Brake Pad Partnership Update

August 2004

The Brake Pad Partnership is a multistakeholder effort to understand the impacts on the environment that may arise from brake pad wear debris generated in the use of passenger vehicles. Manufacturers, regulators, stormwater management agencies, and environmentalists are working together to understand the impacts that may arise from brake pad wear debris generated by passenger vehicles on the environment. BPP efforts are aimed at developing an approach for evaluating potential impacts of copper from brake pads impacting water quality in the South San Francisco Bay as an example. Brake pad manufacturers have committed to adding this evaluation approach to their existing practices for designing products that are safe for the environment while still meeting the performance requirements demanded of these important safety-related products.

BPP Technical Studies Now Underway

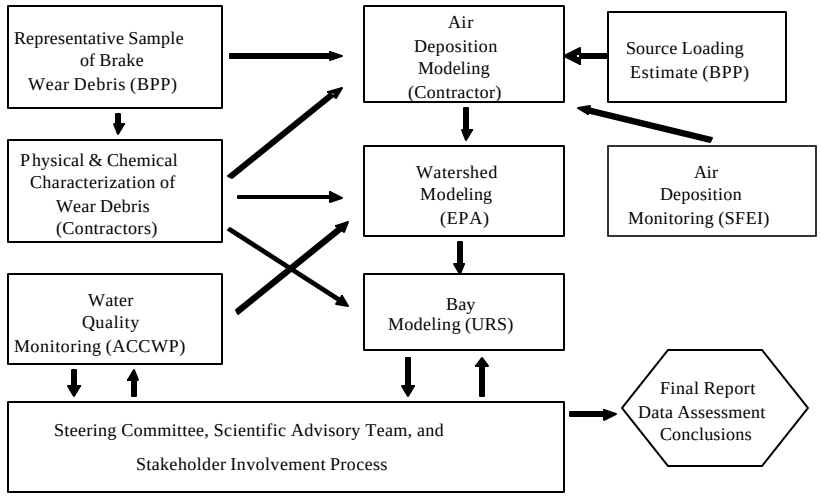
Thanks to the combined efforts of many Brake Pad Partnership (BPP) stakeholders, in October 2002, the State Water Resources Control Board awarded the Brake Pad Partnership a $700,000 grant, pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) for the implementation of California's Nonpoint Source Pollution Control Program.

The grant supports the BPP's effort to carry out a set of interlinked laboratory, environmental monitoring, and environmental modeling studies to understand the fate and transport of copper from automobile brake wear debris in the environment. (Figure 1 shows the interrelationships among the studies.)

The BPP initiated work on these studies in October 2003, when the state made the Proposition 13 funding available. The studies are scheduled to be completed in December 2006.

(Continued on next page)

Figure 1. Brake Pad Partnership Task Flow Diagram



(continued from previous page)

Three environmental modeling studies make up the core of the Partnership's effort:

