meander around edges or through gaps
- Barrier thickness should be adequate for complete coverage to avoid gaps
  - No spaces between or under trees
  - No gaps from dead or dying vegetation; maintenance important

Examples of inadequate barriers due to gaps

Summary - Barriers

- Combination of noise and vegetative barriers may provide most benefit
  - Increase potential for pollutant dispersion and removal
  - May be solid barrier with vegetation behind and/or in front
  - Use of climbing vegetation and hedges with solid barrier may also provide additional benefits
    - Field study results mixed
    - Vegetation on solid wall should extend enough to allow air to flow through

Examples of solid/vegetation barriers

Acknowledgements

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James Faircloth
Richard Snow
Thomas Long

FHWA

Victoria Martinez
Kevin Black
Mark Ferroni
Adam Alexander

USFS

Greg McPherson
David Nowak

NOAA

Dennis Finn
Kirk Clawson

For More Information

- Websites:
  - http://www.epa.gov/nrmrl/appcd/nearroadway/workshop.html
  - http://www.epa.gov/ord/ca/quick-finder/roadway.htm
- References

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  - Baldauf, R.W., E. Thoma, M. Hays, et al. 2008b. J. Air & Waste Manage Assoc. 58:865–878
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  - Hagler, G.S.W., M-Y. Lin, A. Khlystov, et al. 2012. Science of the Total Environment, 419: 7-15
  - Heist, D.K., S.G. Perry, L.A. Brixey, 2009. Atmos. Environ. 43: 5101-5111
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  - Steffens, A., Y.J. Wang, K.M Zhang. 2012. Atmos. Environ. 50: 120-128

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Cornell University

Roadside Vegetation Barrier Designs to Mitigate Near-Road Air Pollution Impacts

K. Max Zhang

Sibley School of Mechanical and Aerospace Engineering

Cornell University

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- Current and former PhD students working on this subject: Zheming Tong, Jon Steffens, and Bo Yang
- Valuable discussions with Drs. Rich Baldauf, Vlad Isakov and Parik Deshmukh at USEPA
- Experimental data from USEPA

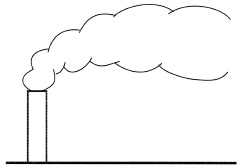
Relevant Properties and Processes

- Leaf area density/porosity
- Drag coefficient
- Width, height
- Barrier layout
- VOC emissions

- Wind speed, direction
- Atmospheric stability

- Highway geometry
- Road properties
- Traffic conditions (volume, mix, etc.)
- Surrounding structures

- Dispersion
- Deposition
- Aerosol dynamics and gas chemistry

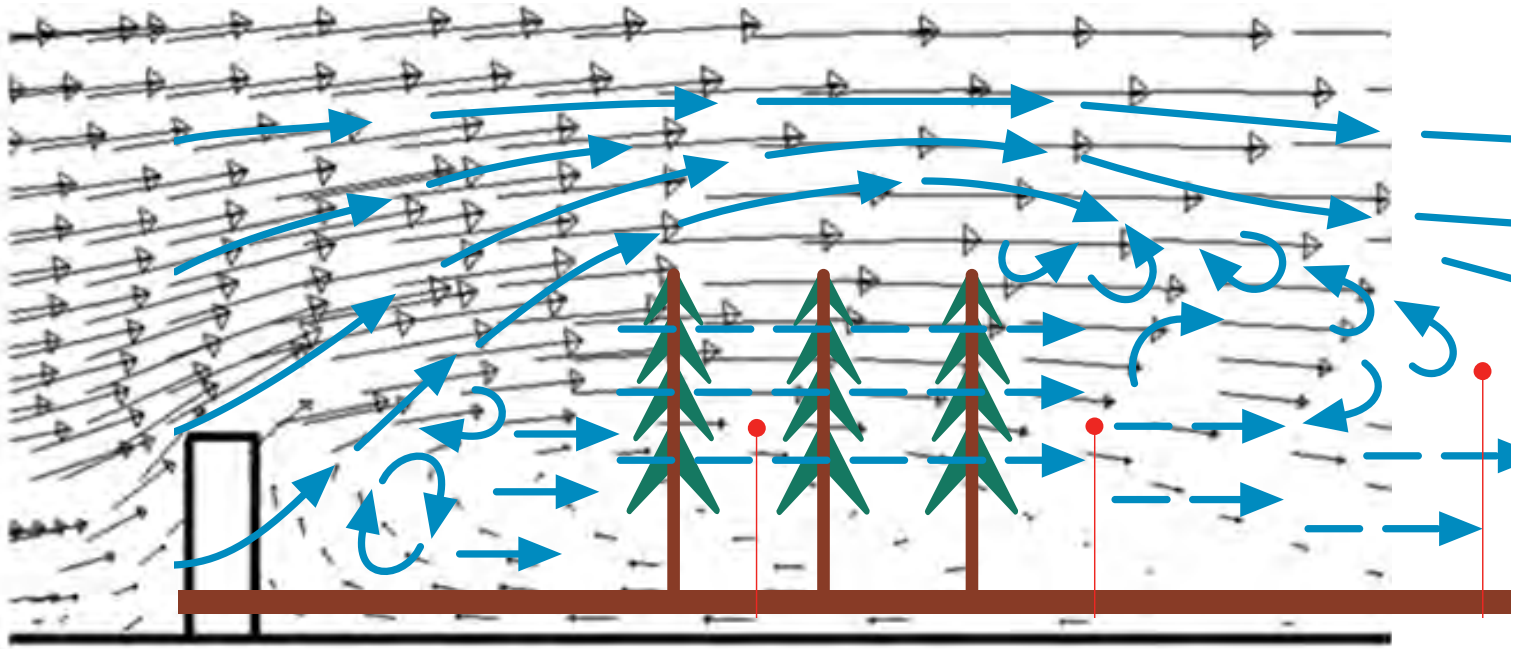


Design parameters

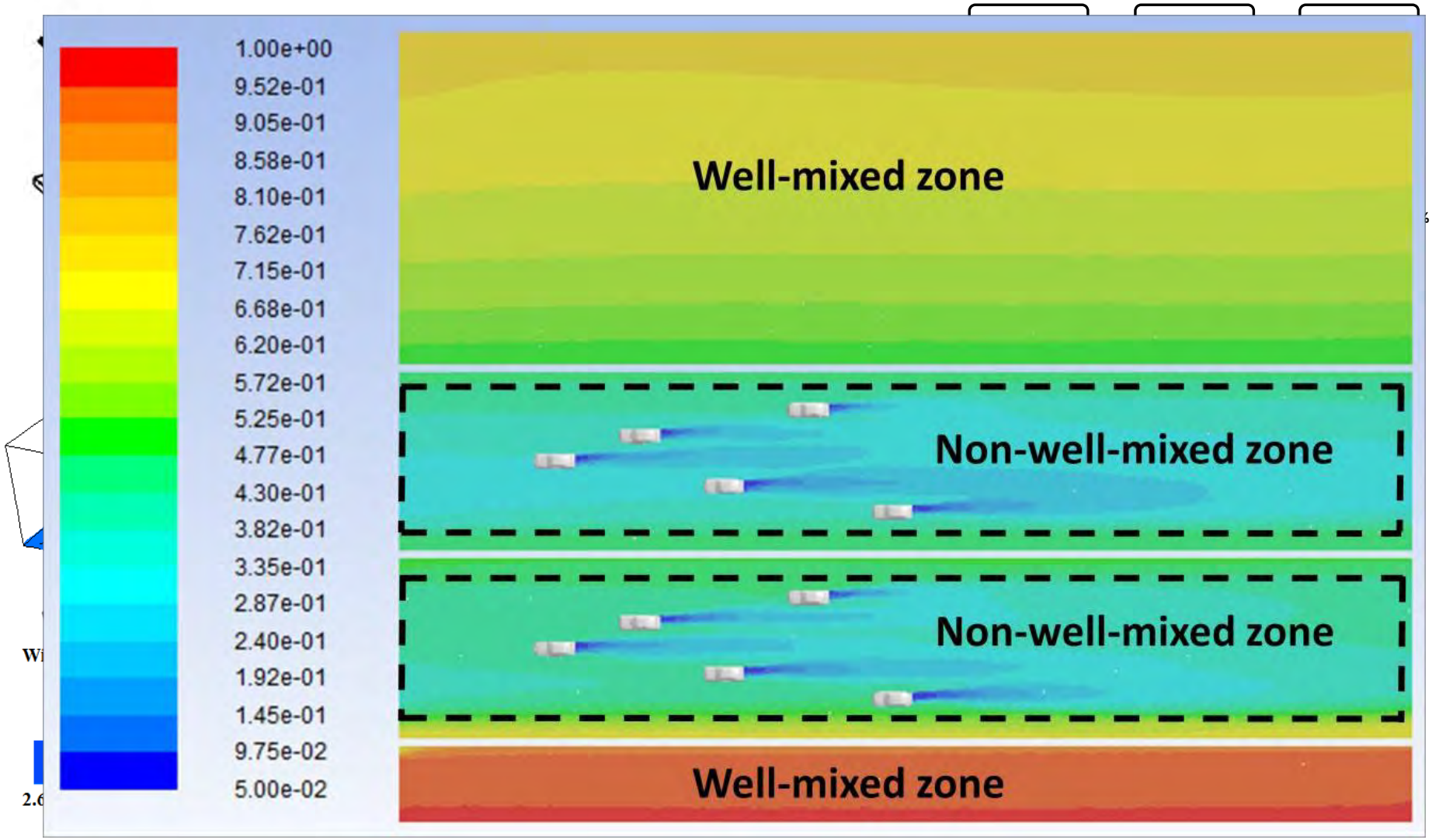
- Particle size distribution
- Concentrations of air toxics
- Human exposure

More on the Atmospheric Processes

- Dispersion
  - Solid barrier effect: creating upward momentum and enhancing plume dispersion -> lower ground level conc. behind the barrier
  - Windbreak effect: plume going through the canopy at slower s
  - C
    g
- Depo
  - S
  - T
  - R
- Aero



Comprehensive Turbulent Aerosol and Gas Chemistry (CTAG)



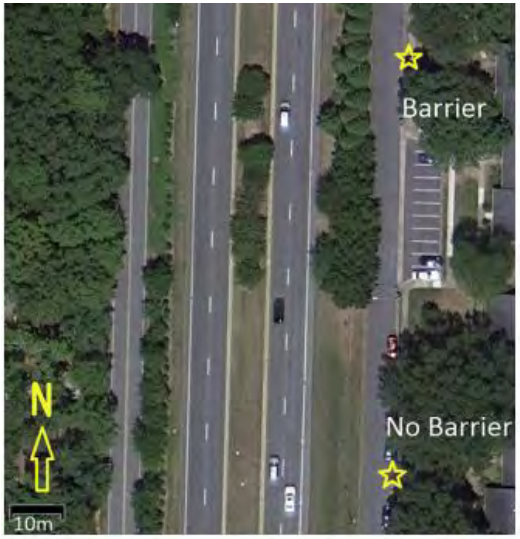
Past work on Transportation and Air Quality

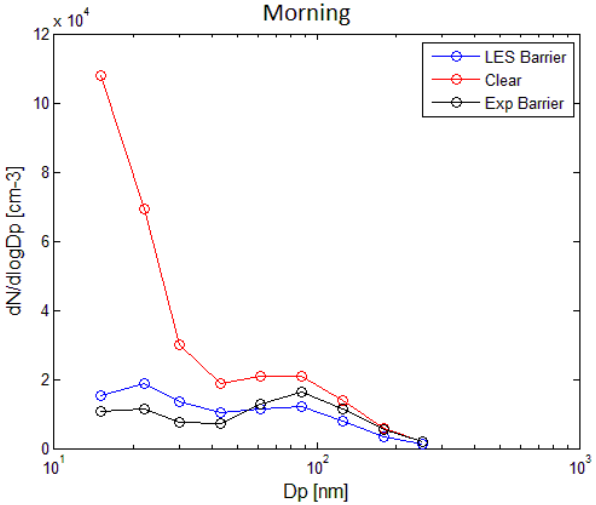
CTAG components	Experimental datasets	Publications
VIT	Turbulent flow filed measurements behind a moving van	Wang and Zhang (2009); Wang et al. (2012)
Road configurations	Horizontal and vertical CO profiles near an elevated highway and a ground-level highway in Los Angeles	Wang and Zhang (2009);
	Particle size distribution and CO measurements near a large highway intersection in Rochester, NY	Wang et al. (2013)
Roadside buildings	Spatial variations of black carbon in a highway-buildings environment in NYC	Tong et al., (2012)
Roadside solid barriers	Near-road tracer study 2008 in Idaho Falls, ND	Steffens et al. (2013)
	USEPA wind tunnel study of 12 road configuration	Steffens et al. (2014)
Roadside vegetation barriers	Field study in Chapel Hill, NC	Steffens et al. (2012)
Gas chemistry	NO and NO_2 horizontal gradients near two roadways near Austin, TX	Wang et al. (2011)
Aerosol dynamics	Particle size distribution measurements behind a diesel car	Wang et al. (2012)
	Particle size distribution and CO measurements near a large highway intersection in Rochester, NY	Wang et al. (2013)

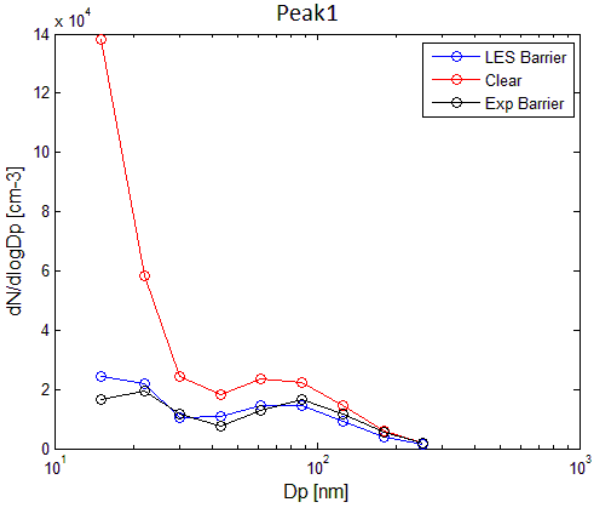
!

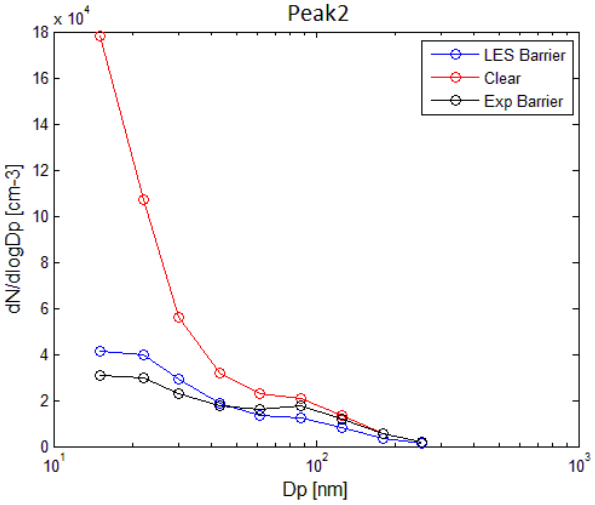
Revisiting Chapel Hill Experimental Dataset with Large Eddy Simulation (LES)

- The Chapel Hill (NC) dataset was collected by USEPA and Duke researchers (Hagler et al., 2011).
- Steffens et al. (2012) employed RANS turbulence model and two different particle deposition models to simulate the dataset.
- We recently applied the Large Eddy Simulation (LES) model to re-simulate the dataset.
- LES model shows generally good agreement.









Tong et al., manuscript in preparation

Design Configurations

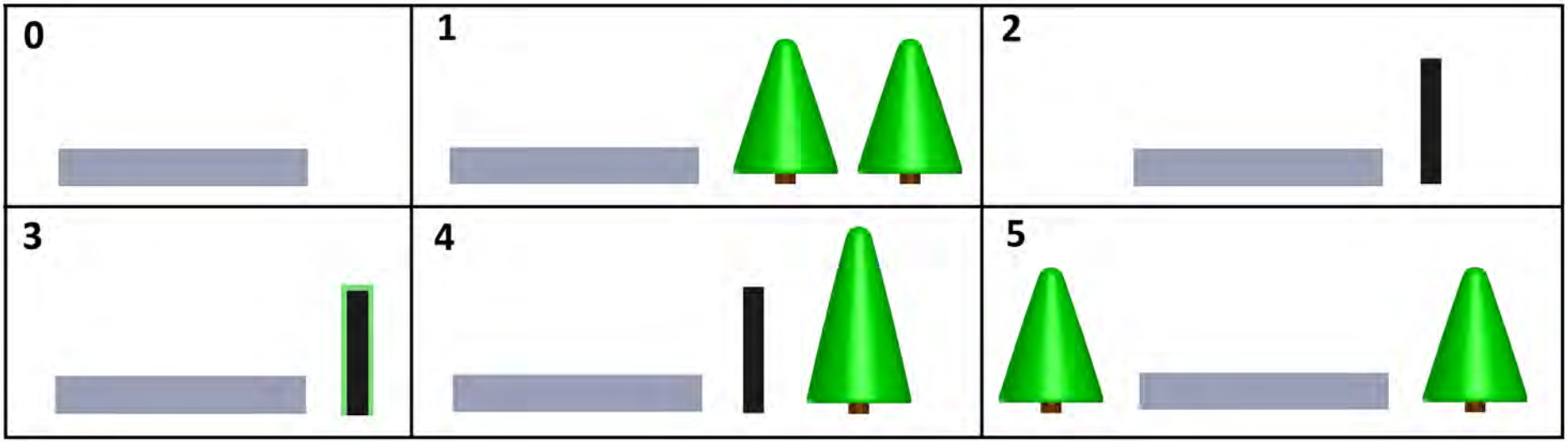


Table 1: Description of roadside barrier geometry for all configurations tested

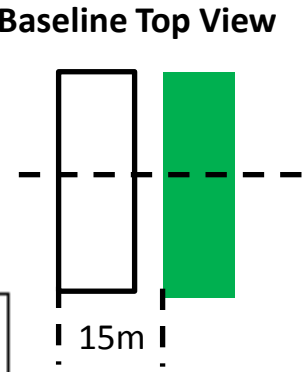
Case #	0	1	2	3[a]	4		5	
					Solid barrier	Vegetation barrier	Upwind vegetation barrier	Downwind vegetation barrier
Height	N/A	6 m	6 m	6 m	6 m	10 m	6 m	6m
Width	N/A	6m,12 m,18m	1 m	1+0.25 m	1 m	6 m	6 m	12m
LAD[b]	1	1 ,1.5	1	0.33[c]	N/A	1, 0.25	1	1
U	2 m/s	1, 2, 4 m/s	2 m/s	2 m/s	2 m/s		2 m/s	
Stability	Unstable	Stable, Unstable, Neutral	Unstable	Unstable	Unstable		Unstable	
Direction[e]	90°	90°	90°	90°	30°, 45°, 90°		90°	

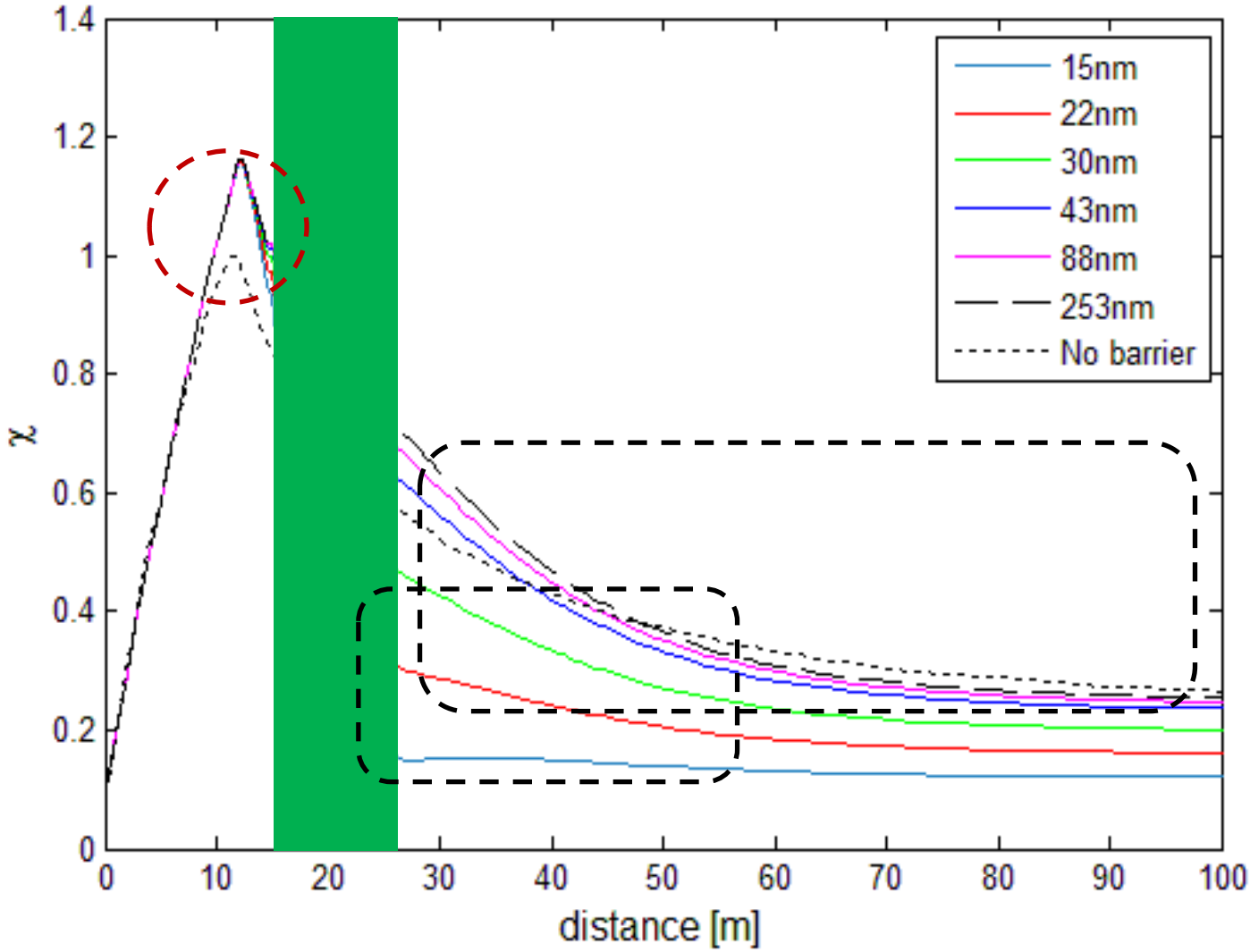
Tong et al., manuscript in preparation

Main Assumptions

- Highway conditions are taken as the same as those in the Chapel Hill experiment
- Infinite long barrier
- Baseline case:
  - Leaf area density and drag coefficient taken from the Chapel Hill experiment (conifer)
  - Perpendicular wind direction

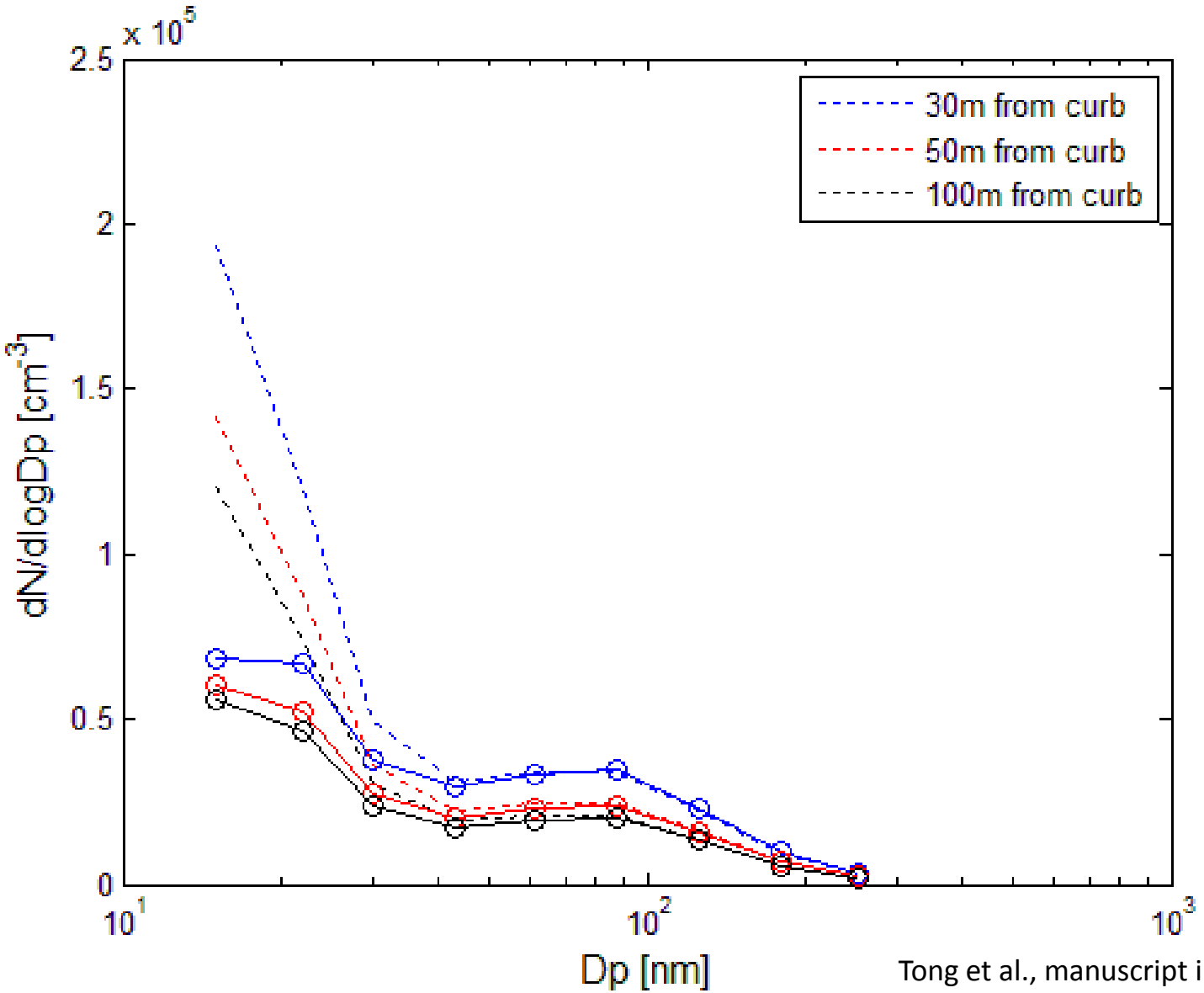
Case 1: Horizontal Gradient





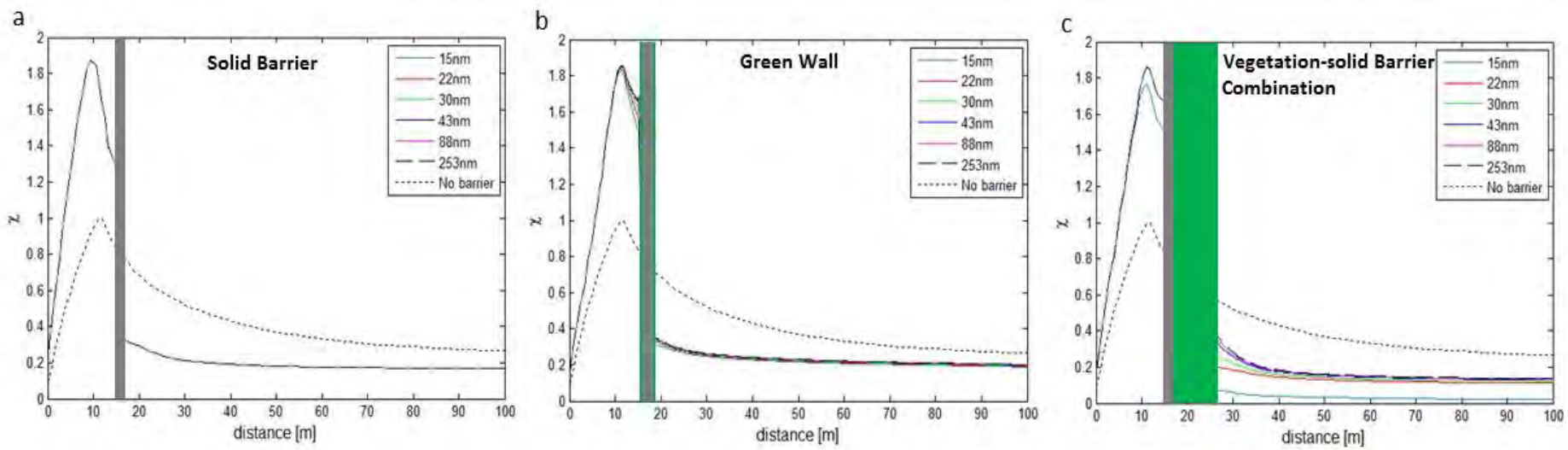
Tong et al., manuscript in preparation

Case 1: Particle Size Distribution



Tong et al., manuscript in preparation

Cases 2, 3, 4: Solid, Green Wall and Combination

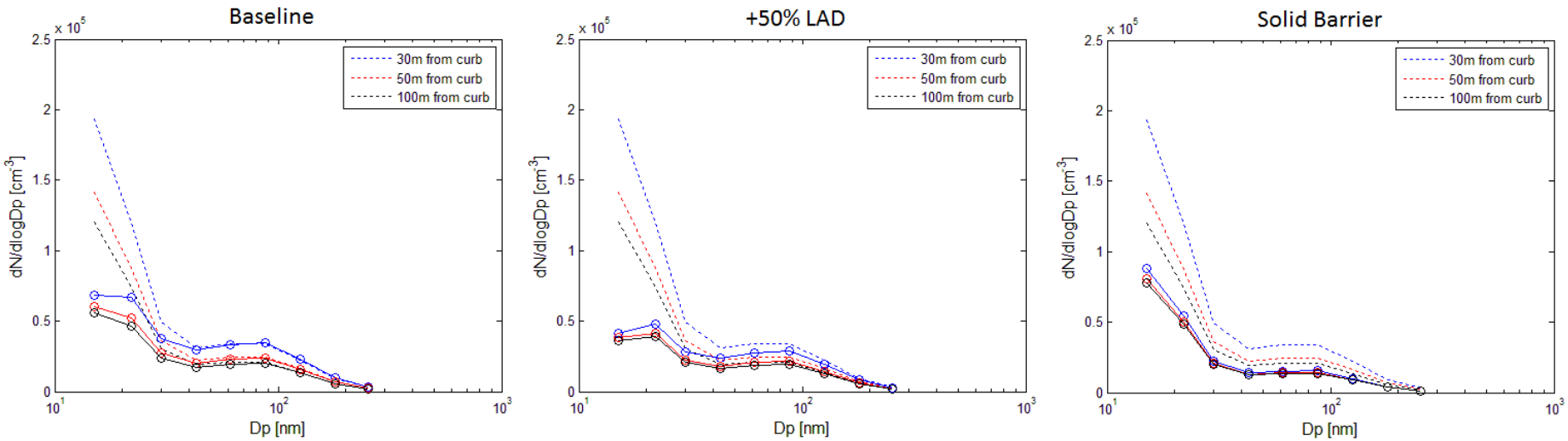


- Solid barrier: significant reduction in conc. behind the barrier with on-road accumulation
- Green Wall: Slight more reduction compared to the solid barrier case
- Vegetation-solid barrier combination: greatest reduction in conc. behind the barrier with on-road accumulation

Tong et al., manuscript in preparation

Sensitivity: Leaf Area Density (LAD)

Increasing LAD →

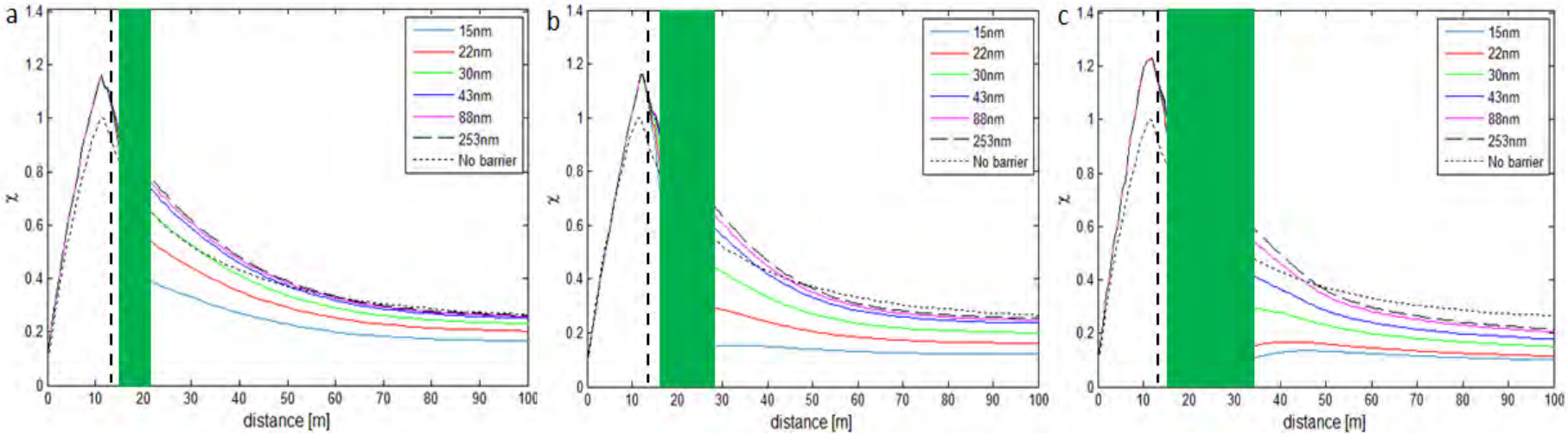


- Increasing LAD leads to more deposition and upward momentum
  - For smaller particles, greater reduction behind the barrier
  - For larger particles with relatively small deposition velocity, approaching the behaviors of a solid barrier

Tong et al., manuscript in preparation

Sensitivity: Barrier Width

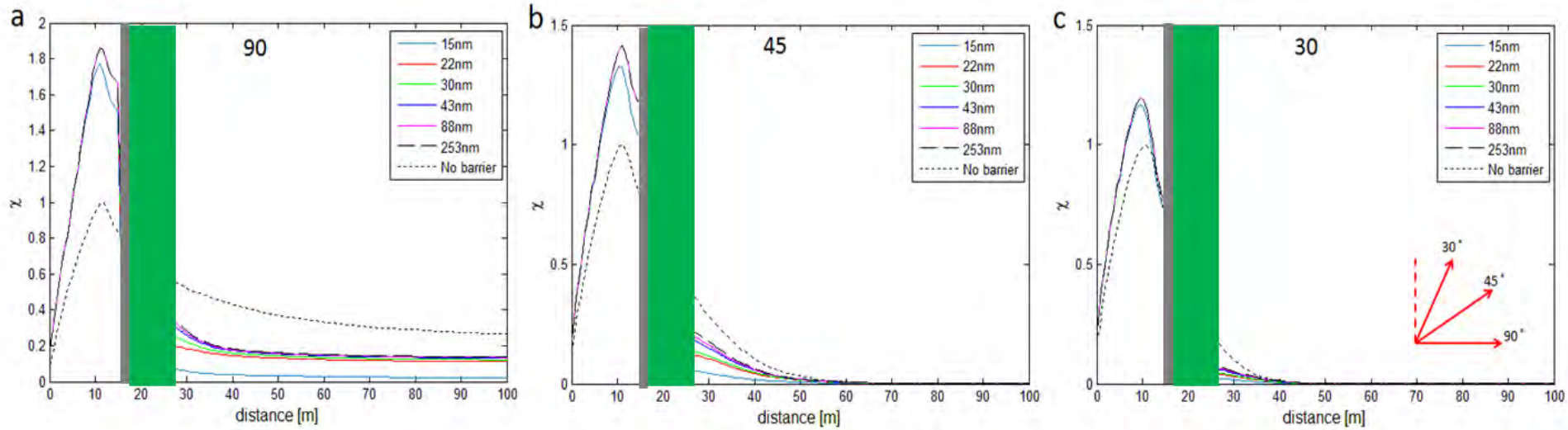
Increasing width



- Increasing width leads to more deposition
  - For smaller particles, greater reduction behind the barrier
  - For larger particles with relatively small deposition velocity, earlier transition to lower conc. compared to the no-barrier case
- On-road accumulation is modest compared to solid barrier

Tong et al., manuscript in preparation

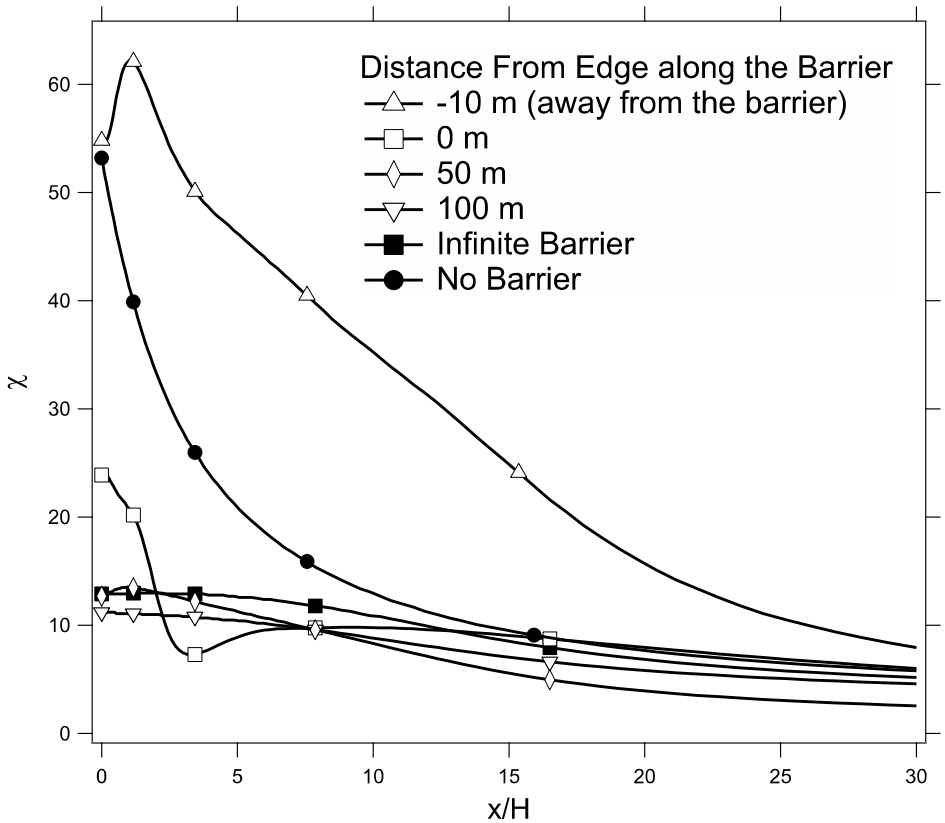
Sensitivity: Wind Direction



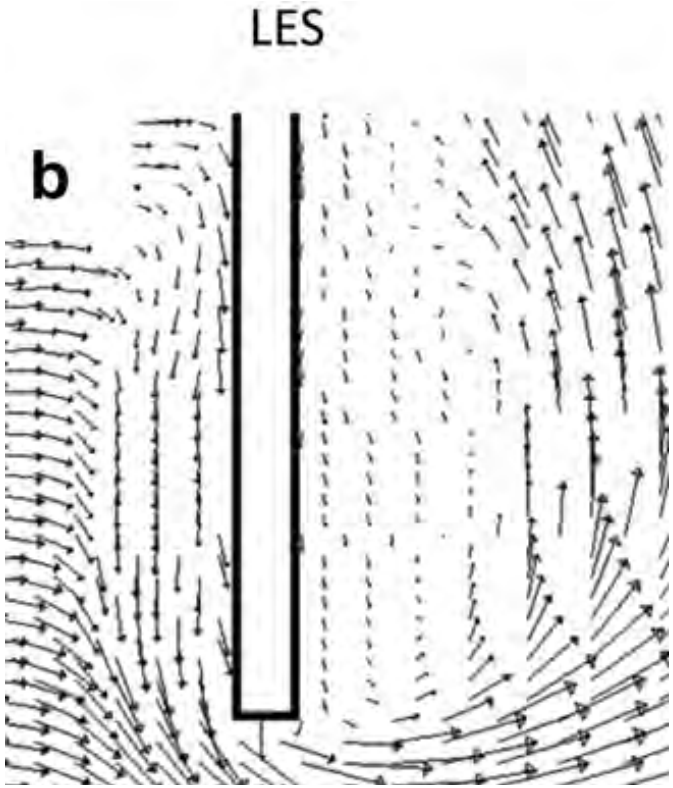
- The degree of on-road increase is contingent on oncoming wind direction.
- The on-road concentration decreases with more parallel wind to the road

Tong et al., manuscript in preparation

Edge Effects



Steffens et al. (2014)