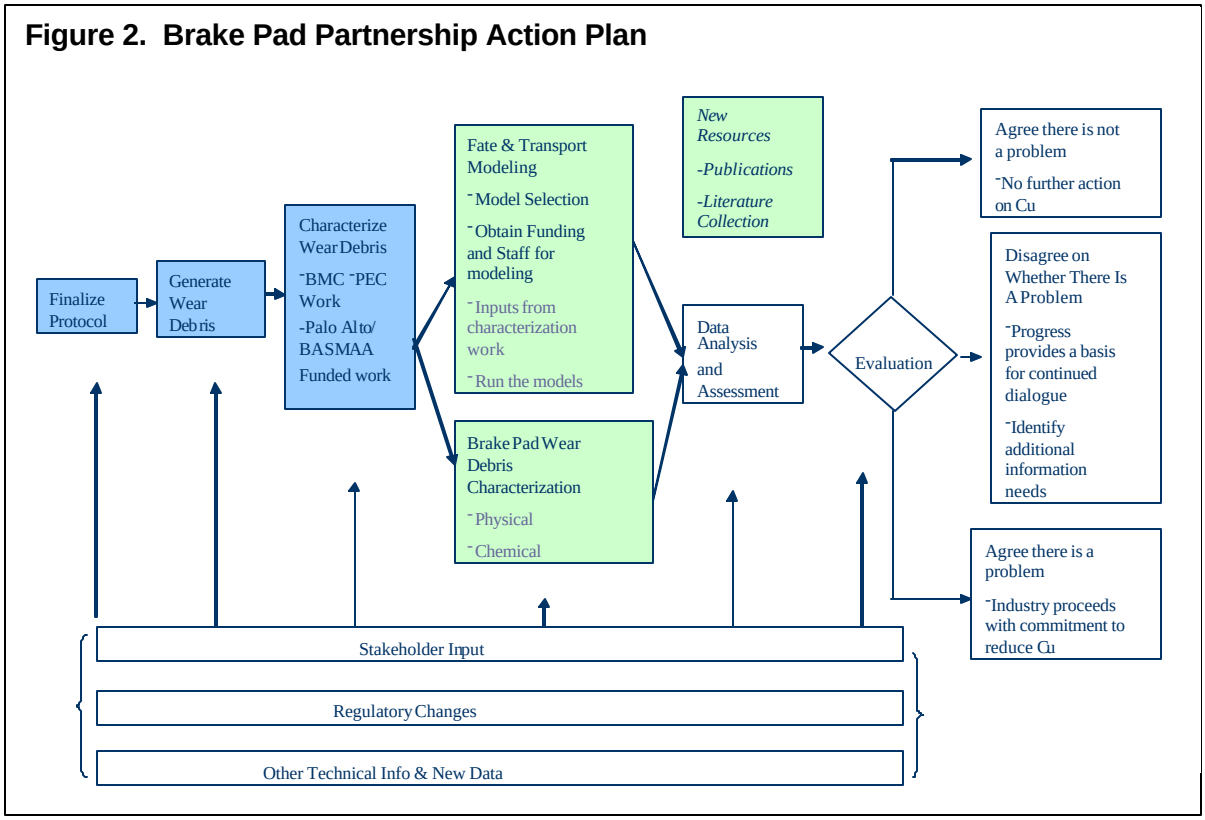
- Air Deposition Model – This model will be used to predict how much brake wear debris is released and deposited in the study watershed (Castro Valley).
- Watershed Model – This model will estimate how much copper from the deposited wear debris washes into the storm drainage system and eventually reaches the waters of the South San Francisco Bay.
- Bay Model – This model will determine whether and, if so, to what extent copper from brake wear debris affects short- and long-term concentrations of copper in the bay.

In support of these modeling efforts, the Partnership is conducting additional studies to develop accurate input data for the models. An air deposition monitoring effort will provide data necessary to evaluate the air deposition model. Stormwater monitoring data are being collected to help calibrate and evaluate the watershed modeling study. In addition, the Partnership will to conduct physical and chemical characterization analyses to determine model parameters specific to brake wear debris.

The Brake Pad Partnership Action Plan

The Brake Pad Partnership Action Plan shown in Figure 2 illustrates how the technical studies fit into the Partnership's overall effort to determine whether copper from automobile brake pads is a significant source of copper to the South San Francisco Bay. The blue boxes (darker shading) indicate work that already has been completed—specifically the development of the wear debris generation protocol and laboratory methods for evaluating total copper and leaching potential of brake wear debris material. The green boxes (lighter shading) indicate work that is now underway—specifically the technical studies to characterize a representative sample of brake wear debris, and to model its transport and fate in the environment. The unshaded boxes indicate tasks to be undertaken when the results of the technical studies are available—specifically, the evaluation of the results and determination of ensuing actions.

Figure 2. Brake Pad Partnership Action Plan



Recent Accomplishments

Since the last Stakeholder Update, the Brake Pad Partnership has made substantial progress. A list of accomplishments is shown in Table 1 below. Many of these accomplishments are described in greater detail in the text that follows.

Table 1. Recent Accomplishments of the Brake Pad Partnership

Action Plan

- Obtained $700,000 in Proposition 13 Grant funding for technical studies
- Developed and began implementing a detailed Action Plan for the technical studies (see page 3)
- Developed test procedure to measure total copper in brake pad wear debris
- Studied leaching of copper from wear debris from one brake pad

Technical Studies

- Selected and hired seven technical contractors (see box on page 10)
- Approved four work plans:
  - Atmospheric Deposition Modeling
  - Air Deposition Monitoring
  - Characterization of Airborne Brake Wear Debris
  - Stormwater Monitoring
- Arranged for in-kind watershed modeling from U.S. EPA
- Conducted preliminary modeling of Castro Valley and Bay Watershed
- Monitored stormwater in Castro Valley creek for copper in 2003-2004
- Located monitoring sites and started air deposition monitoring in the Castro Valley watershed
- Initiated measurements of brake pad wear debris aerodynamic particle size diameter
- Generated representative brake pad wear debris sample

Publications Resulting from the BPP's Work

- J. Trainor, T. Duncan, and R. Mangan, *Disc Brake Wear Debris Generation and Collection*, 2002-01-2595, SAE Technical Paper Series, SAE International, Warrendale, PA, 2002.
- J. Hur, S. Yim, and M.A. Schlautman, M.A. 2003, "Copper Leaching from Fallout Disc Brake Wear Debris," *Journal of Environmental Monitoring*, 5:837-843.
- J. Hur, M.A. Schlautman, and S. Yim 2004, "Effects of Organic Ligands and pH on the Leaching of Copper from Brake Wear Debris in Model Environmental Solutions," *Journal of Environmental Monitoring*, 6:89-94.
- Brake Pad Partnership, January 2004, *Copper Use Monitoring Program Results for Model Years 1998–2002.*