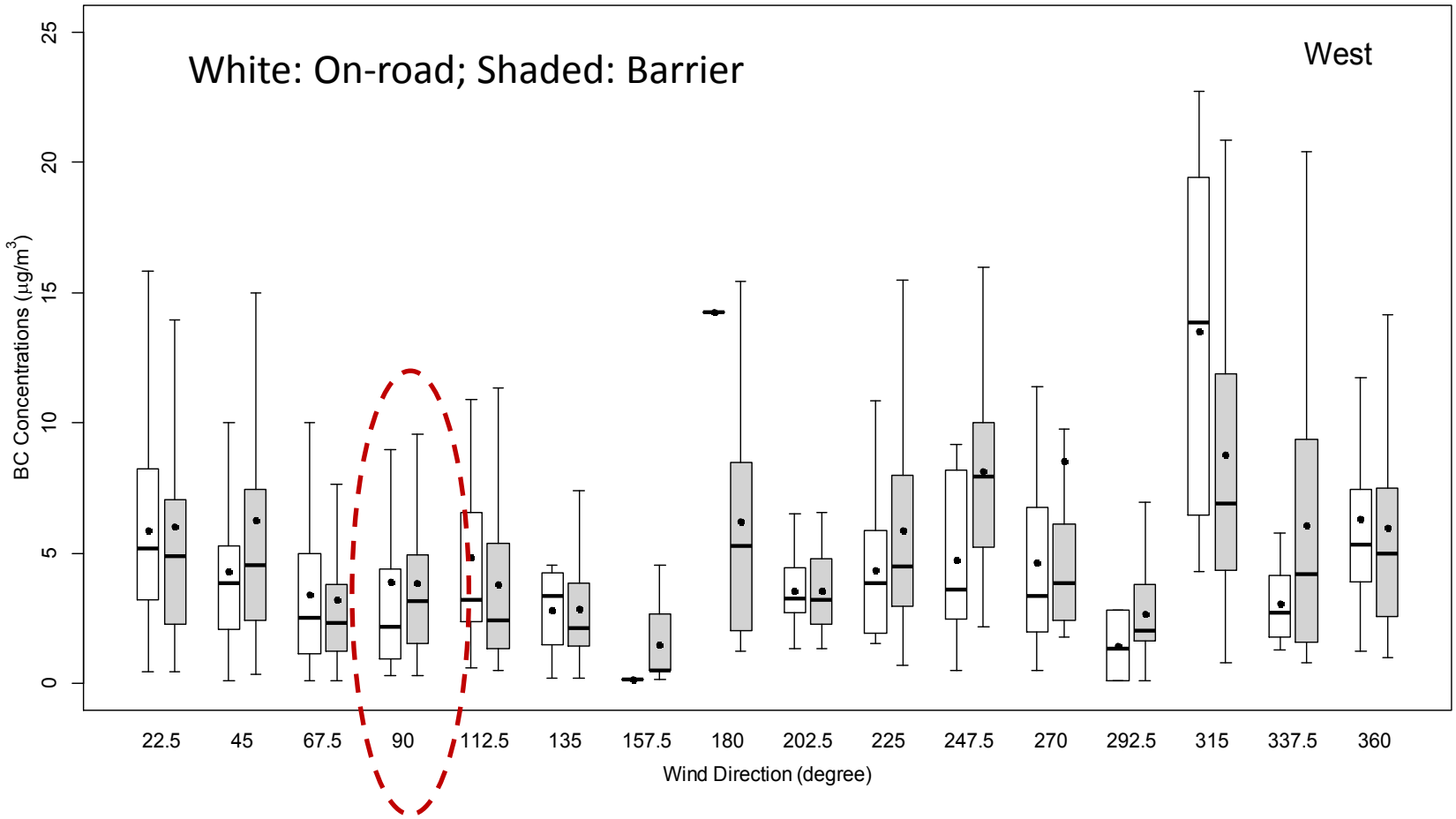


Steffens et al. (2013)

Report Card for Model Capability

- Modeling results capture the general phenomena very well
  - Vegetation-solid barriers show greatest reduction
  - Wider and denser trees lead to more reduction
  - Edge effects can be captured
  - …
- Research needs
  - More testing against different vegetation barrier configurations, meteorological and traffic conditions
  - Turbulence modeling: drag vs. wind speed
  - Deposition modeling
  - Effects of vegetation barriers on near-source chemistry and regional ozone chemistry
  - Parameterization
  - …

*The effect of wind direction on **on-road** concentrations*



Baldauf et al., manuscript under review

The State of Roadside Air Toxics Analysis in CEQA

Austin Kerr
Ascent Environmental
austin.kerr@ascentenvironmental.com

June 2, 2015

California Environmental Quality Act (CEQA)

State and local agencies must:

- Analyze and disclose to the public the environmental impacts of proposed projects
- Determine whether impacts to the environment are significant
  - Using significance thresholds
- Mitigate impacts to less than significant, or to the extent feasible

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Example CEQA Projects

- Housing development
- Wastewater treatment plant
- High school
- New freeway on-ramps
- Ski resort expansion
- City/County General Plan update
- Biomass power plant
- Motorsports race track
- Trucking distribution center
- New state park
- Zero emissions vehicle regulation

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Example CEQA Analyses

Scenario	Threshold Basis	Mitigation
Building houses near Swainson's hawk habitat	Proximity to active nests	Cease construction activity during nesting season
New airport runway near existing neighborhood	Noise exposure standards	Upgrade windows of affected houses; Limit take-off and landings
Roadway widening project	Filling a wetland	Alignment relocation; construct wetland at suitable offsite location
Building homes next to a freeway	?	setbacks, HVAC systems, vegetation

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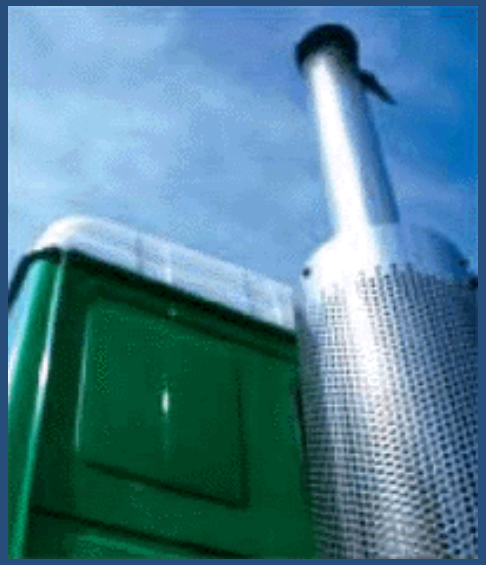
Current State of TAC Analysis

- Focus is on diesel particulate exhaust
- Little attention to non-cancer chronic risk or acute risk from freeways
- Very little attention to tire wear and brake wear



Cancer Risk Thresholds for TACs

	A	B
Scenario	Locating a new source of TACs near existing receptors	Locating new receptors near existing TAC source
Threshold	Incremental increase in cancer risk of 10 in one million	No established threshold!

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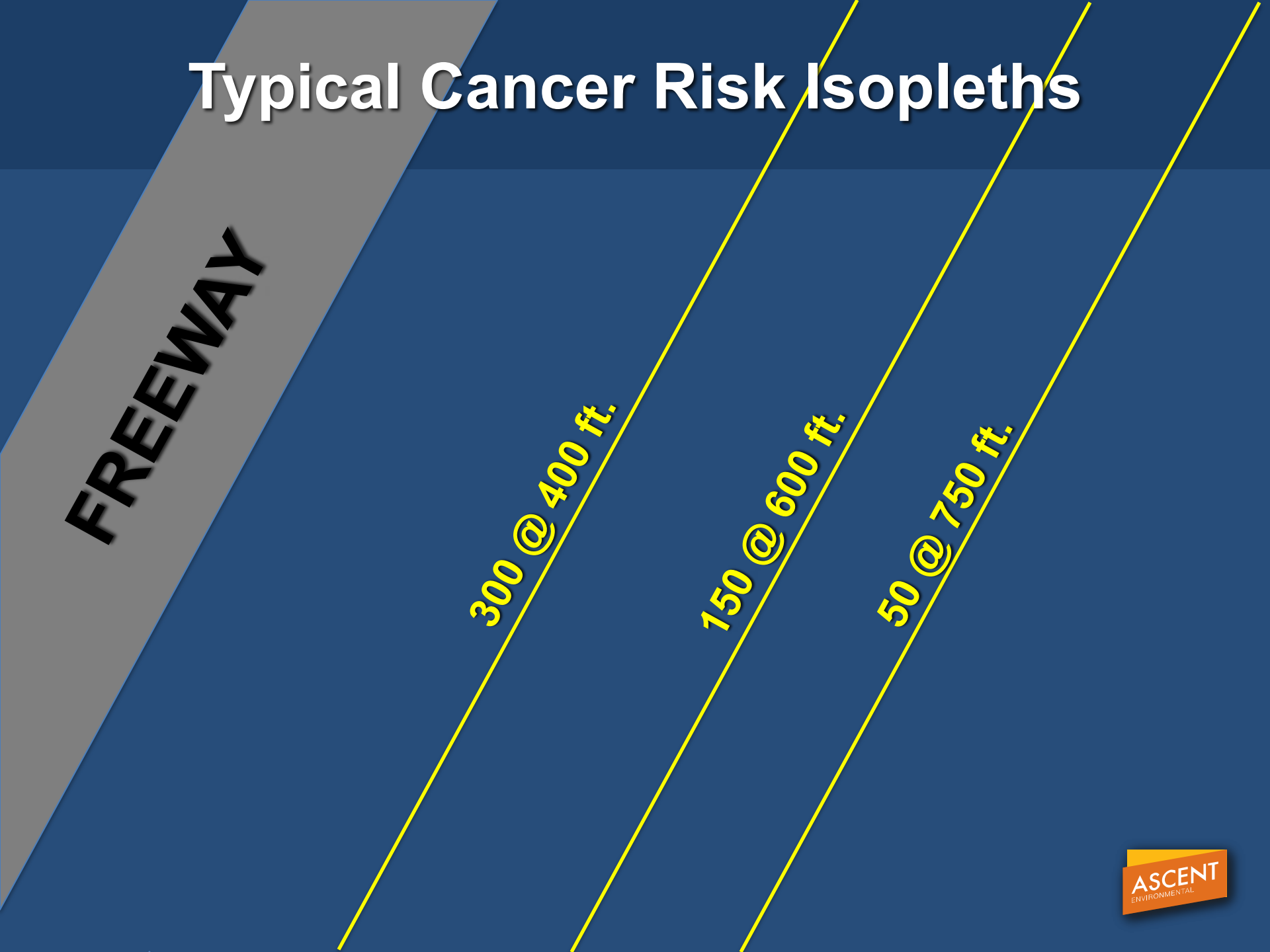
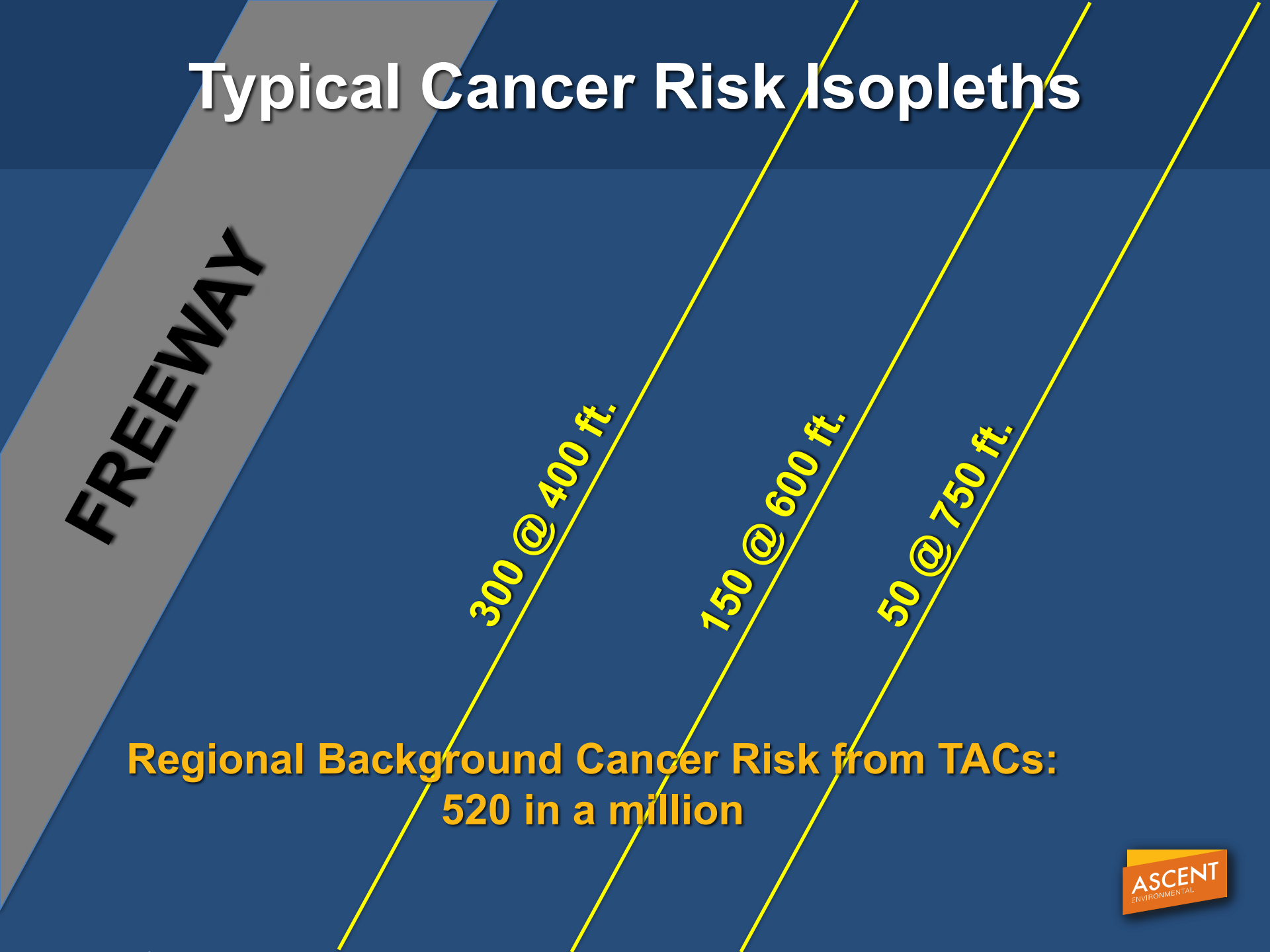
Typical Cancer Risk Isopleths



Typical Cancer Risk Isopleths



Regional Background Cancer Risk from TACs: 520 in a million

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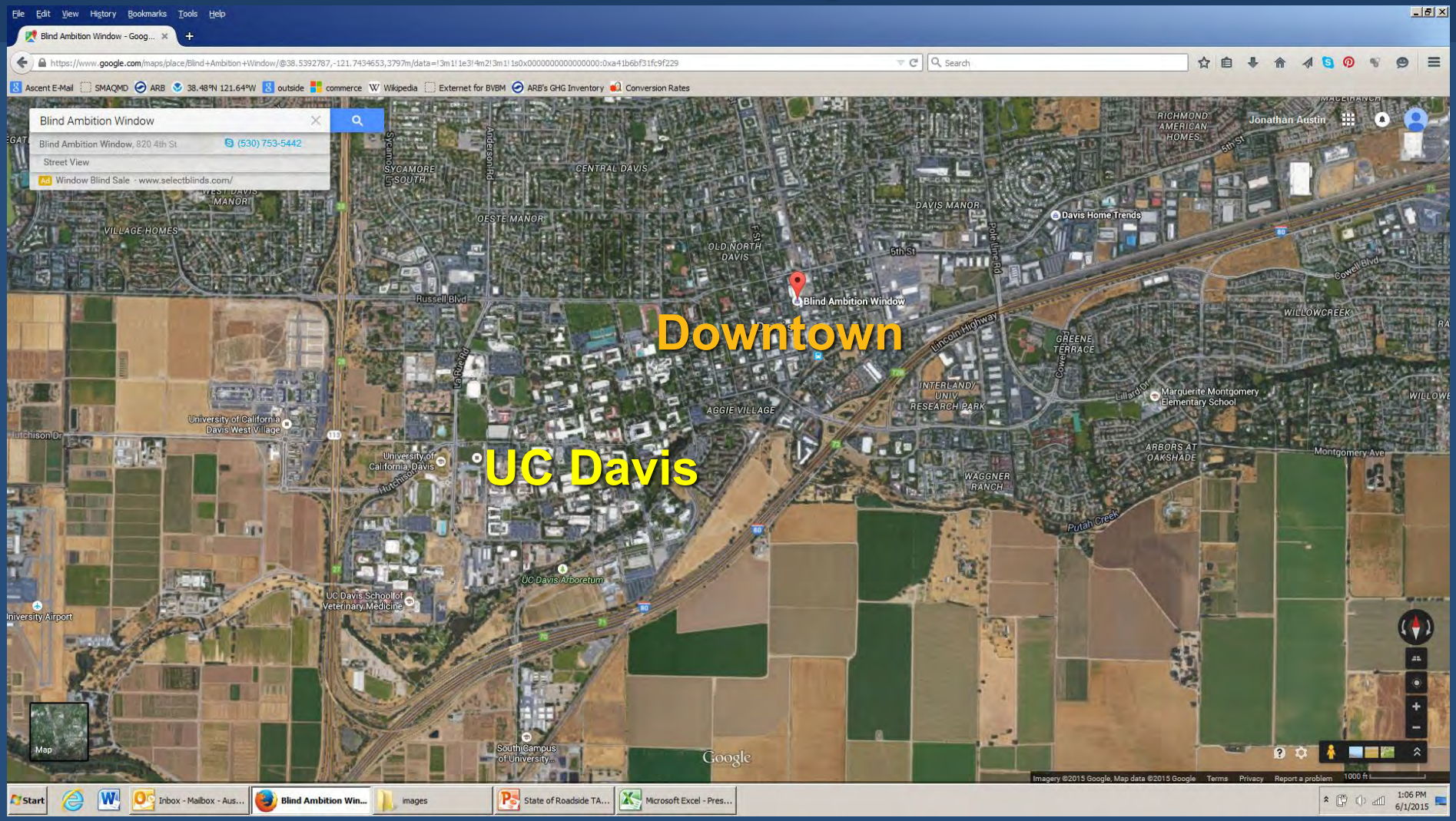
Infill vs. Sprawl



Mitigation Measures

- Setbacks
- High-performing HVAC Systems
  - Better air filtration
  - Positively pressured buildings
- Noise barriers?
- Vegetation

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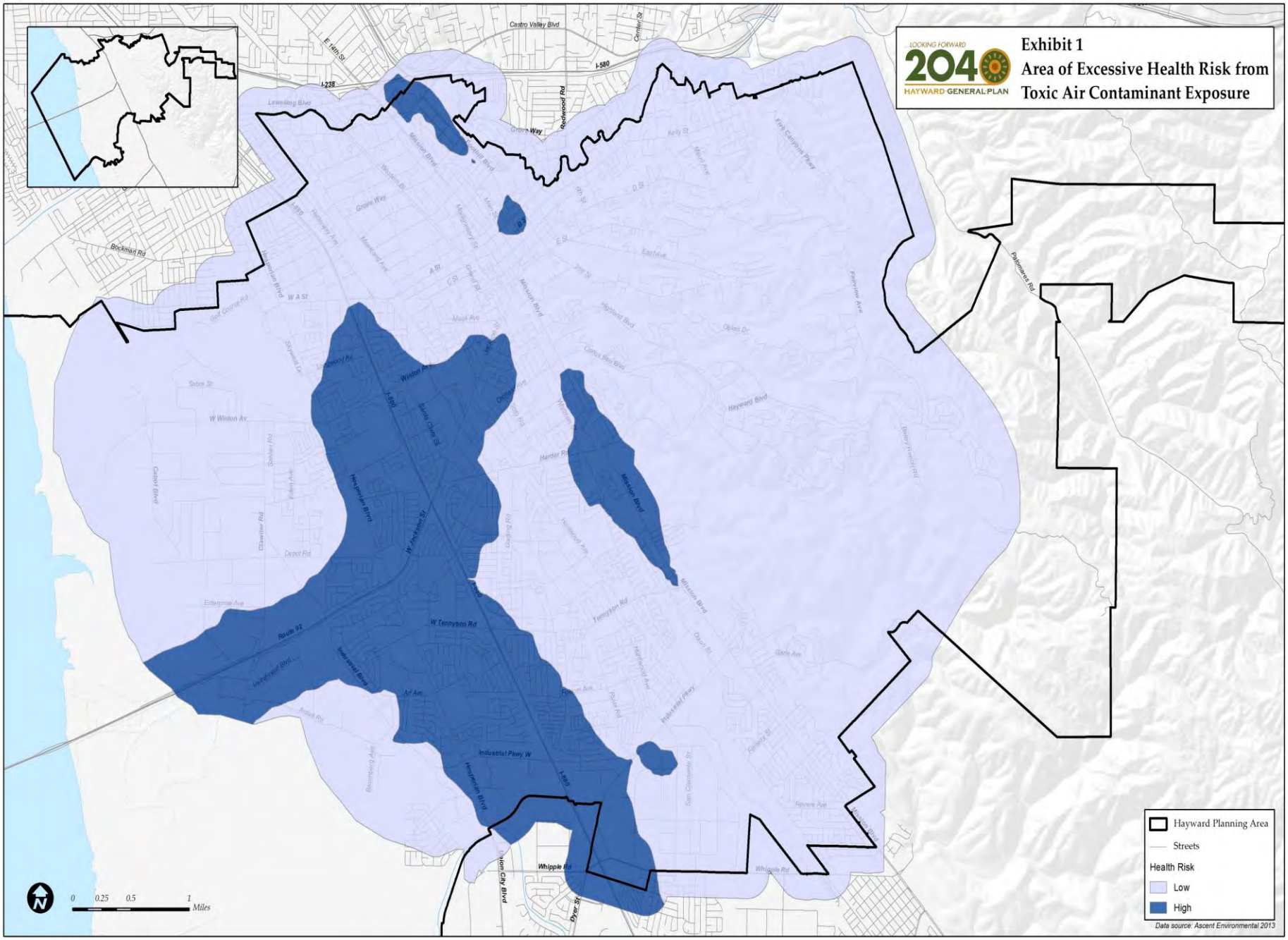
A Call for Input

- How much air toxics risk is too much?
- Prioritizing diesel particulate, break wear, and tire wear
- Quantification of risk reduction achieved by mitigation
  - including vegetation

ASCENT ENVIRONMENTAL

Austin.Kerr@AscentEnvironmental.com



Cancer_Risk

January, 2014

Policy Considerations:
Balancing Research & Action

Vegetation & Near-Roadway Air Quality
June 2, 2015

Cindy Blain
Executive Director

CALIFORNIA ReLEAF

What would a perfect roadway look like?

Thanks to Teri Duarte
WALKSacramento

What would a humane roadway look like?

Thanks to Teri Duarte
WALKSacramento

Why aren't our roadways humane?

- Human health
- Safety
- Community
- **MANY Co-Benefits**

- "Cost"
- "Space"
- "Lack of research"
- ***Priorities***

Ongoing Discussion

Disbenefits vs Benefits

- Trap polluted air
- Gaps -> higher concentrations
- *Pollen production*
- *Water demand*
- *Invasive species*
- *Fire threat*
- *Visibility obstruction*
- *Tree failure threat*
- *Expanded urban footprint*

- **Increased air mixing**
- **PM capture**
- **Carbon sequestration**
- **UHI reduction (heat stress)**
- **Energy savings**
- **Rainwater capture**
- **UV Protection**
- **Noise reduction**
- **Stress reduction**
- **Social cohesion increase**
- **Self-efficacy improvement**
- **Worker productivity increase**
- **Walkability improvement**

Biggest Health Threat

Chronic Disease:

- Obesity
- Diabetes
- Hypertension

Howard Frumkin, MD, DrPH
American Journal of Preventive Medicine 2013

"What threshold of evidence should we reach before we draw tentative conclusions?"

"In contrast, the downside risk of nature contact is often no worse than a few bee stings and poison ivy rashes."

CALIFORNIA ReLEAF

Howard Frumkin, MD, DrPH
American Journal of Preventive Medicine 2013

"What threshold of evidence should we reach before we draw ~~tentative~~ **actionable** conclusions?"

"In contrast, the downside risk of nature contact is often no worse than a few bee stings and poison ivy rashes."

CALIFORNIA ReLEAF

The Perfect Tree?

Thinking Beyond the Box:
How to prioritize trees?

Caltrans: Aesthetics & Habitat / 30 ft rule

Prop 39/AHSC: Included - not incentivized

Active Trans: Light on green infrastructure

Cities: Traditional priorities & designs

CALIFORNIA ReLEAF

$10,000/ light/ year
- first 10 years
$200/year next 10 yrs

40,000: $408M / 20 yrs

$54/ tree/ year

100,000: $108M / 20 yrs

Not If – But How

Good Policy News

GHG Reduction Fund

- Reduce & Sequester CO2 Emissions
- ***Bring Co-Benefits to Communities***
  - 2014-15: $17.8M for Urban Forests
  - 2015-16: $37.8M Projected

Prop 1 – Water Bond

- Stormwater Management Grants $100M

Good Policy News

What made it happen?

- Solid Science
- Policy Building Blocks
- Coalitions

COALITION FOR CLEAN AIR · CALIFORNIA RELEAF · APEN · The Nature Conservancy · PUBLIC ADVOCATES · TRUST for PUBLIC LAND · urban forests

May 28, 2015

The Honorable Mark Leno, Conferee
Senate and Assembly Joint Budget Conference Committee
State Capitol Building
Sacramento, CA 95814

RE: May Revise for Urban Forestry and the Greenhouse Gas Reduction Fund – SUPPORT

Dear Senator Leno:

We are writing to urge the Conference Committee to continue its commitment to CAL FIRE's Urban and Community Forestry Program through the Greenhouse Gas Reduction Fund by supporting the proposed allocation and language for this Program in the Governor's May Revise. The revised proposal directly addresses two major recommendations from stakeholders that we believe will further strengthen the program by creating more opportunities for transformative investments in California's communities.

1. **Augments the proposed 2015-16 allocation to $37.8 million**

CAL FIRE's call for concept proposals to its Urban and Community Forestry Program in late 2014 yielded $107 million in requests for $15.7 million in available local assistance grants funding – leaving the program oversubscribed by 600%. The proposed $37.8 million in the revised 2015-16 Expenditure Plan for this Program represents a milestone investment in this important urban natural resource, and will significantly move the Program closer to closing this funding gap.

SUPPORT PRIORITY GGRF INVESTMENTS THA
2015-16 BUDGET
ultiple coalitions and
mentation and cap-and-trad
e Conference Committee to
either the Legislature or
PPORT MAY REVISE
SUPPORT SENATE VERSION
DACs
omposting and recycled con
VERSION

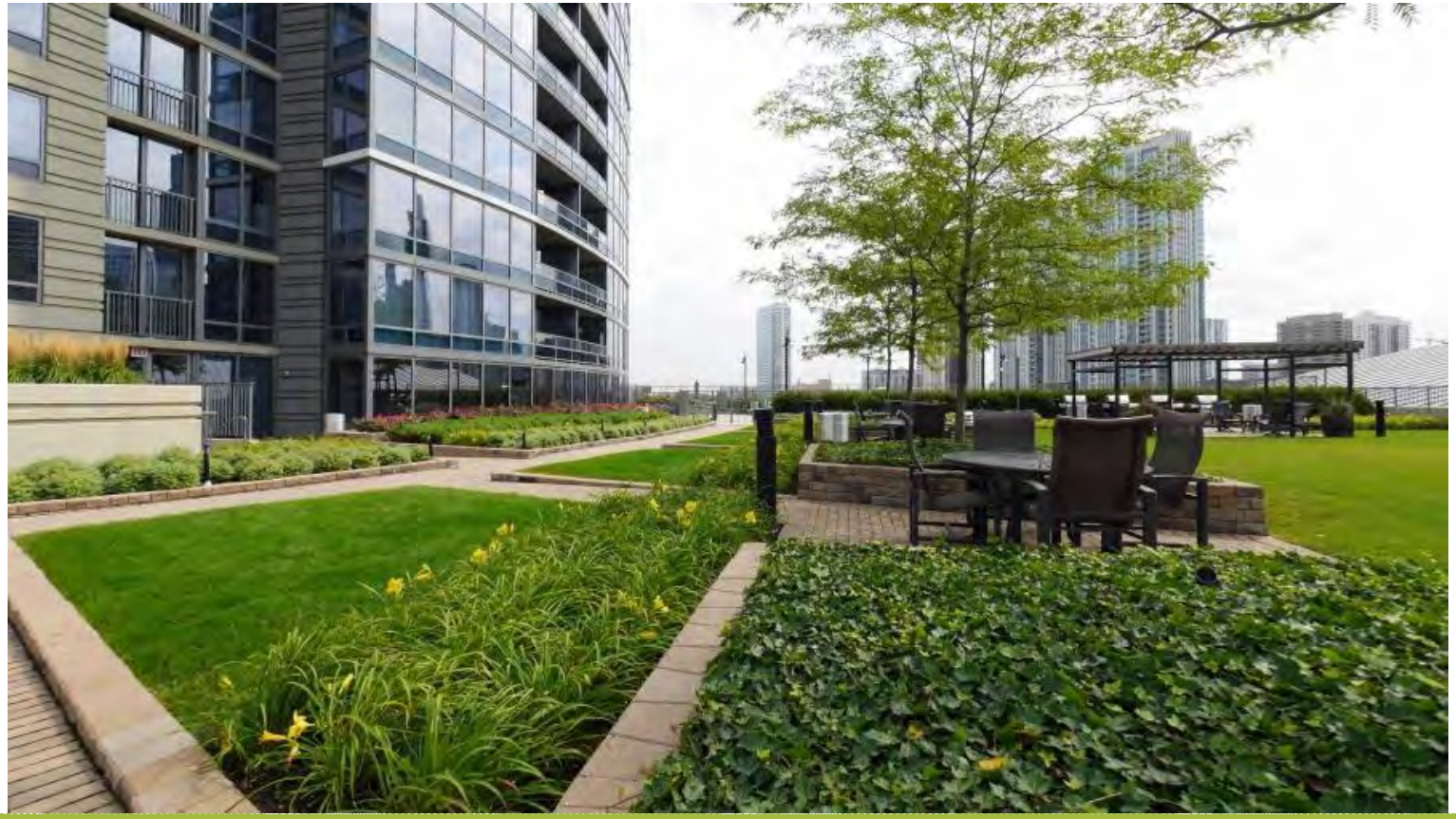
Atlanta

Cape Town, South Africa

Thank you!…Questions?

Cindy Blain
cblain@CaliforniaReLeaf.org
(916) 497-0034

Chicago Green Roof Park



PLANTING THE SEEDS OF SUCCESS.

Climate-Ready Trees for Near-Roadway Air Quality Mitigation

Dr. Greg McPherson
USDA Forest Service
PSW Research Station
Davis, CA

Dr. Alison Berry
Dept. of Plant Sciences
UC Davis, Davis, CA

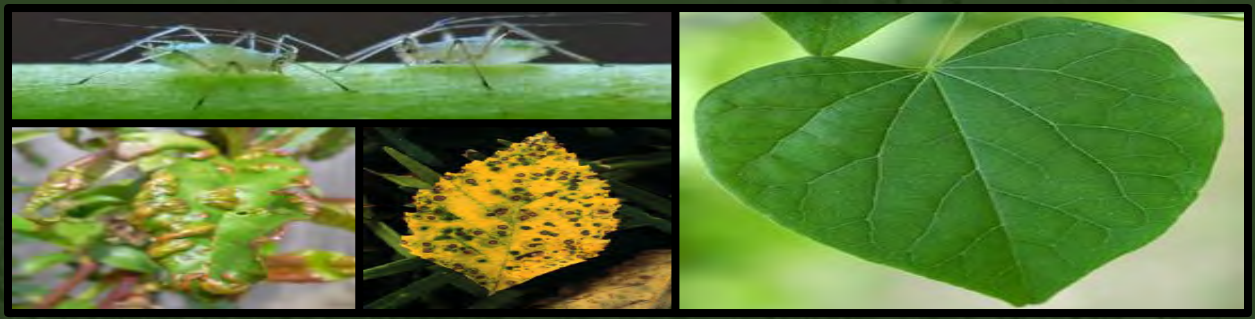
Elizabeth Roeble
Graduate Student
Horticulture & Agronomy
UC Davis, Davis, CA

Conference on Use of Vegetation as Near-Roadway Mitigation for Air Pollution, June 2, 2015

Goal: Stable, Healthy, Functional Roadside Vegetation

Background

- Risk of tree loss
  - Limited diversity
  - Poorly-adapted species
- Two points of leverage
  - Tree selection
  - Tree maintenance

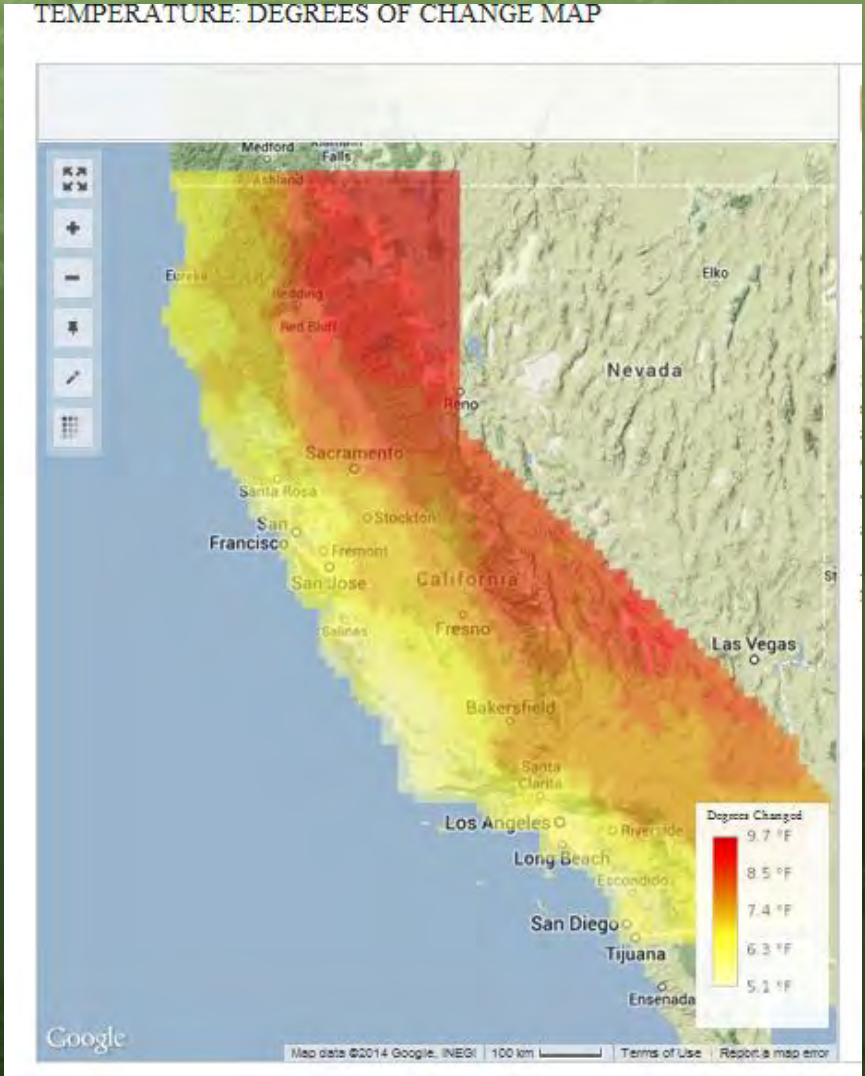


Goal

- Change tree palette to more resilient species
- 20-year study to test promising cultivars
  - Resilience to climate change
  - Other qualities
- Network of sites and collaborators
- Share performance information

Adaptation

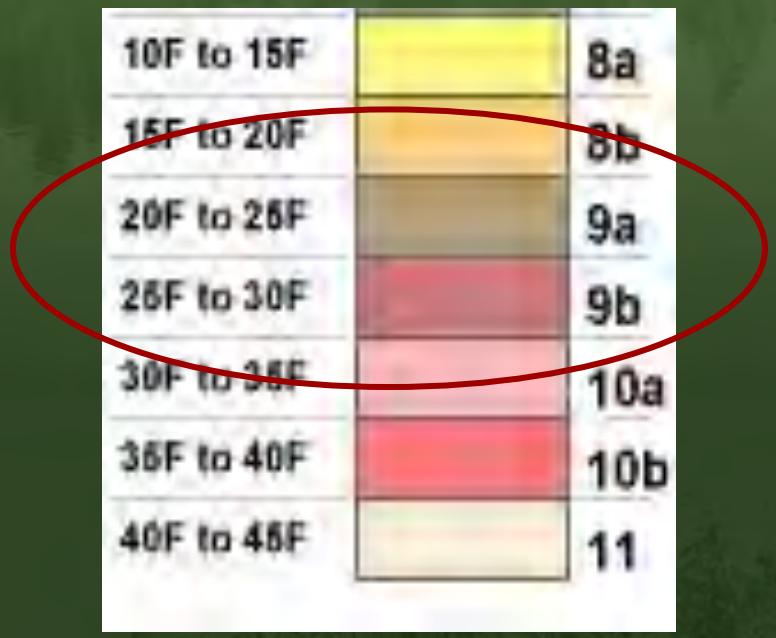
- Exposure – extent?
  - Temperature
  - Precipitation
  - Wind
- Sensitivity – how react?
- Adaptive Capacity – potential to adapt?



Existing Climate Zones

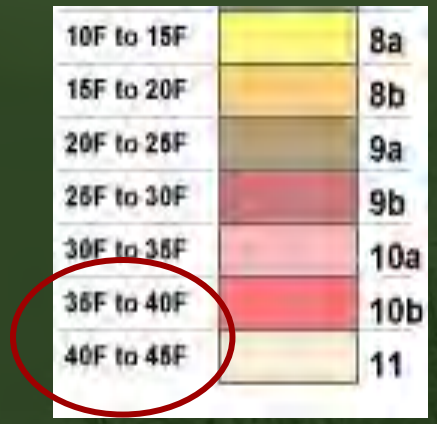
- USDA Hardiness Zones: average annual minimum temperature
- Inland Valley:

  Zones 9A and 9B



Projected Climate

- Temperature
  - 1½ zone changes
- Precipitation
  - 110% increase
  - More winter, less summer



Projected Changes in USDA Hardiness Zones				
City	2010-2019 Avg Min Temp (°F)	Current Hardiness Zone	2080-2089 Avg Min Temp (°F)	Predicted Hardiness Zone
Redding	34.1	**9B** ->10A	40.6	10A-> **11A**
Sacramento	36.7	**9B** ->10B	42.4	10B-> **11A**
Merced	33.6	**9A** ->10A	38.9	10A-> **10B**
Fresno	34.6	**9B** ->10A	40.0	10A-> **11A**
Bakersfield	36.3	**9B** ->10B	41.5	10B-> **11A**

http://cal-adapt.org/tools/

Species Profiles

TRAIT	Source	Description
HABITAT SPECIFICITY		
Soil Moisture	Selec Tree	Soil moisture required by tree species for establishment.
Soil Texture and pH	Selec Tree	Trees species tolerance of a range of soil pH and textures.
Sunlight Exposure	Selec Tree	Tree species tolerance of full sun, shade, and filtered exposure.
PHYSIOLOGY		
Drought Tolerance	WUCOLS	Water needs of tree species: high, moderate, or low water needs.
Wind Tolerance	Selec Tree	Branch strength of tree species: strong, medium, weak.
Salt Tolerance	Selec Tree and Wu and Dodge 2005	Salinity tolerance
Cold Hardiness	USDA Cal-Adapt	Species tolerance of minimum temperatures in Central Valley.
BIOLOGICAL INTERACTIONS		
Invasiveness	Cal-IPC	Potential for species invasiveness: severe, moderate, minor.
Current Pest and Disease Threats	Pest Vulnerability Matrix (PVM)	Current pest and disease threats that pose risk to tree species.
Emerging Pest and Disease Threats	Pest Vulnerability Matrix (PVM)	Emerging pest and disease threats that could pose risk to tree species in the future.

12 Selected Cultivars

Scientific Name	Common Name
Australia	
Acacia aneura	Mulga
Acacia stenophylla	Shoestring Acacia
Eucalyptus papuana	Ghost Gum
Southwest US- Drought Tolerant	
Chilopsis linearis	Desert Willow
Parkinsonia x 'Desert Museum'	Desert Museum Palo Verde
Prosopis glandulosa x 'Maverick'	Thornless Honey Mesquite
Oklahoma-Texas US - Deciduous	
Celtis reticulata	Netleaf Hackberry
Ebenopsis ebano	Texas Ebony
Maclura pomifera 'White Shield'	White Shield Osage Orange
Quercus canbyi	Canby's Oak
Asia	
Dalbergia sissoo	Rosewood
Ulmus propinqua	Emerald Sunshine Elm

Southwest US

Desert Willow

Honey Mesquite

Palo Verde "Desert Museum"

Osage Orange 30’-50’

Texas Ebony (thorns, borer)

Canby Oak – up to 50’

Netleaf Hackberry - up to 80’

Oklahoma, West Texas

Australia

Shoestring acacia

Ghost gum (*Eucalyptus papuana*), 60’ height

Mulga (*Acacia aneura*)

Asia

Elm ‘Emerald Sunshine’
Ulmus davidiana v *japonica*

35’; DED, elm leaf
beetle resistance

Rosewood (*Dalbergia sissoo*; India)

60’, full leafy crown, highly
decay resistant, few pests
(root suckers)

Experimental Design

- Control plot UCD (48)
- 4 Sacramento parks (24 at each)
- Measure
  - Tree size
  - Crown vigor
  - Pruning, pest, disease
  - Soil type, temp, moisture
  - ET, minimum temperatures
  - Leafing out date
- Inland Empire & Coastal SoCal

SPCODE	Scientific	Common_Nam	Size
AA	Acacia aneura	Mulga	#15
AS	Acacia stenophylla	Shoestring acacia	#15
CR	Celtis reticulata	Netleaf Hackberry	#15
CL	Chilopsis linearis 'Bubba'	Desert Willow	#15
DS	Dalbergia sissoo	Rosewood	#15
EE	Ebenopsis ebano	Texas Ebony	24 box
EP	Eucalyptus papuana	Ghost gum	#15
MP	Maclura pomifera 'White Shield'	White Shield Osage Orange	BR
PD	Parkinsonia x 'Desert Museum'	Desert Muesum Palo Verde	#15
PG	Prosopis glandulosa x Maverick	Thornless Honey Mesquite	24 box
QC	Quercus canbyi	Canby's oak	24 box
UP	Ulmus propinqua	Emerald Sunsine Elm	BR

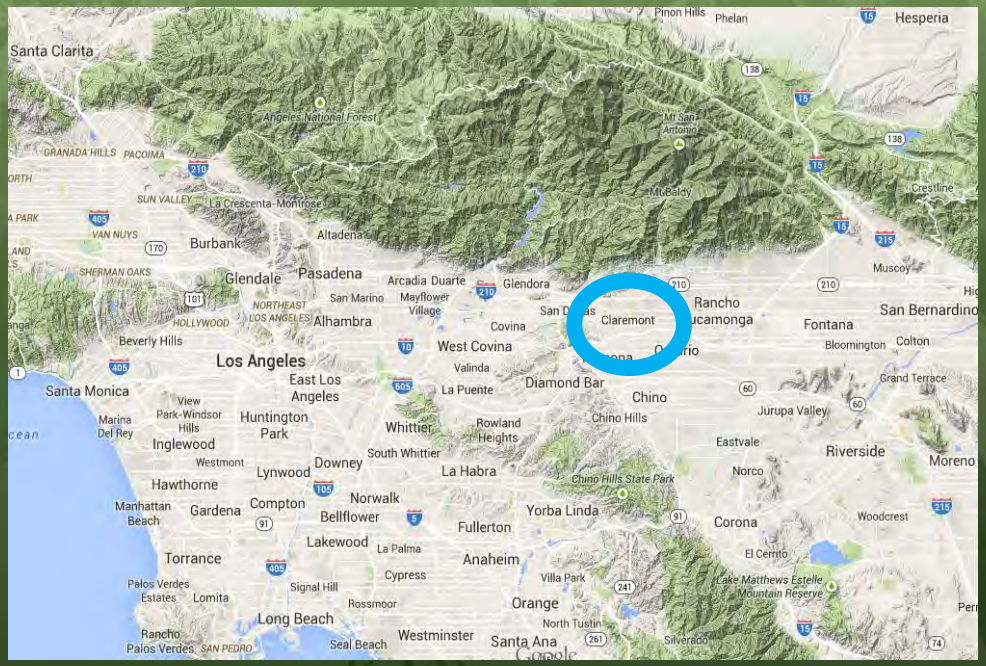
Sacramento Tree Foundation

Remeasurement of Claremont's Street Trees: What Can We Learn 14 Years Later?