Stakeholder Involvement, and Public Outreach and Communication Tools

- Established BPP Internet Site: www.suscon.org/brakepad/index.asp
- Established BPP list-serve: BPP-list-serve-subscribe@topica.com
- Assembled BPP Literature and Technical Reference Library: www.tdcenvironmental.com/brake/
- Established Scientific Advisory Team
- Held Stakeholder Conference Meeting on May 21, 2004

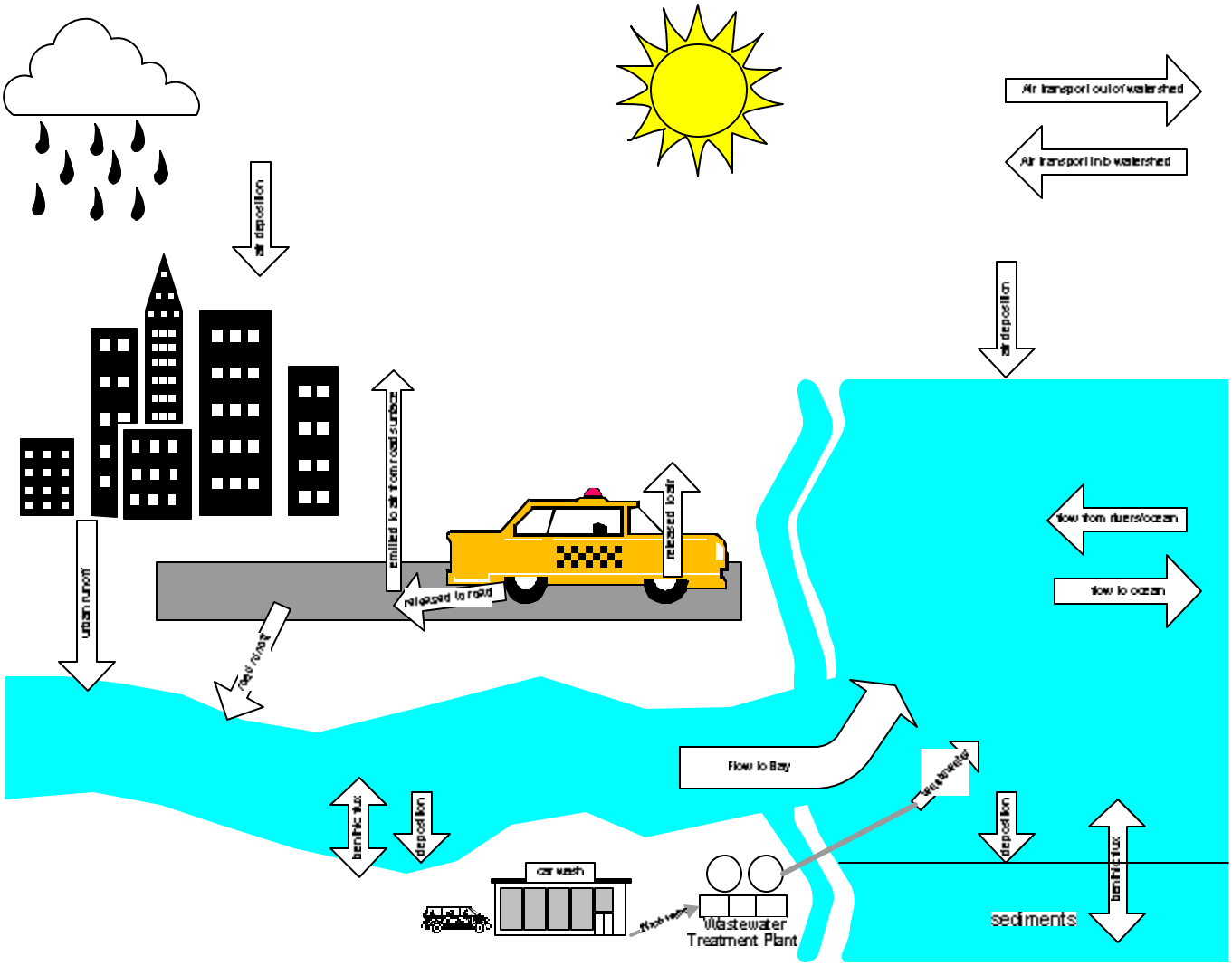
Interested in Getting Involved in the Brake Pad Partnership?

For information on how to participate in the BPP's efforts, please subscribe to the BPP list-serve. You will receive project updates, information on the availability of draft and final reports and the opportunity to provide your input, along with information on upcoming stakeholder events. To subscribe, please send a blank e-mail to: BPP-list-serve-subscribe@topica.com. Use of the BPP list-serve is reserved exclusively for disseminating and sharing information about the BPP.

The BPP's Technical Studies: The Big Picture

The BPP's technical effort under the Proposition 13 grant entails a set of interlinked laboratory, environmental monitoring, and environmental modeling studies needed to understand the fate and transport of copper from automobile brake wear debris in the environment. Figure 3 shows the pathways for the transport of brake wear debris in the environment that the BPP is considering.

Figure 3. Environmental Transport and Fate Pathways



Environmental Modeling Studies

At the core of the effort are three environmental modeling studies—the air deposition, watershed, and bay models—to evaluate how copper in brake wear debris moves through the environment. The additional laboratory and environmental monitoring studies are designed to provide critical input to the modeling studies and to validate the model results.

Air Deposition Modeling

The air deposition model will be used to predict how much brake wear debris is deposited in the study watershed (Castro Valley) through dry and wet deposition. Once copper is emitted to the atmosphere from a source, it may be transported by wind a distance determined by both the particle size of the

copper and the wind velocity and direction. The air deposition model simulates this transport for all sources of copper at the watershed and regional level. The inputs to the model include relevant meteorological parameters (i.e. precipitation, wind speed, wind direction and parameters that characterize the mixability of the atmosphere) and information on the location and magnitude of copper sources and the particle sizes of those sources.

The output of the model will be the total amount of copper depositing on the watershed in a given amount of time at locations specified by the modeler. This information will then be used as an input to the watershed model. With appropriate source information, one can run the model with different sources (e.g. with and without brake pads or with and without upwind emissions) and for different modeling areas, thereby distinguishing deposited copper originating from brake pads or from outside the watershed. The BPP has contracted with AER, Inc. to conduct the modeling work. A copy of the Work Plan for Air Deposition Modeling is available on the BPP's website at: http://www.suscon.org/brakepad/pdfs/AER%20BPP%20Final%20Work%20Plan%2001-30-04.pdf.

Watershed Modeling

The watershed model will estimate how much copper from brake pad wear debris washes into the storm drainage system and eventually reaches to the waters of the South San Francisco Bay. Jim Carleton of the U.S. Environmental Protection Agency's (USEPA) Health Protection and Modeling Branch is carrying out the watershed modeling effort for the BPP. He will use the EPA model HSPF (Hydrologic Simulation Program-Fortran) to simulate runoff in the 5.5 square mile Castro Valley watershed, located in Alameda County, California. The model will be calibrated against stream flow and water column monitoring data collected from Castro Valley Creek at the outlet of the watershed. Daily mean flow has been measured by a USGS gauging station at this location since 1971. Water column suspended sediment and total copper concentration data have been collected at the same location intermittently since 1989. Together this information forms a data set that will be used to calibrate the model. Model parameters associated with build-up and wash-off of copper from impervious surfaces will be obtained in part from copper deposition monitoring data to be collected by the BPP, in part from the results of atmospheric deposition modeling, and in part by optimization of HSPF parameters so that model simulations most closely match the available water column data.

With HSPF calibrated against the Castro Valley data, a multi-subwatershed model will be constructed of all of the land immediately surrounding the San Francisco Bay, i.e., all bay drainage except for the San Joaquin and Sacramento River drainage areas. The model will be used to estimate spatially and temporally distributed anthropogenic copper loadings to the bay. Water column copper monitoring data, where available from streams draining the other watersheds, will be used to help verify the reasonableness of model parameter selection and associated anthropogenic copper loading estimates. A draft work plan for the watershed modeling effort is now available for review at: http://www.suscon.org/brakepad/documents.asp.

Technical Consultants

Air Deposition Modeling
Atmospheric and Environmental Research, Inc.

Watershed Modeling
Office of Water
U.S. Environmental Protection Agency

Bay Modeling
URS Corporation

Stormwater Monitoring
Alameda Countywide Clean Water Program

Air Deposition Monitoring
San Francisco Estuary Institute

Chemical & Physical Characterization of Brake Wear Debris
Clemson University

Estimation of Copper from Brake Sources
Process Profiles

Project Management, Steering Committee and SAT Coordination
Sustainable Conservation

Bay Modeling

The bay modeling effort will determine whether and, if so, to what extent copper from brake wear debris affects short- and long-term concentrations of copper in the South San Francisco Bay. The BPP has contracted with URS Corporation to use a version of MIKE 21, a hydrodynamic, sediment transport, and water quality model that already has been calibrated for San Francisco Bay and previously used to explain spatial and seasonal fluctuations in dissolved copper concentrations. The URS version of MIKE 21 will use input data from the atmospheric deposition and watershed models to estimate short-term copper concentrations. Practical limitations prevent the use of the MIKE 21 model over long periods of time (i.e., decades). Thus, a compartmental model will be integrated with MIKE 21 to make the long-term copper concentration estimates.