Drs. Greg McPherson & Natalie van Doorn
Davis, California

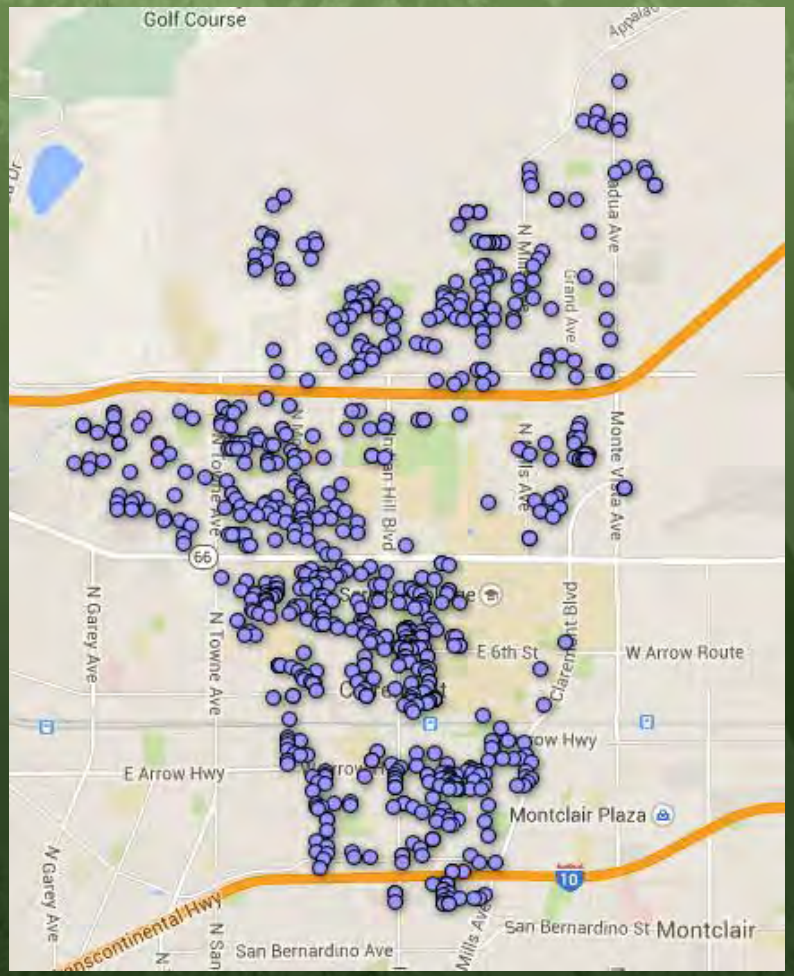
- **Q1: What is the demography of the street tree population?**

- **Q2: Will the Claremont street tree population be resilient to a changing climate?**



Methods

- 762 sites visited in 2000 & 2014
- 21 most abundant species
- Random selection stratified by size class



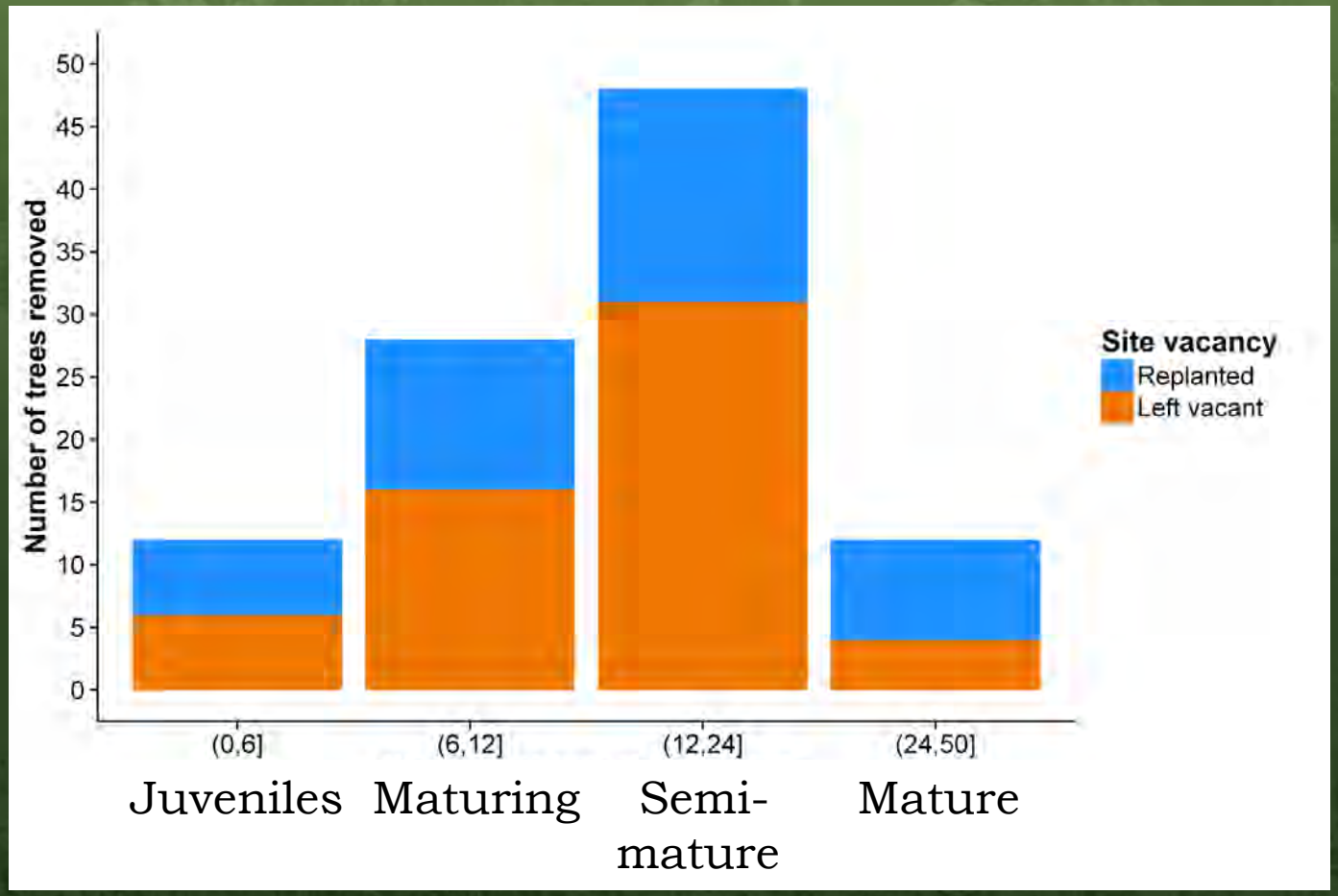
GROWTH

MORTALITY

REPLACEMENT

Replaced or left vacant?

- 58% of sites were left vacant
- Highest vacancy in semi-mature class

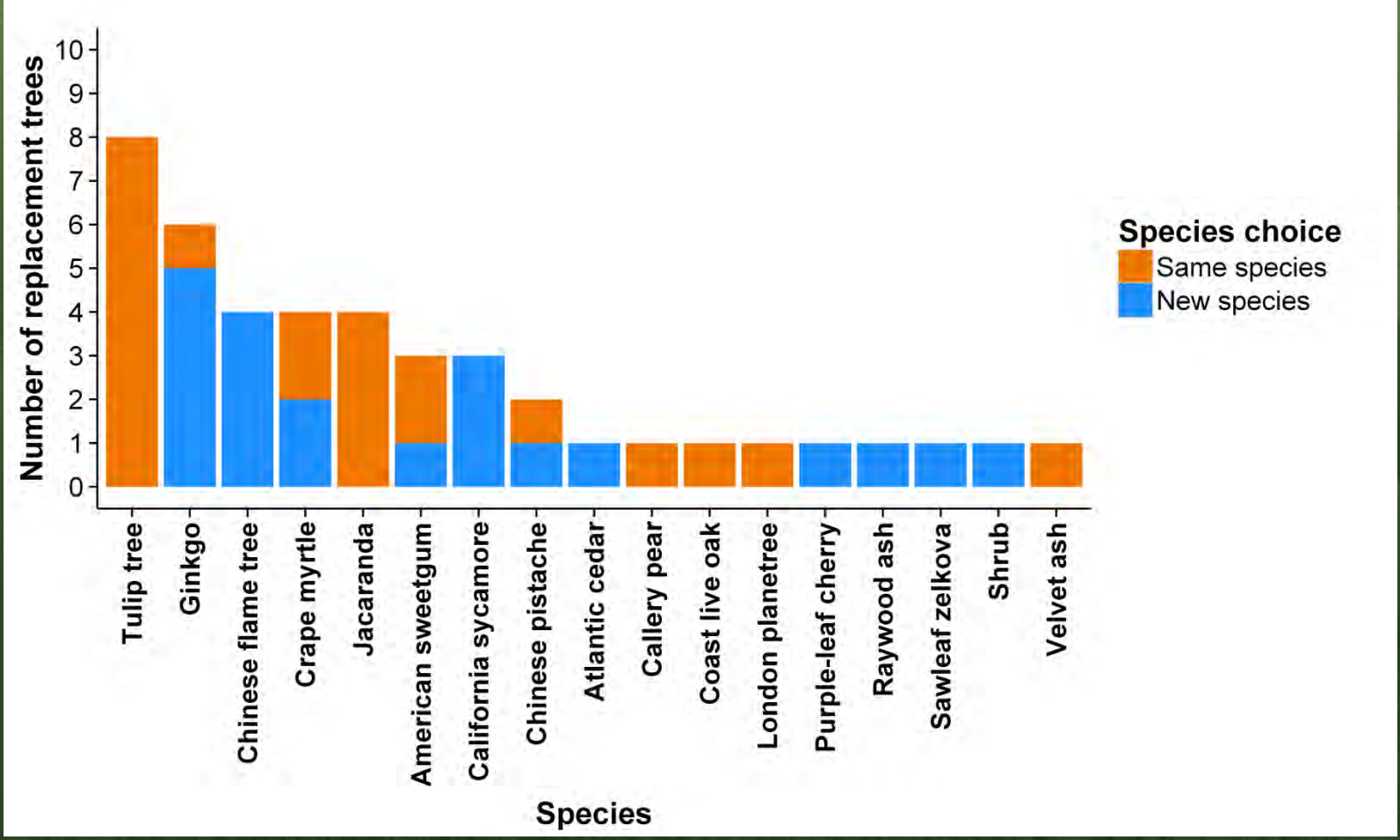


GROWTH

MORTALITY

REPLACEMENT

What are removed trees being replaced with?



GROWTH

MORTALITY

REPLACEMENT

Climate-readiness +

Special Features
Biogenic emissions
Shade potential
Longevity
Biodiversity
Aesthetics
Root damage potential
Litter
Native to CA
Carbon storage

GROWTH

MORTALITY

REPLACEMENT

Results

	Climate Ready
Pinus brutia	5
Schinus molle	5
Brachychiton populneus	4
Pinus canariensis	3
Pistacia chinensis	3
Schinus terebinthifolius	3
Quercus agrifolia	3
Quercus ilex	3
Ginkgo biloba	3
Eucalyptus sideroxylon	3
Cinnamomum camphora	2
Platanus racemosa	1
Cedrus atlantica 'Glauca'	1
Fraxinus uhdei	1
Platanus x hispanica	1
Fraxinus angustifolia	0
Lagerstroemia indica	0
Koelreuteria bipinnata	0
Pyrus calleryana	0
Zelkova serrata	-1
Jacaranda mimosifolia	-1
Fraxinus velutina	-1
Liquidambar styraciflua	-1
Liriodendron tulipifera	-2
Prunus cerasifera 'Atropurpurea'	-2
Magnolia grandiflora	-2

+

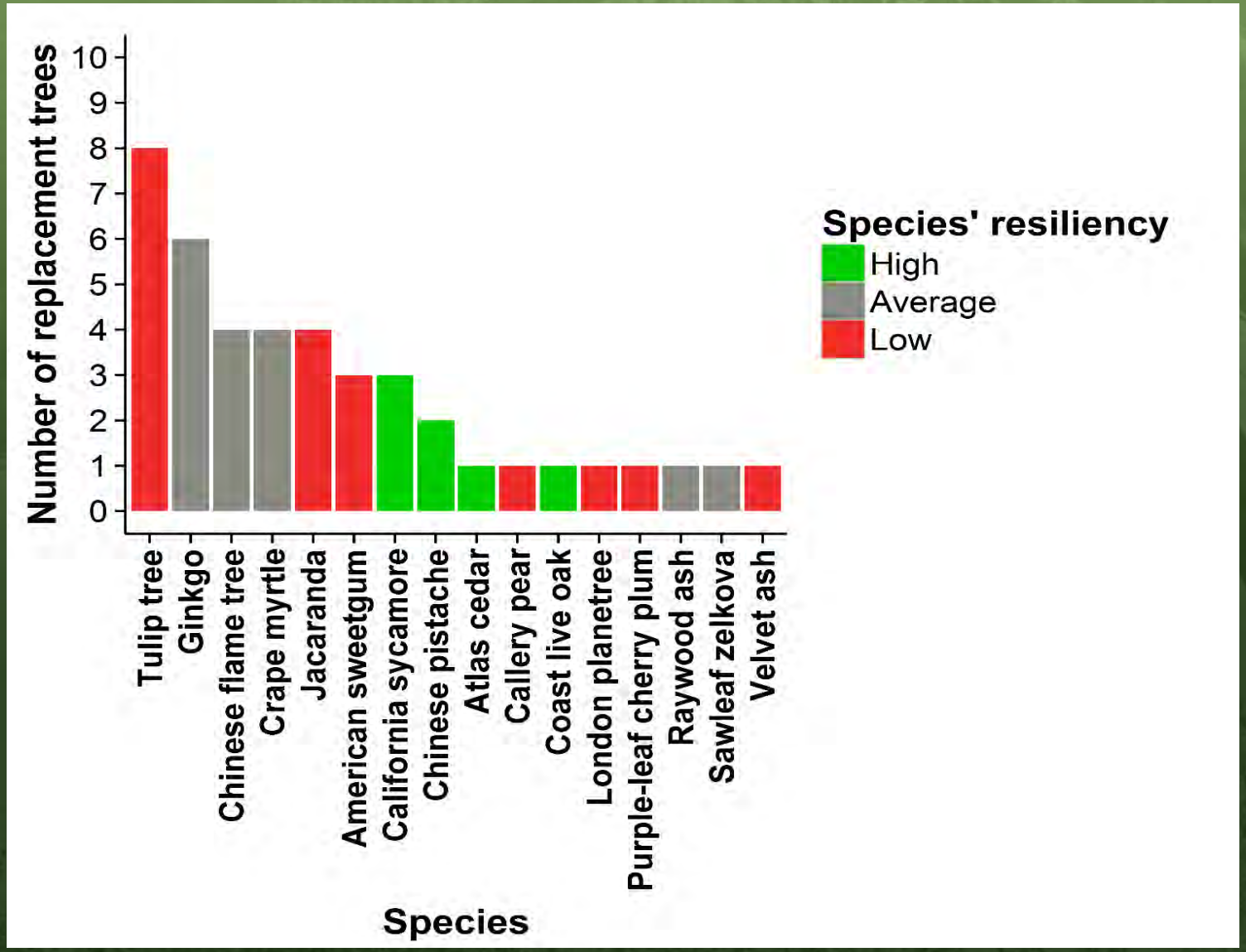
Special Features	GRAND TOTAL	
4	9	Pinus brutia
5	8	Pinus canariensis
2	7	Schinus molle
2	6	Brachychiton populneus
3	6	Pistacia chinensis
5	6	Cedrus atlantica 'Glauca'
2	5	Schinus terebinthifolius
2	5	Quercus agrifolia
2	5	Quercus ilex
4	5	Platanus racemosa
1	4	Ginkgo biloba
2	4	Cinnamomum camphora
0	3	Eucalyptus sideroxylon
3	3	Fraxinus angustifolia
3	2	Zelkova serrata
0	1	Fraxinus uhdei
1	1	Lagerstroemia indica
1	1	Koelreuteria bipinnata
0	0	Pyrus calleryana
1	0	Jacaranda mimosifolia
2	0	Liriodendron tulipifera
-2	-1	Platanus x hispanica
1	-1	Prunus cerasifera 'Atropurpurea'
1	-1	Magnolia grandiflora
-1	-2	Fraxinus velutina
-2	-3	Liquidambar styraciflua

GROWTH

MORTALITY

REPLACEMENT

Replacement Species



Summary

- Claremont tree replacement
  - 42% is too low
  - 45% species with low resiliency is too low - need more resilient species
- Identifying roadside species for evaluation
  - Score climate-readiness
  - Identify & score other features (evergreen, BVOC, etc.)
- Evaluating performance
  - Experimental design
  - Partnerships and planting
  - Measurements and reporting

Questions?

http://www.fs.fed.us/psw/programs/uesd/uep/

STONEBRIDGE
PROPERTIES, LLC

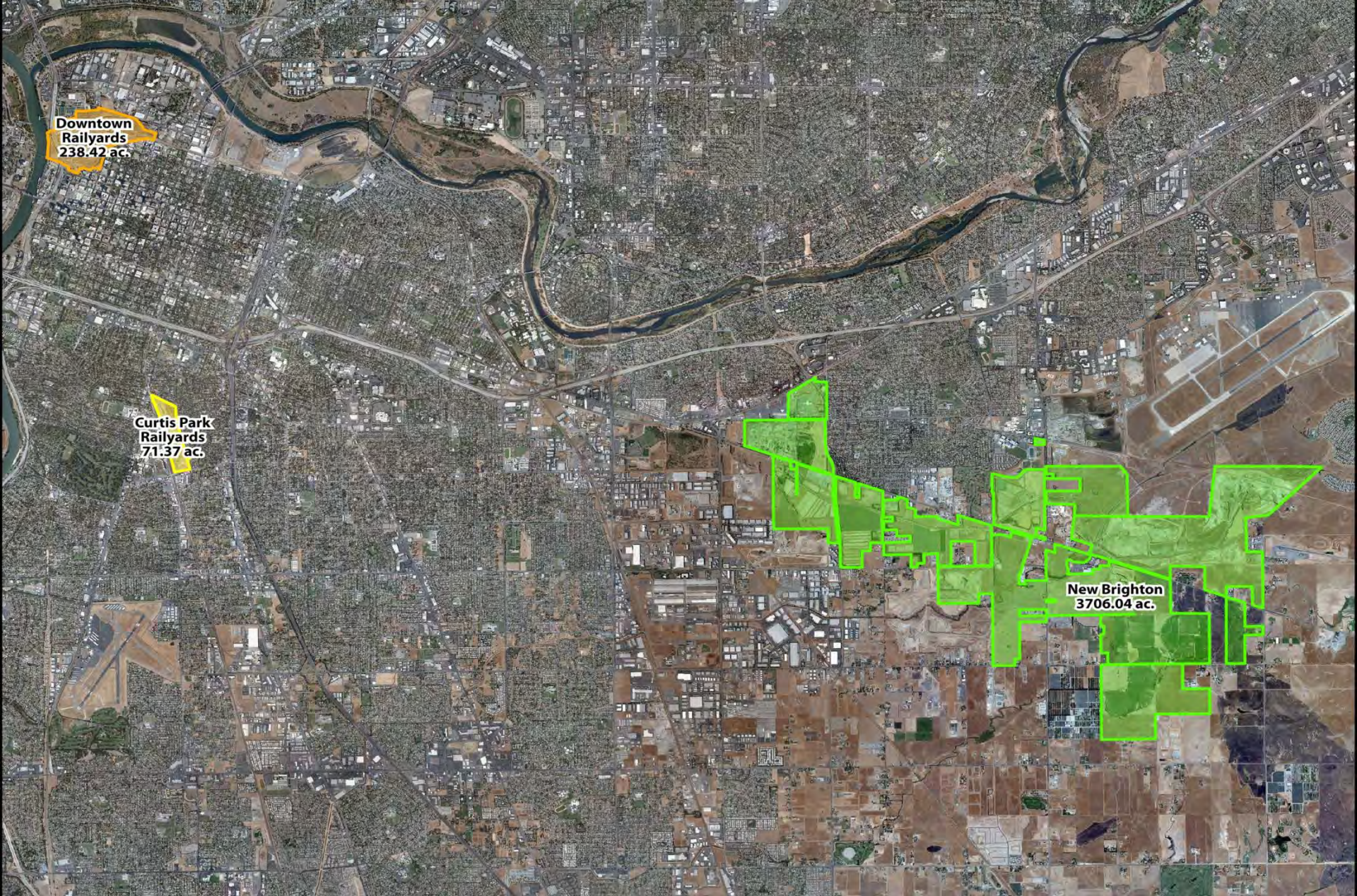
Planning for Tree Friendly Healthy Communities