Laboratory Studies

To accurately model the movement of copper from brake wear debris through the environment, additional information is needed on the amount of copper released in brake wear debris, and the chemical and physical characteristics of the wear debris particles.

Representative Sample of Brake Pad Wear Debris

Many factors may affect the amount and form of brake pad wear debris released to the environment, including the composition of and the manufacturing process for the brake pad, the type of vehicle, driving conditions, and even individual driving styles. For the purposes of the BPP's technical studies, it is important to have data on wear debris that is representative of brake wear material being released to the environment under on-road driving conditions.

Thus, the BPP embarked on an effort to generate a "representative" wear debris sample that can be tested to determine physical and chemical characteristics required for the modeling studies. Previously the BPP developed a dynamometer-based protocol for generating wear debris representative of that likely to be generated under on-road driving conditions[1] and used it to generate wear debris from one copper-containing brake pad.

In its current effort, the Brake Manufacturers Council-Product Environmental Committee (BMC-PEC) has identified a set of brake pad materials that, when the wear debris produced from them is combined in the appropriate proportions, comprise a more representative sample of wear debris from copper-containing brake pads than any single pad. The BMC-PEC effort to generate a representative sample of brake wear debris has been carried out in a manner that protects the manufacturers' proprietary business information while providing a brake pad wear debris sample the BPP is using to gain information on various attributes of brake wear debris needed for the environmental models.

Characterizing Brake Wear Debris

To accurately model the movement of copper from brake wear debris through the environment, additional information is needed on the chemical and physical characteristics of the wear debris particles. The BPP has identified specific needs for characterizing the airborne and non-airborne fractions of brake wear debris. It may identify and conduct additional characterization tests depending on the results of these initial tests and whether any additional data is needed for the modeling studies.

Characterization of Airborne Brake Wear Debris

The Brake Pad Partnership has contracted with researchers from Clemson University's School of the Environment—Professors Christos Christoforou and Mark Schlautman—to characterize the representative sample of airborne brake wear debris. Specifically the Clemson team will measure the total copper content and aerodynamic particle diameter of airborne wear debris.

[1] J. Trainor, T. Duncan, and R. Mangan, *Disc Brake Wear Debris Generation and Collection*, 2002-01-2595, SAE Technical Paper Series, SAE International, Warrendale, PA, 2002.

In late June, Professors Christoforou and Schlautman traveled to Link Testing Laboratories in Detroit where a dynamometer was specially equipped for collecting brake wear debris. Professors Christoforou and Schlautman set up a micro-orifice uniform deposit impactor (MOUDI) to sample airborne wear debris particles released from the brake apparatus. The MOUDI instrument essentially sorts particles by size into 10 fractions ranging from 0.056 to 18 microns. The particles in each size fraction are collected on stages holding Teflon substrates onto which the particles deposit. An eleventh stage collects any particles smaller than 0.056 microns that flow past the other filters. Professors Christoforou and Schlautman sampled airborne particles generated from each of the brake pad materials used to generate the representative sample. Using gravimetric analysis (i.e., by weighing the mass of the material deposited on each substrate), they will determine the mass-based particle size distribution and overall average aerodynamic diameter. This information will be used in the air deposition model to help predict how airborne wear debris is transported and deposited in a watershed.

Professors Christoforou and Schlautman will also conduct chemical analyses to determine the total copper and iron contents of the airborne brake wear debris, using the analytical technique developed by Professor Schlautman's research group to analyze the single pad sample of wear debris generated previously.[2] The results of these analyses will be compared to those for the fallout fraction (see below) to determine if copper content differs between the fallout and airborne fractions. The results will also provide input data for the watershed and bay models.

Chemical Characterization of the Fallout Brake Wear Debris

A critical part of the BPP's effort is to understand to what extent copper in brake wear debris may leach from wear debris particles when the particles come into contact with rainwater. Thus, the BPP is planning to conduct solubility and leaching tests on the fallout fraction (i.e., the non-airborne fraction) of the representative sample.