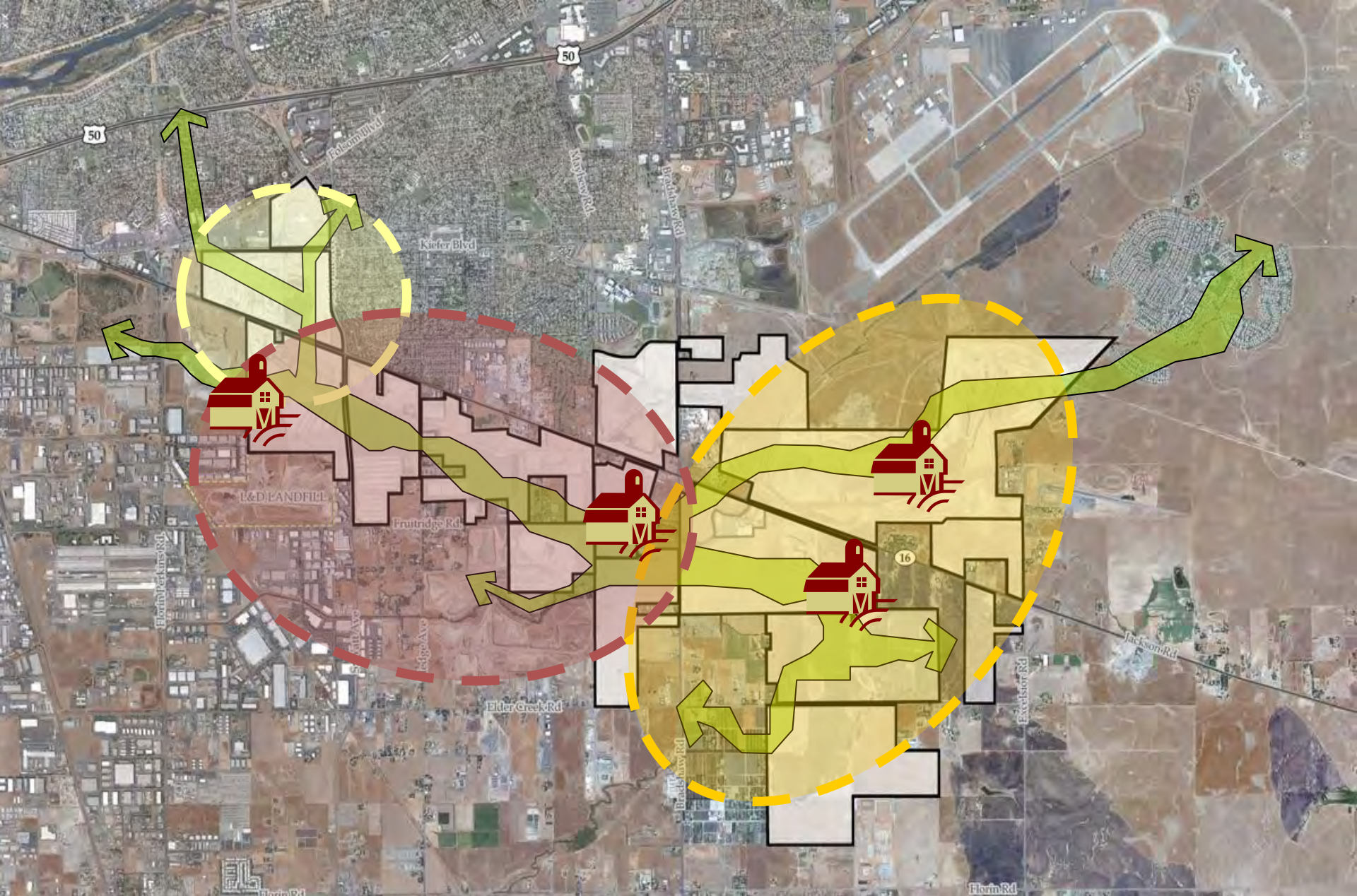
STONEBRIDGE
PROPERTIES, LLC

Our Holistic Approach.

Legacy Approach: Looking backward…to move forward

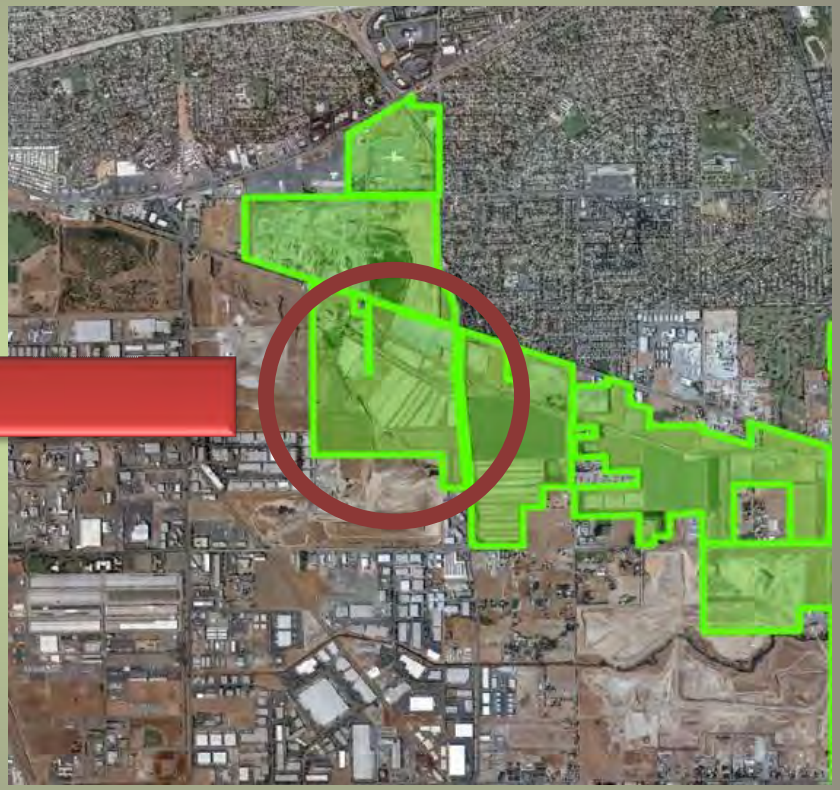
StoneBridge Publications


Downtown
Railyards
238.42 ac.
Curtis Park
Railyards
71.37 ac.
New Brighton
3706.04 ac.


50
50
Folsom Blvd
Mayhew Rd
Bradshaw Rd
Kiefer Blvd
L&D LANDFILL
Fruitridge Rd
Florin Perkins Rd
Ridge Ave
Elder Creek Rd
Bradshaw Rd
16
Excelsior Rd
Jackson Rd
Florin Rd
Florin Rd

Sacramento State University
UCD Med Center
65th Street/University Village Opportunity Area
Granite Regional Park Development Area
Highway 50
Folsom Blvd
Potential 14th Ave Extension
Power Inn Road
Howe Ave
Watt Ave
NEW BRIGHTON

CITY OF SACRAMENTO, CALIFORNIA
SEPTEMBER 2, 2009
SHEET 3 OF 5
NAPOTS
Jackson Highway
MDR
Commercial Center
HDR/CMU
HDR/CMU
HDR/CMU
Urban Farm
Neighborhood Park
HDR
HDR/CMU
HDR/CMU
HDR
South West Avenue
Bike Trail
Residential Lot Types
30' x 90' Interior (Minimum)
40' x 90' Interior (Minimum)
45' x 90' Interior (Minimum)
50' x 100' Interior (Minimum)
55' x 100' Interior (Minimum)
60' x 100' Interior (Minimum)
MDR - Medium Density Residential
HDR - High Density Residential
HDR/CMU - High Density Residential / Commercial Multi Use



Aspen 1 – New Brighton

• Single Family Units	482 units
• Multi-Family Units	883 units
• Commercial SF	±200K SF
• School	±9.8 acres
• Open Space	20 acres
• Urban Farm	27 acres
• Parks	25 acres

Total Acreage 232 acres

Total Units 1,365

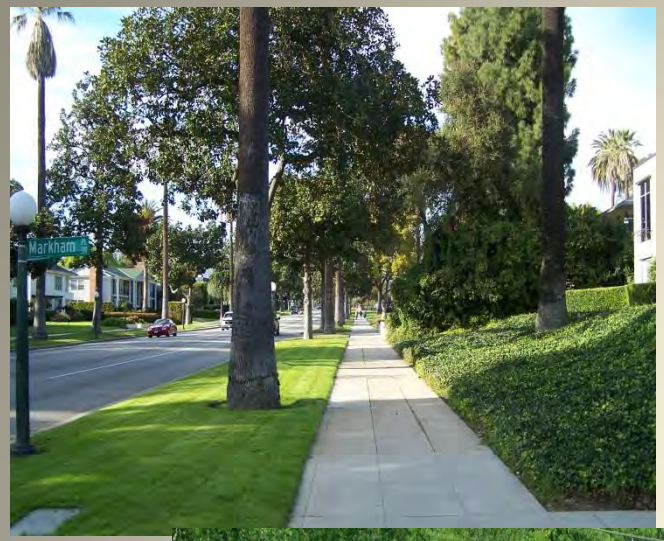
***Plan proposes over 7,500 trees**

Mixed Residential

Local Commercial

Recreational Amenities

Multimodal Transportation



Urban Farm

New Brighton Urban Forest

Worked with USDA Forest Service Center for Urban Forest Research to develop a comprehensive urban forest comprised of over 7,500 trees and more than 50 species which provide the following Ecosystem benefits:

- Reductions in energy use
- Improvements to air quality
- Reductions in levels of atmospheric greenhouse gases
- Improved water quality

New Brighton Urban Forest

REDUCTIONS IN ENERGY USE:

Lowering summertime temperatures through shading buildings and evapotranspiration, and moderating winter temperatures by slowing winter winds..

The trees of New Brighton are estimated to reduce electricity use by 225,000 kWh annually in the early years and by up to 875,000 kWh as the urban forest matures

Did you know?
The average California Household uses approximately 8,000 kWh of electricity each year. Energy reductions in New Brighton are roughly the equivalent of 28-110 households.

New Brighton Urban Forest

IMPROVEMENTS TO AIR QUALITY:

By reducing energy use, trees also reduce the amount of air pollutants produced at the power plant.

In addition, their leaves intercept and absorb air pollutants

As the urban forest in New Brighton matures, total absorption and interception will equal 7,200 kg and avoided emissions 743 kg per year.

Did you know?

Air quality benefits are closely tied to tree size, with large trees intercepting up to 12 times more pollutants than small trees.

New Brighton Urban Forest

Did you know?

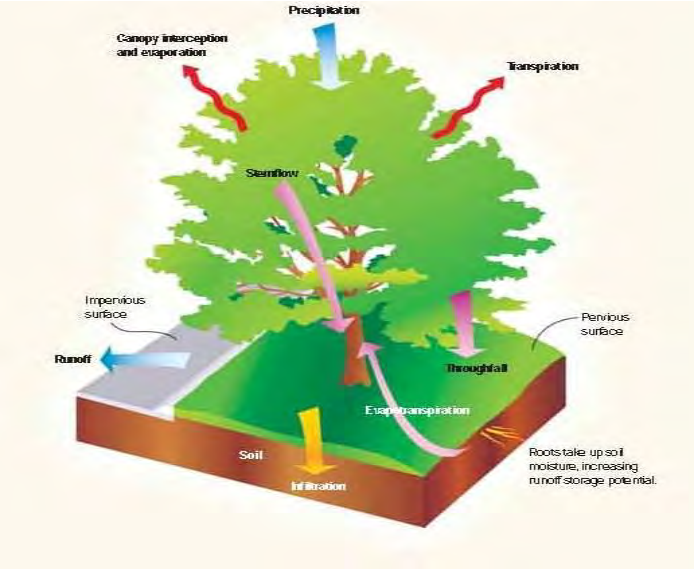
Large trees sequester as much as 100 times more CO_2 than small trees (30 tons versus 350 kg) over the trees lifetime.

GREENHOUSE GAS REDUCTIONS:

As trees reduce energy use, they reduce the amount of greenhouse gases produced at the power plant. As they grow, trees also sequester carbon dioxide CO_2 from the atmosphere.

Together these climate change benefits in New Brighton will result in annual CO_2 reductions of approximately 650 metric tons per year during the early phases of the project, and 2,000 annually at the peak.

New Brighton Urban Forest



Did you know?

Water quality benefits are related to size and species type, i.e. whether trees have leaves during the rainy season. The largest broadleaf evergreen tree will intercept up to 3,500 gallons whereas the smallest deciduous tree will capture 135 gallons.

IMPROVED WATER QUALITY:

Urban forests improve water quality by intercepting rainfall before it flows into streams and storm drainage systems.

In the early years, the trees of New Brighton are estimated to intercept 1.9 million gallons of runoff per year, in later years they are estimated to intercept up to 12.8 million gallons per year.

New Brighton Urban Forest

ADDITIONAL BENEFITS OF AN URBAN FOREST:

- Neighborhood Beautification
- Increased Property Values
- Attractiveness of Retail Settings
- Human Health
- Wildlife Habitat
- Reduced Street Maintenance Costs

Low Impact Development

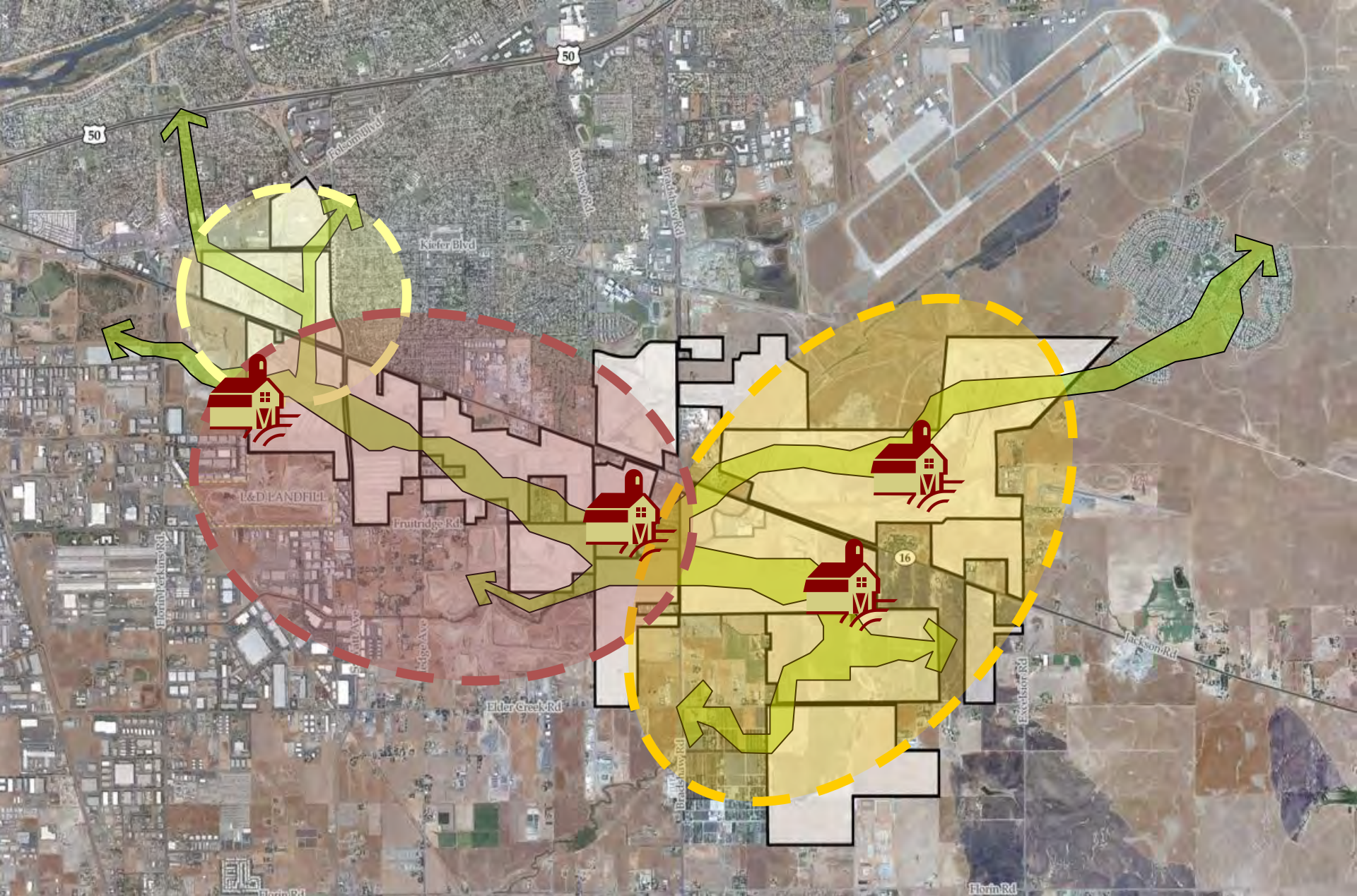
We use a variety of simple tools in order to:

1. Slow down runoff.
2. Provide areas for storm water to percolate into pervious surfaces.
3. Improve water quality

Urban Farm

Urban Farm

- Increases Access to Fresh Local Produce
- Connects people with the natural world
- Reduces Transportation Costs & Associated Pollution
- Creates Opportunities for Community Engagement
- Serves as "Bridge" to Rural Farmers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Folsom Blvd
Mayhew Rd
Bradshaw Rd
Kiefer Blvd
L&D LANDFILL
Fruitridge Rd
Florin Perkins Rd
Ridge Ave
Elder Creek Rd
Bradshaw Rd
16
Excelsior Rd
Jackson Rd
Florin Rd
Florin Rd

www.stonebridgeproperties.com

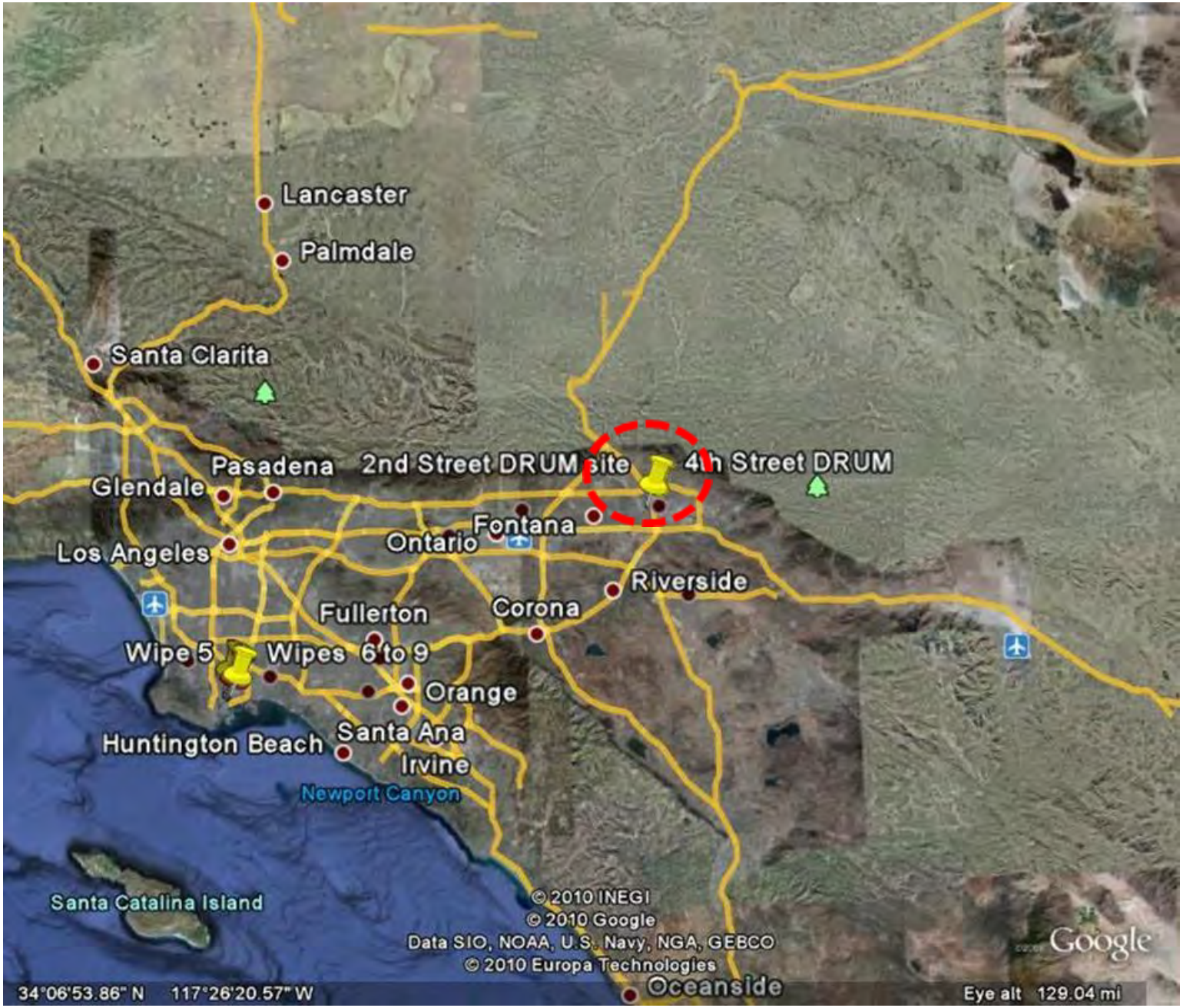
Mitigation at BNSF Intermodal Facility, San Bernardino and Mira Loma