Previously, Professor Mark Schlautman, developed total copper, solubility, and leaching test protocols using the wear debris sample generated from a single brake pad. Professor Schlautman and his research group evaluated copper leaching from the test sample using standard extraction solutions[2] and model environmental solutions.[3]

The BPP is contracting with Clemson University to carry out the protocols developed by Professor Schlautman's team on the fallout fraction of the representative sample of wear debris. The total copper results from this work will be compared with those obtained for the airborne fraction to determine if there are any differences between the two. The data will also provide important input on wear debris chemistry for the watershed and bay models.

Estimating Copper Loading to the Watershed

One of the most critical inputs to the modeling efforts is the "source term"—i.e., the estimate of the quantity of copper released to the watershed from vehicles (brake sources) and other copper sources (non-brake sources). The BPP Steering Committee has begun to develop a conceptual framework for estimating the inputs from brake sources, and is initiating work with the modelers to inform the development of an estimate of copper from non-brake sources.

Estimation of the amount of copper released in brake wear debris in the study watershed requires taking into account a variety of factors, including different brake material compositions for different types of vehicles, brake pad wear and replacement rates, age of the vehicle fleet, and traffic volumes. A complicating factor in conducting this work involves reconciling the different categorization approaches used in developing traffic-related versus data on brake types and composition. The BPP has contracted

[2] J. Hur, S. Yim, and M. Schlautman (2003). Copper leaching from brake wear debris in standard extraction solutions. *J. Env. Monit.* 5:837-843.

[3] J. Hur, M. Schlautman, and S. Yim (2004). Effects of organic ligands and pH on the leaching of copper from brake wear debris in model environmental solutions. *J. Environ. Monitor.* 6:89-94.

with Kirsten Sinclair Rosselot of Process Profiles work with the Steering Committee to develop a work plan for estimating copper loadings from vehicle brake sources.

With regard to estimating copper from non-brake sources, the BPP intends to build on the work now being conducted by the Clean Estuary Partnership in support of the development of the copper TMDL for the San Francisco Bay north of the Dumbarton Bridge. The BPP Steering Committee will confer with the consultants conducting the air deposition, watershed, and bay modeling to understand specifically what information is required prior to developing a conceptual framework and solidifying its approach to this task.

Environmental Monitoring Studies

Stormwater Quality Monitoring

The BPP is supporting the Alameda Countywide Clean Water Program's (ACCWP) collection and reporting of monitoring data on copper in stormwater runoff during the 2003-2004 wet season in Castro Valley Creek. Jim Scanlin of ACCWP collected flow-weighted and/or time-weighted samples from nine storm events from October 2003 through February 2004 (flow and time-weighted samples were collected for seven events). All samples were analyzed for total copper using EPA Method 160.2 and total suspended solids using EPA Method 200.8. Jim reported the draft results at the May 21 Stakeholder Conference; a draft report is due this fall.

This sampling effort adds a ninth year of data to Alameda County's copper monitoring data set that was begun in 1989. The entire data set is being used to calibrate and validate the watershed model.

Air Deposition Monitoring

The San Francisco Estuary Institute (SFEI) is conducting a study under contract to the BPP to monitor the deposition of copper from the atmosphere in the Castro Valley watershed. The results of this monitoring effort will be used to validate the air deposition model. The air deposition monitoring effort involves the collection of dry and wet deposition samples over the course of approximately one year. To best support the modeling effort, the BPP and SFEI have worked to find sites that are different as possible with respect to traffic impacts.

Finding appropriate sites proved more difficult than initially anticipated. The wet deposition monitors require an electrical power source to operate the sampler cover that opens when it is raining and closes when the rain stops. Because of the cost of these instruments, it is also very important to place them in secure locations where they will not be stolen or tampered with. The dry deposition samplers do not need an electrical power source, however they do need to be placed in secure locations.

The siting strategy recommended by the air deposition modelers is to place the samplers in locations that are as different from each other as possible with respect to traffic intensity. Thus, one sampler should be placed in an area that is highly impacted by vehicle traffic, within approximately 20 meters of a major roadway (to capture particles that do not travel far before depositing to the ground), and close to the ground (to capture deposition to the ground surface). The other sampler should be placed in an area that has little vehicle traffic, such as a park or low-density residential neighborhood.

Don Yee of SFEI worked hard to locate sites having all the appropriate characteristics. For the wet deposition monitoring, access to two building rooftops in Castro Valley was secured and two sets of week long wet deposition samples were collected in March. For the dry deposition monitoring, a rooftop location adjacent to an I-580 off-ramp was selected as the site more heavily impacted by traffic, and a reservoir in the upper portion of the watershed, near the ridgeline, was selected as the site having relatively little impact from vehicle traffic. Dry deposition sampling began in mid-July. http://www.suscon.org/brakepad/pdfs/SFEI%20Air%20Dep%20WkPln-SAP%2002-04.pdf

Partnering to Produce Results

The BPP's success depends on the coordinated collaborative effort of many people and organizations. The Steering Committee developed an Operating Plan that describes the operational procedures, processes, and policies used by the Brake Pad Partnership to carry out its work, including arrangements for collaborating, deliberating, conducting technical studies, obtaining expert scientific input and peer review, making decisions, and communicating with stakeholder communities and the interested public. A copy of the BPP Operating Plan can be found at: http://www.suscon.org/brakepad/. The Brake Pad Partnership Organizational Chart is shown in Figure 4.

Project Coordination and Management

The Brake Pad Partnership's work is coordinated and facilitated by Sustainable Conservation, which is responsible for assisting the Steering Committee in its deliberations; coordinating with regard to project scheduling, tasks, milestones, and deliverables among the Steering Committee, Technical Consultants, Technical Advisor, Scientific Advisory Team, and the San Francisco Estuary Project; organizing and convening stakeholder workshops to facilitate interactive communication among Steering Committee members and the different stakeholder communities; developing and disseminating information about the Partnership and its progress broadly to the stakeholder communities and interested public.

The BPP's Proposition 13 grant was awarded to the Association of Bay Area Governments (ABAG) on behalf of the San Francisco Estuary Project (SFEP), which is serving as the Brake Pad Partnership's fiscal agent for the purpose of this grant. SFEP/ABAG is responsible for contract and subcontract administration and management. The San Francisco Bay Regional Water Quality Control Board serves as the contract manager on behalf of the SWRCB. Sustainable Conservation is responsible for assisting SFEP/ABAG in subcontract management relating to technical content and reporting, including approval of invoices, and for assuring that the Steering Committee's directions are carried out through the work of the subcontractors.

Scientific Advisory Team

The Brake Pad Partnership has created a Scientific Advisory Team (SAT) process to provide independent scientific review of work plans and work products. The purpose of the SAT is to ensure that key decisions and assumptions that go into the development, performance, and evaluation of the BPP's studies are technically sound. The Scientific Advisory Team is co-chaired by:

- Dr. Jerry Schubel, Aquarium of the Pacific, Long Beach, California
- Professor Mark Schlautman, School of the Environment, Clemson University, South Carolina

As the Team's core advisors, they will participate in review efforts and provide input for decision-making throughout the entire study process, lending continuity to the effort.

Additional SAT members will participate primarily as technical peer reviewers on an as-needed basis providing in-depth review of materials relating specifically to their areas of specialized expertise. In April, the BPP conducted a technical work product review process of the Work Plan for Characterization of Airborne Brake Wear Debris. Professor Tom Cahill of the University of California at Davis joined the Scientific Advisory team at that time providing an independent technical review of the Work Plan.