A presentation for Vegetation for Mitigation

June 2, 2015

Tom Cahill, David Barnes and the UCD DELTA Group,

Kristen Boberg and Peter Wood, the CA Department of Toxic Substances Control


Lancaster
Palmdale
Santa Clarita
Pasadena
2nd Street DRUM Site
4th Street DRUM
Glendale
Fontana
Ontario
Los Angeles
Riverside
Fullerton
Corona
Wipe 5
Wipes 6 to 9
Orange
Santa Ana
Huntington Beach
Irvine
Newport Canyon
Santa Catalina Island
© 2010 INEGI
© 2010 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Europa Technologies
Google
Oceanside
34°06'53.86" N 117°26'20.57" W
Eye alt 129.04 mi

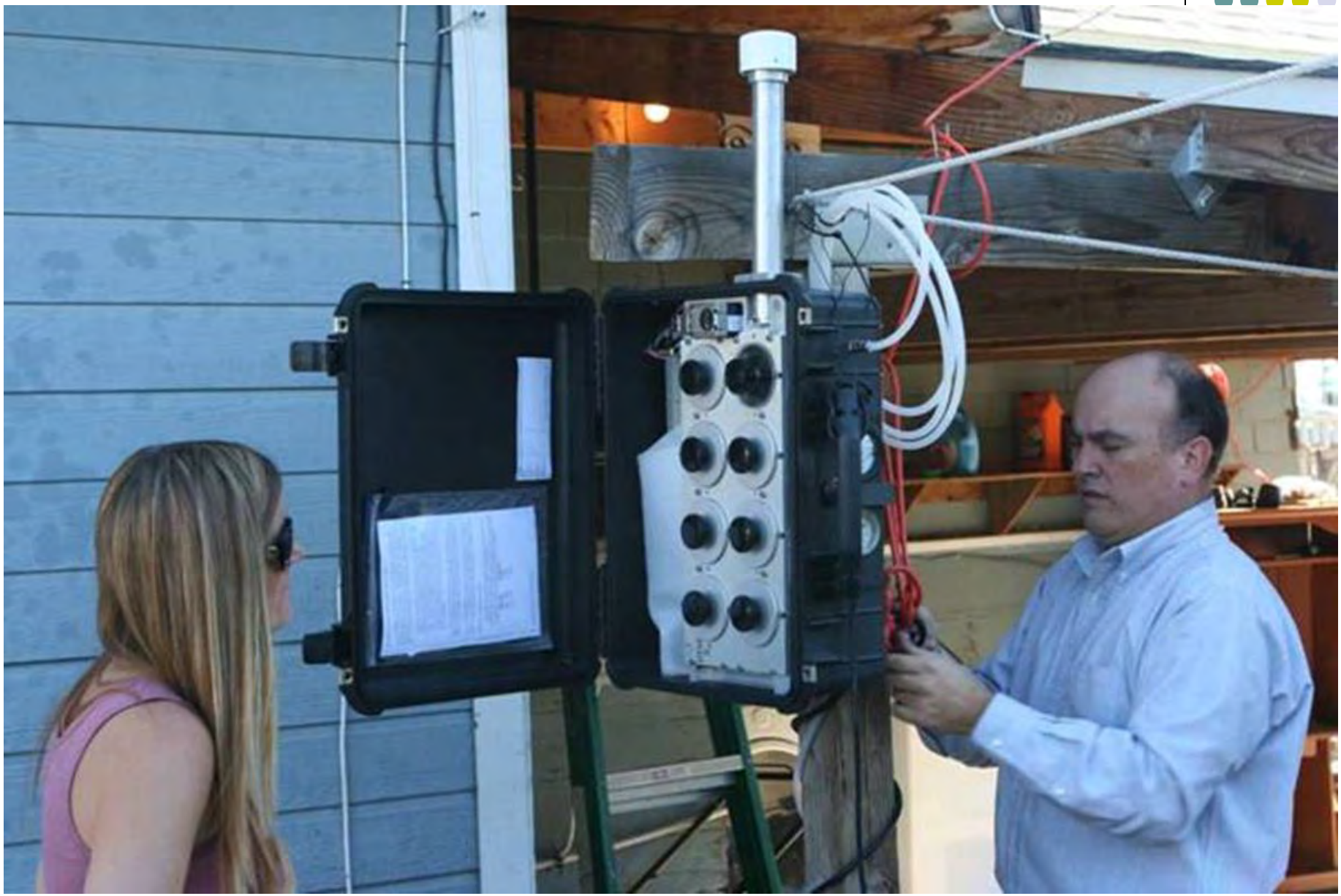
The BNSF San Bernardino intermodal facility – rail to truck

The problem? **ARB estimates the highest excess cancer rate of any facility in California occur NE.**

Our sampling and mitigation sites

The Vernon Street sampling site with a California pepper tree.

Davis and Kristen – outside DRUM

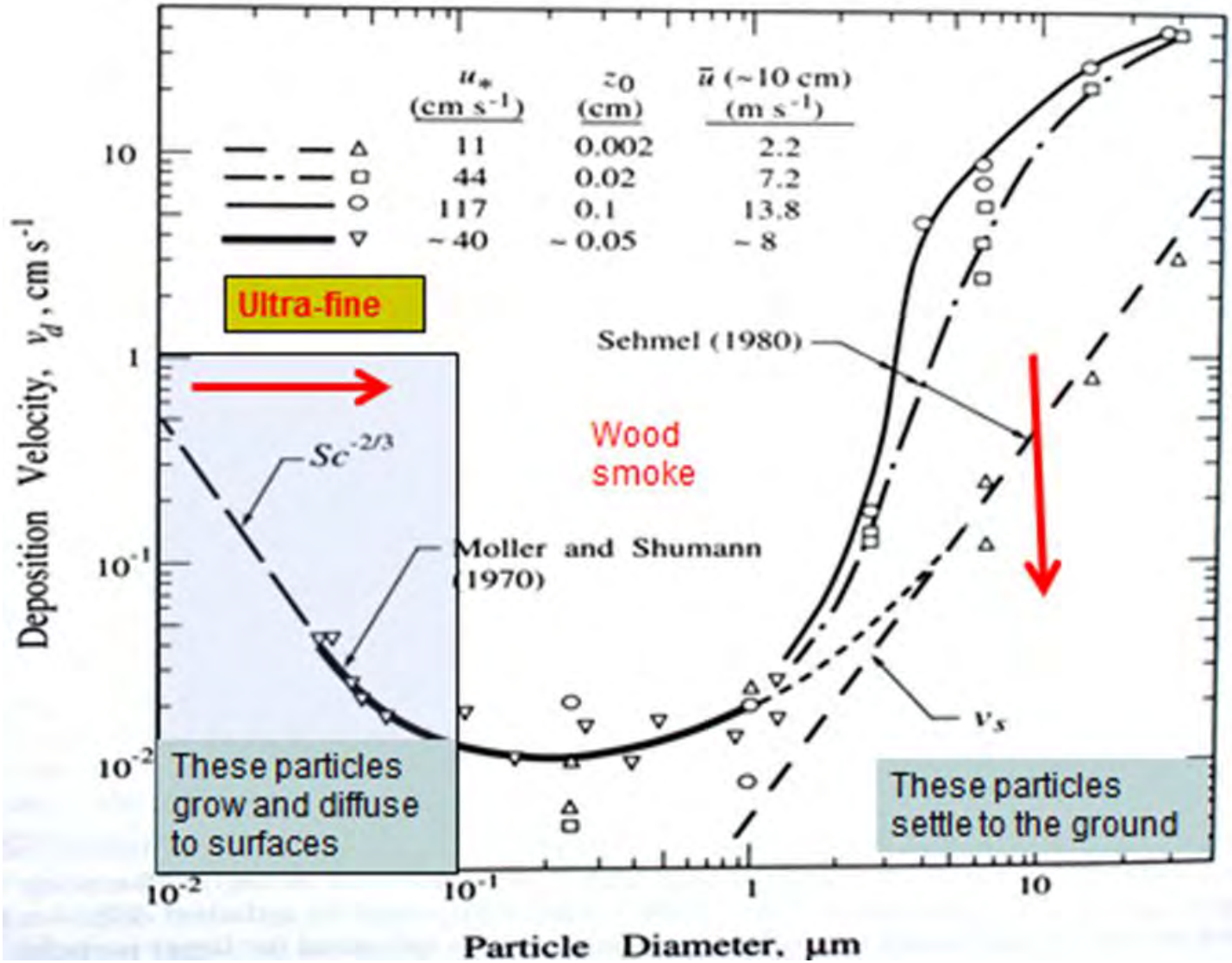


4th Street mitigation corridor

California pepper tree

One of our favorites – the California (ne′e Peruvian) Pepper Tree

Removal of aerosols



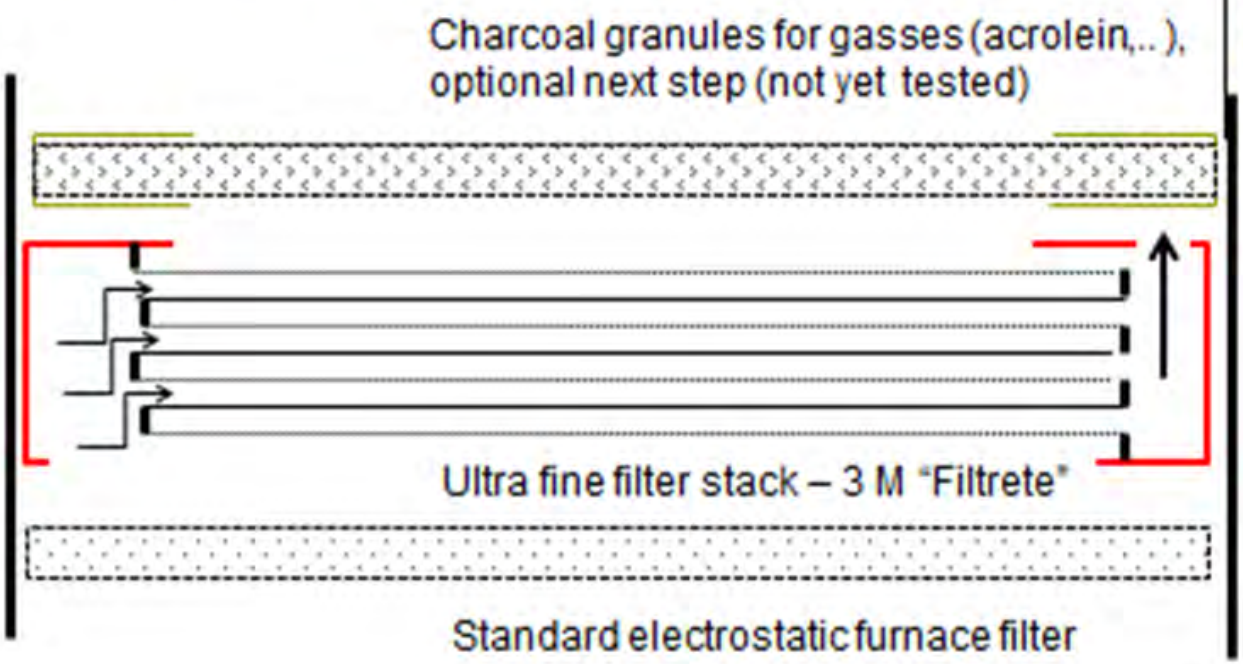
Funded mitigation – 2 miles of California peppers, plus understory, by tearing up two lanes of the old Hwy 66 (4th Street). Our sampling and mitigation sites

4th Street mitigation corridor

Indoor mitigation: Checking the “Green Air” enhanced filtration system

The “Green Air” system

And for the retrofits….4 filters in parallel



UC Davis DELTA Group
“Green Air” system;
estimated cost $300, from any hardware store

Air flow direction

Mira Loma project – now a settlement has been reached with the Dept. of Justice.

Combining the Watt Avenue results and the literature on health impacts ..

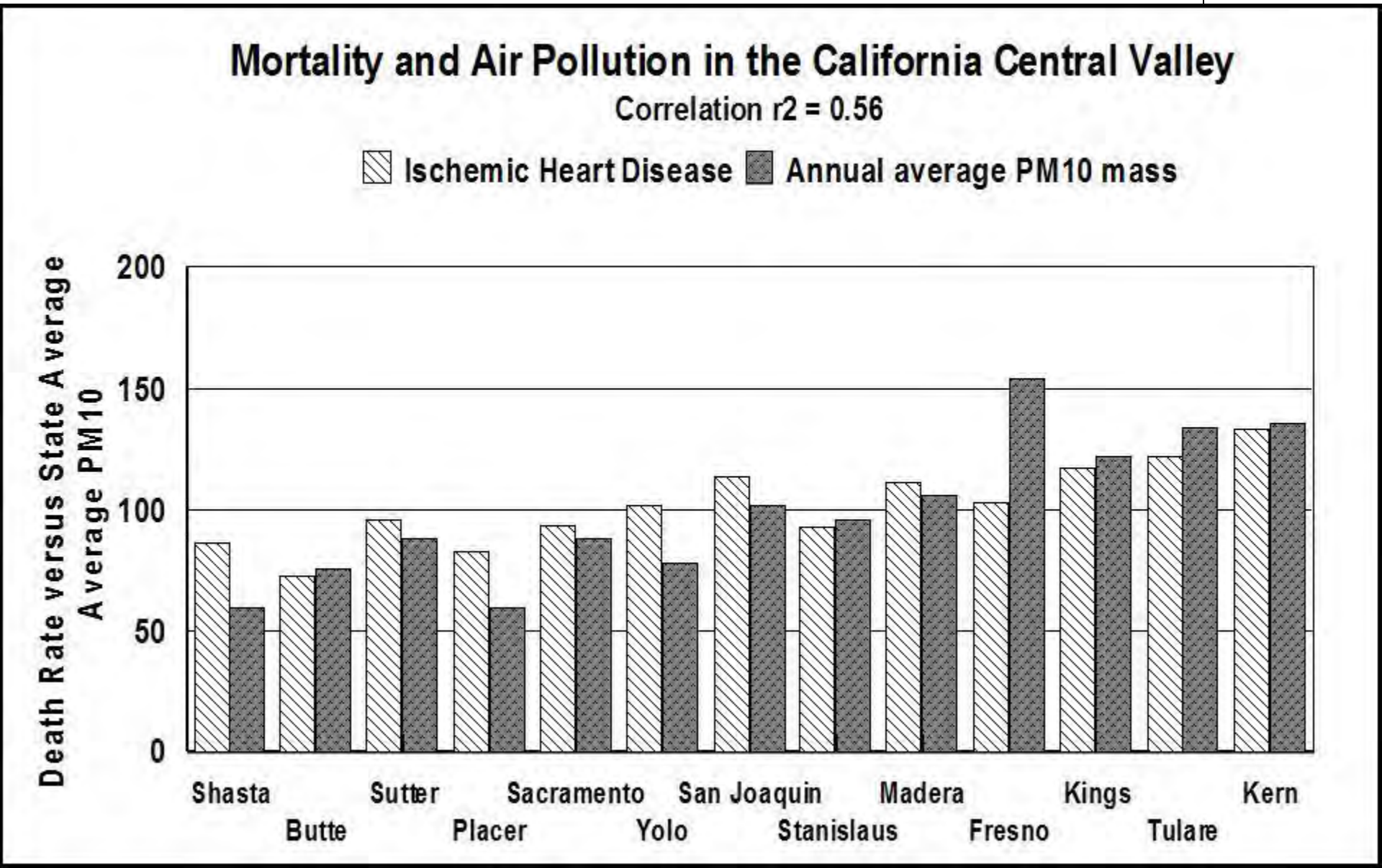
My personal priorities:

- **Source reduction**
  - Remove metals from brake pads (↓ ultra fine aerosols)
  - Remove zinc thio-phosphate from motor oils
  - Ban metallic smoke reducing additives in diesel fuel
- **Impact reduction**
  - Don't build any more elevated freeways
    - Mitigate those you already have (barrier vegetation?).
  - Minimize choke points that trigger braking
  - Avoid residences downwind of elevated freeways
    - Especially at points where braking commonly occurs
  - Plant and maintain heavy canopy vegetation
  - Enhanced filtration in at-risk residences, schools, etc.

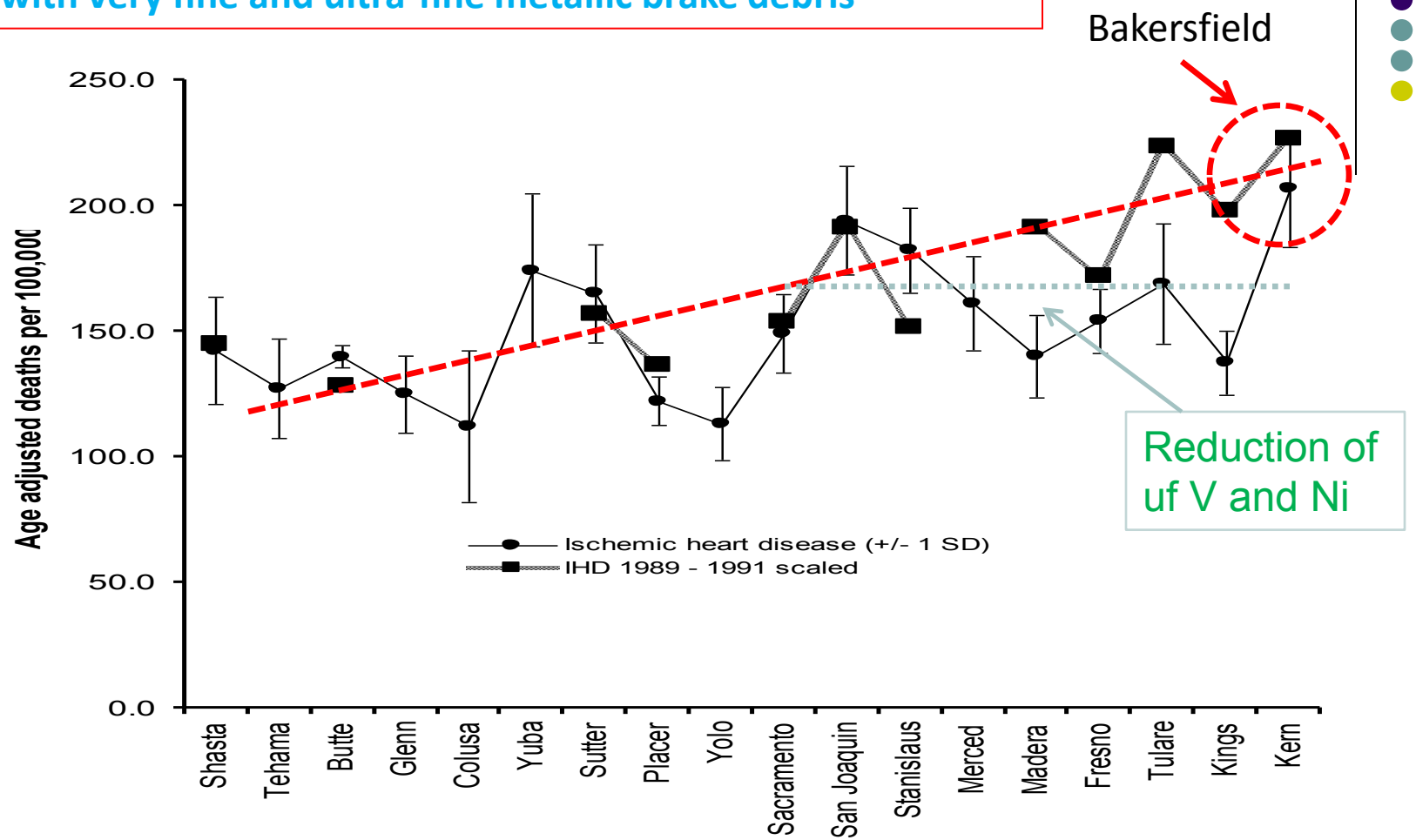
My personal evaluations of the problems:

- Problem #1 What do we need to mitigate?
  - Ultra fine metals (cardio-vascular) and very fine to ultra fine diesel (heavy PAHs like BaP), (and more to follow).
- Problem # 2 Despite greatly reduced roadway emissions, health impacts continue to be observed.
  - “Wear” aerosols are medically important and have not declined.
- Problem #3 The health effects seen near roadways extend much farther out than models and data predict.
  - Raised freeways and sound walls project aerosols far downwind
- Problem #4 The growing important of metallic “wear” aerosols that lack data and are hard to model versus vegetation.
  - Measurements can be made mimicking ultra fine “wear” aerosol emissions in ambient conditions