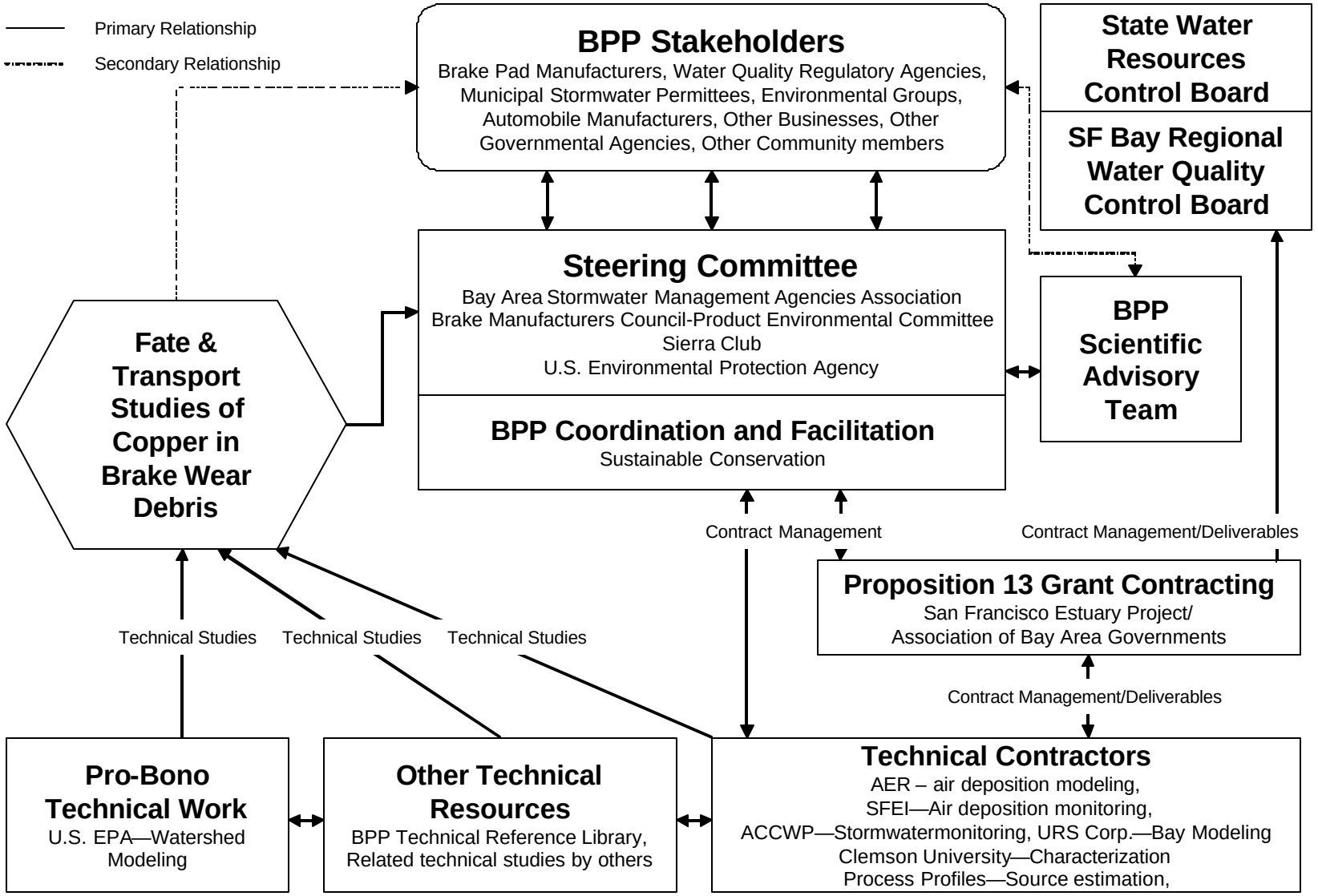
Technical Work Product Review

The BPP has developed a process for the review of its technical work products, with three goals in mind. The Technical Work Product Review process is designed to provide:

- ***A scientific check and independent review*** to ensure that the approach and results of the Brake Pad Partnership's work products are technically sound from a credible, objective, scientific point-of-view.
- ***A source of outside ideas*** that could further strengthen the technical work.

(continued on page 11)

Figure 4. BPP Organization Chart



- ***Engagement, advice and guidance*** that can help build in-depth understanding of and confidence in the technical studies on the part of the Steering Committee and the stakeholder communities.

The Brake Pad Partnership has developed two levels of review for technical work products. The draft reports resulting from the three environmental modeling tasks—air deposition modeling, watershed modeling, and bay modeling—will undergo a very intensive review process involving members of the Scientific Advisory Team, Steering Committee, and interested stakeholders. Draft Work Plans for all the tasks and draft reports for the laboratory and monitoring tasks, will undergo a somewhat less intensive review process in which stakeholders will still have the opportunity to participate. Detailed descriptions of the review processes for each type of product can be found in the BPP's Operating Plan. Table 2 provides a list of the technical work products and the status of the review process.

Table 2. Technical Work Product Review Status List

Technical Work Product	Review Status
Air Deposition Modeling (AER, Inc.)	
Work Plan	Approved by BPP Steering Committee Jan. 2004
Report	Draft report due July 13, 2005
Watershed Modeling (USEPA)	
Work Plan	Draft work plan now available for review
Report	Draft report due Dec 20, 2005
Bay Modeling (URS Corp.)	
Work Plan	Draft work plan due Aug 26, 2005
Report	Draft report due Aug 15, 2006
Characterization of Airborne Brake Wear Debris (Clemson University)	
Work Plan	Approved by BPP Steering Committee July 2004
Report	Draft report due Aug 27, 2004
Chemical Characterization of Brake Wear Debris (Clemson University)	This will be performed in phases:
Work Plan	First phase work plan (Solubility Testing) approved by Steering Committee June 2004
Report	Draft report due Oct 31, 2004 Second phase work tbd
Loading Estimate of Copper from Brake Pads (Process Profiles)	
Work Plan	Draft procedure due Aug 6, 2004
Report	Draft report anticipated Dec 13, 2004
Loading Estimate of Copper from Non-brake Souces (to be determined)	
Work Plan	Contractor to be selected
Report	
Water Quality Monitoring (Alameda Countywide Clean Water Program)	No work plan required
Work Plan	
Report	Draft report due Sept 15, 2004
Air Deposition Monitoring (SFEI)	
Work Plan	Approved by BPP Steering Committee Jan 2004
Report	Draft report due April 4, 2005
Project Management and Final Report (Sustainable Conservation)	
Operations and Communications Plan	Completed March 2004
Final Report	Draft report anticipated Dec 2006