Results of the HETF BCSET Central Valley Report (1997)

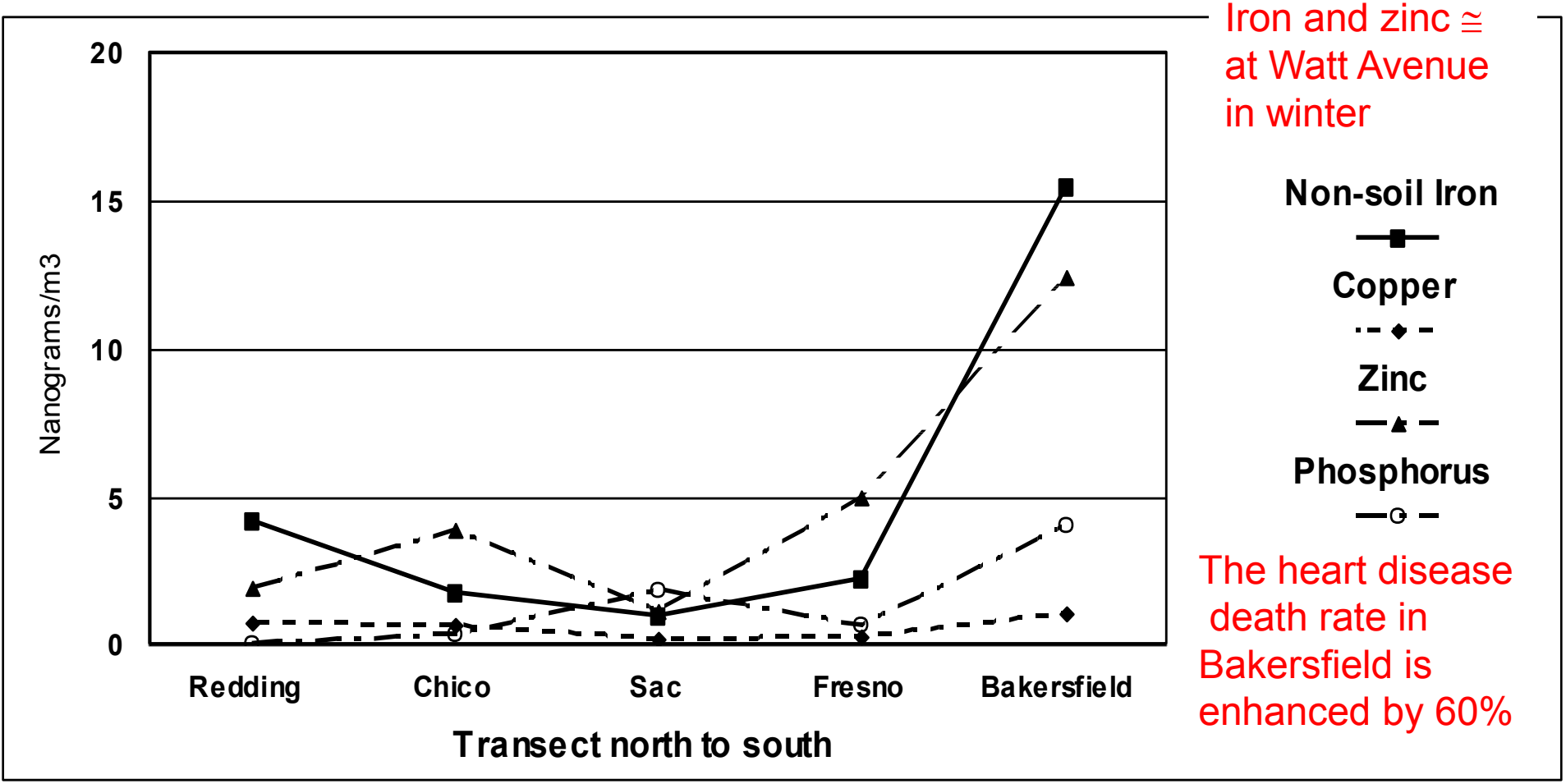


EPA/AS&T papers on Ischemic Heart Disease associated with very fine and ultra-fine metallic brake debris

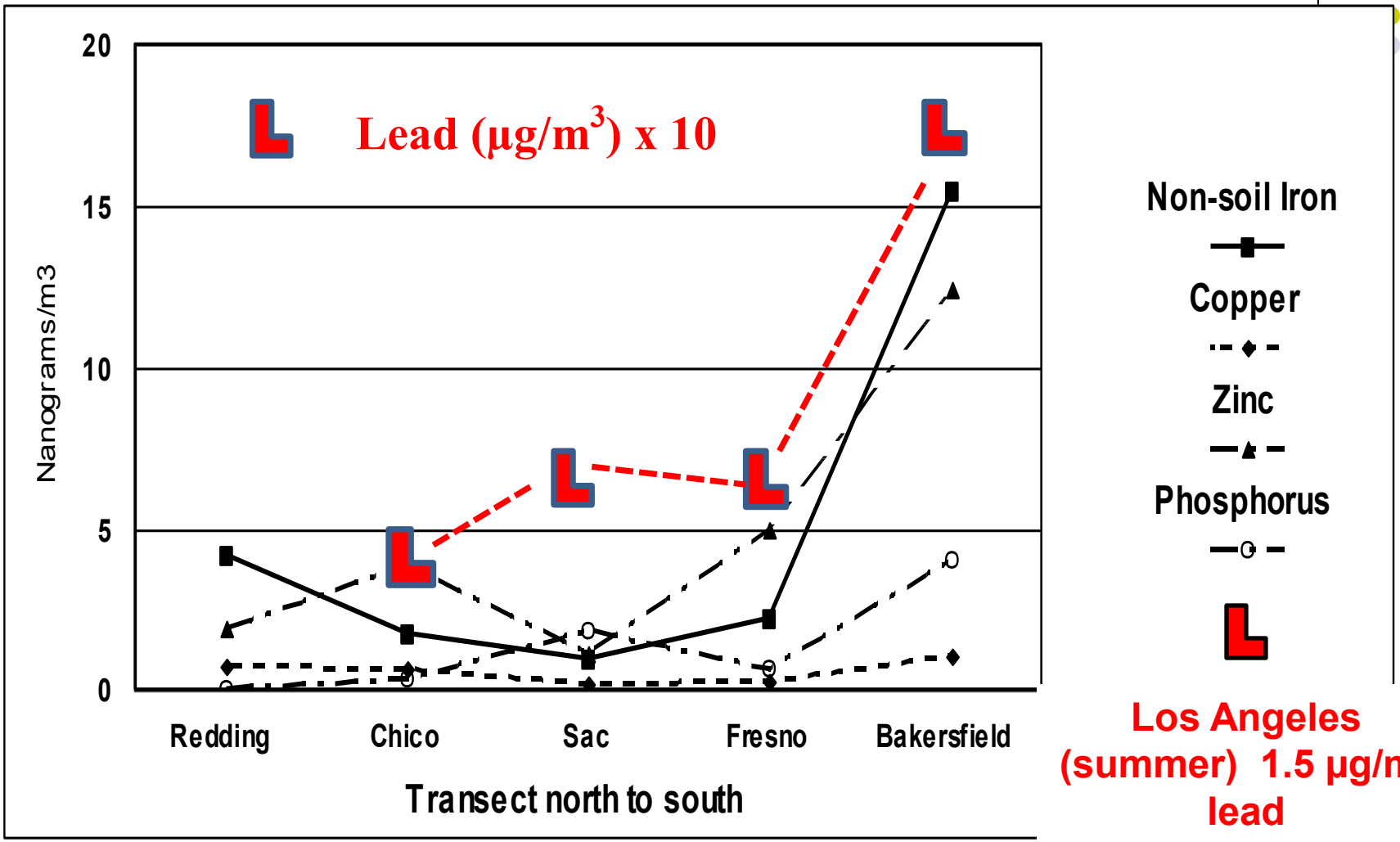


Ischemic heart disease (IHD) in the California Central valley, 1989 -1991 versus 2003 – 2007, associated with vf and uf metals from brakes and V and Ni from petroleum. Removal of the V and Ni reduced IHD. (Cahill et al 2011b)

Problem #3: HETF study (1997) found enhanced heart attack death rates in Bakersfield. **In 2009, we found that the same ultra fine metallic aerosols from braking seen downwind of Watt Avenue are elevated in Bakersfield.**



Adding lead from 1973



Los Angeles (summer) 1.5 µg/m³ lead

In the winter, air flows from Bakersfield north, so no Bay Area impact

But in winter Bakersfield is downwind of high mountain passes with two major freeways

Planning Our Future

Presented by
Anne Fenkner
Davey Resource Group

June 2, 2015

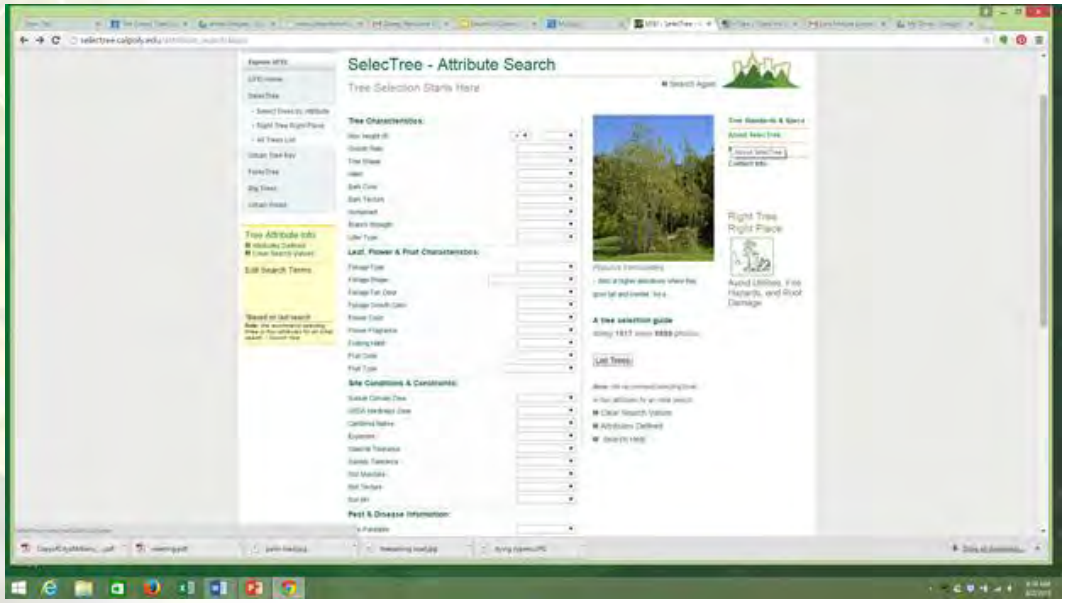
Reisgt
Avenue

Developing the Urban Forest Management Plan

- Why is an urban forest management plan important?
- Planning process
- Implementation (Inventory, i-Tree, Canopy, UFMP)
- Results

www.itreetools.org

www.selectree.calpoly.edu



Thank you for your time

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Green Prescription: The Link Between Urban Tree Canopy Cover & Health Behaviors and Outcomes

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Health is the state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.

— World Health Organization

Our Health and the Health of Our Children are Hanging in the Balance

- Over 1.4 million lives were lost due to heart disease, cancer, chronic lower respiratory diseases, and stroke — CDC, 2011
- About 68% of adults and 33% of children and teens are overweight or obese — NHANES, 2009-2010
- Lifestyle habits play a major role
- The most common chronic diseases are costing the economy more than $1 trillion annually — Milken Institute, 2007

Busy, Sedentary, and Exhausted

Stressed Out

Marketing, Marketing Everywhere!

Walking the Dog Takes on New Meaning

Escalators and Fitness?

And the Commute Goes On and On…

Community Design Matters

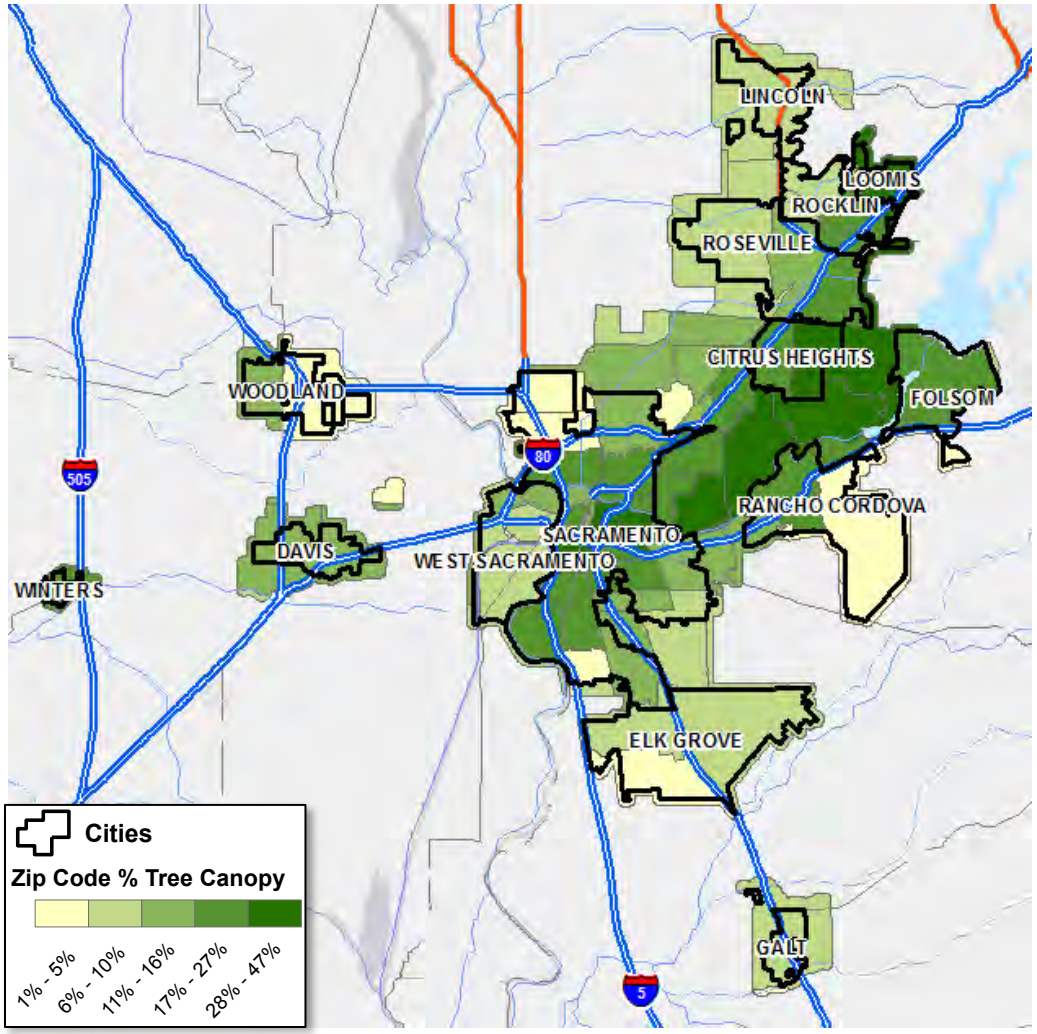
Vs.

Green Prescription

Specific Aims

1. Explore the relationships between neighborhood tree canopy in the greater Sacramento region and multiple measures of health among adults, teens, and children
   - Physical activity
   - Body mass index
   - Type 2 diabetes
   - Cardiovascular disease
   - Asthma
   - Mental/emotional health
   - Attention Deficit Hyperactivity Disorder
   - Social cohesion
   - General health status
2. Estimate the differences in health outcomes of two hypothetical neighborhoods, one with 18% tree canopy cover and the other with 28%

Study Area

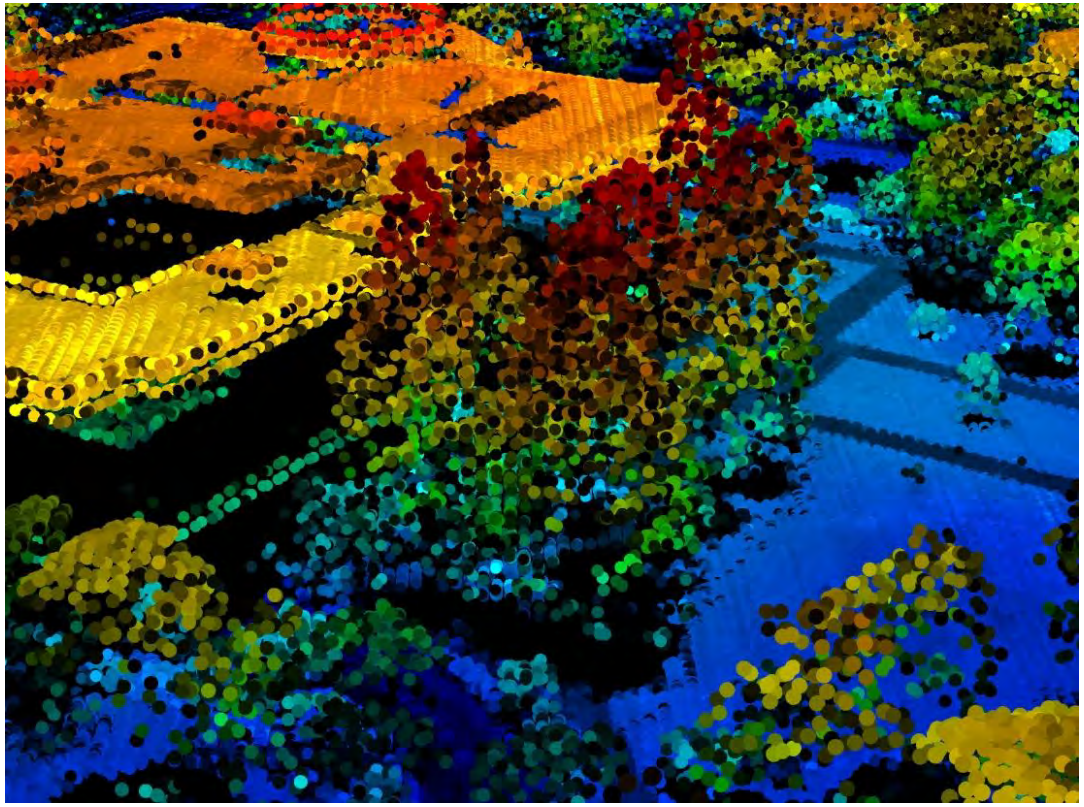

LINCOLN
LOOMIS
ROCKLIN
ROSEVILLE
CITRUS HEIGHTS
FOLSOM
WOODLAND
80
505
RANCHO CORDOVA
SACRAMENTO
DAVIS
WEST SACRAMENTO
WINTERS
ELK GROVE
GALT
5
Cities
Zip Code % Tree Canopy
1% - 5%
6% - 10%
11% - 16%
17% - 27%
28% - 47%

Methods

- Health behavior and outcome measures
  - California Health Interview Survey (CHIS)
    - Largest state health survey in the United States
    - Samples over 50,000 California households every two years
    - Statistically representative of the California population
    - Used 2003, 2005, 2007, and 2009 CHIS survey results

Methods

- Tree canopy measure
  - Light Detection & Ranging (LiDAR) and high-resolution satellite imagery (1 meter) in the urbanized areas of the Sacramento region
    - Central Valley Floodplain Evaluation and Delineation Program, 2008
    - National Agricultural Imagery Program, 2009



Methods

- Multiple regression models were used to estimate the association between tree canopy cover and each health behavior/outcome
- Adjusted for selected covariates
  - Demographics (age, gender, race/ethnicity)
  - Socioeconomic status
  - Household composition (size, number of children, marital status)
  - Housing (type of dwelling, owner/renter status, length at current residence)
  - Smoking status
  - Health insurance status
  - Walkability of neighborhood, etc.

Results

- Increased neighborhood tree canopy was associated with self-reported better general health among adults, teens, and children
- The greater the neighborhood tree canopy:
  - The less likely children, teens and adults were to be overweight or obese
  - The more likely adults were to participate in vigorous physical activity
  - The more likely adults experienced higher levels of social cohesion
  - The less likely adults were to have asthma
  - The more likely teens had improved mental health

Results

- If two neighborhoods are the same in all respects, but one has 28% tree canopy cover and the other 18% canopy cover, do the residents differ in their health?

Health measure	Adults	Teens	Children
Number of people either overweight or obese	-10%	-23%	-13%
Number of people obese	-18%	-15%	-20%
Number of people currently suffering from asthma	-10%	-3%	-11%
Number of adults with Type 2 diabetes	-20%	NA	NA
Number of adults participating in vigorous physical activity	+11%	NA	NA

NA = not applicable (i.e., this was not a component of the study)

Conclusions

- Greater tree canopy cover is important to health
  - Trees contribute to healthier lives and better health outcomes: general health, healthier weight, activity levels, social cohesion, asthma, and mental health
  - The link between health and environment is supported by a growing body of scientific evidence
  - Trees play a role in improving the environment: removing air pollutants, reducing storm water runoff, reducing energy use, offering habitats to wildlife, and so much more

Nurture trees now in the ground and plant new ones

"When one tugs at a single thing in nature, he finds it attached to the rest of the world."

— John Muir