THE BRAKE PAD PARTNERSHIP

Compilation of Technical Reviewers and Stakeholders Comments on Draft Work Plan for Watershed Modeling for the Environmental Fate and Transport of Copper from Vehicle Brake Pad Wear Debris

October 1, 2004

Background and Charge to Reviewers

On behalf of the Brake Pad Partnership, US EPA will conduct watershed modeling of the environmental fate and transport of copper from vehicle brake pad wear debris to better understand how copper in brake pad wear debris travels through the environment and the potential impacts on water quality in the San Francisco Bay. The watershed modeling effort is one of three interlinked modeling components at the core of the BPP's effort. An air deposition model will be used to estimate the amount of copper from brake wear debris that is deposited in the watershed. The results of that model will provide inputs to the watershed model. The watershed model will estimate the amount of copper from brake wear debris that is discharged from the watershed in runoff. That information will provide inputs to the bay model which will estimate short- and long-term concentrations of copper in the South San Francisco Bay.

The Brake Pad Partnership Steering Committee is seeking an independent expert review of the Draft Work Plan for watershed modeling for the environmental fate and transport of copper from vehicle brake pad wear debris to ensure that the approach and results of this element of the Partnership's work are technically sound, to determine if there are feasible opportunities to strengthen this work, and to help build in-depth understanding of and confidence in the technical studies on the part of the Steering Committee and the stakeholder communities.

Charge

With the aim of meeting these objectives, the Steering Committee has developed the following questions on which it is seeking specific comments from the reviewers:

1. In your assessment, is the proposed methodology appropriate to the task of watershed modeling for the fate and transport of copper from vehicle brake pad wear debris in the environment? Are there any other approaches or modifications to the approach described here that you recommend?

2. Based on your experience with similar fate and transport of pollutant efforts, kinds of advice do you have for the US EPA watershed modeler in conducting watershed modeling for the environmental fate and transport of copper?

3. Will the data generated by the planned modeling efforts be appropriate inputs for the Bay Modeling? Would you recommend any modifications to the procedures to improve the usefulness of the model data for the Bay Modeling?

4. Will the data generated by the air deposition model provide appropriate inputs for the watershed modeling approach described in this workplan?

<u>Comments Received</u>

Comments of Professor Mark Schlautman, BPP Technical Advisor, School of the Environment, Clemson University, (July 22, 2004).

The only questions I have for Jim concern mass balance and how the model treats BPWD/copper landing on pervious surfaces. If I understand correctly, only BPWD/copper that lands on impervious surfaces is subject to washoff and ultimate transport to streams and the Bay. What happens to BPWD/copper that lands on pervious surfaces? Does this "compartment" merely act as a sink for BPWD/copper in terms of mass balance? Can soil erosion and/or overland flow of other particulate matter from pervious surfaces (e.g., when rainfall has high intensity) be important? Does the fact that rainwater potentially can leach copper from BPWD (that is, change it from particulate to dissolved forms) make any difference in its potential for mobilization from pervious surfaces to streams?

Comments of Tim Merkel, Representing friction material manufacturers (July 26, 2004).

I reviewed both of the attached documents. My only suggestion for Jim Carleton is that he should run spell check on the final document since there are several typos, including the title.

Comments of Arlene Feng, member of ACPWA (July 26, 2004).

Pg. 3 For the modeling described in this report, HSPF will be used to simulate runoff in the 5.5 square mile Castro Valley watershed (Figure 2),

Page: 2
The “Castro Valley Creek watershed” is not the same as “Castro Valley”, an unincorporated community that extends over several watersheds.

Pg 4. With each input, the associated uncertainties will be compiled to the extent possible.

Pg 5. Figure 2. Proposed domains for multiscale modeling: (a) San Francisco Bay Area domain for the box model sim[illegible]on of regional background (source: http://www.mapquest.com, 2003), (b) the Castro Valley

Pg. 10 Comprehensive storm drain network maps for the San Francisco Bay drainage area are in the process of being compiled, but do not exist at this time (Eric Wittner, SFEI, personal communication). The City of San Francisco itself is served primarily by a combined sewer system, which delivers most of its runoff into the ocean rather than the Bay (Arleen

Pg. 11 The California Interagency Watershed Mapping Committee's Calwater 2.0 (http://www.ca.nrcs.usda.gov/features/calwater/) watershed map may serve as an initial template. Boundaries may be added or modified to include watersheds with pour points **

Comments of Arlene Feng, member of ACPWA (August 6, 2004).

2.2 A potential advantage of HSPF is that it is better than SWMM at modeling hydrological processes in natural, less-urbanized areas, of which there are significant areas in some watersheds.

Lack of distinction between BPWD and other copper sources is likely to be a sticking point, especially in light of Kelly's recent finding for CEP that marine antifouling coatings may represent a source of similar magnitude in Bay--should at least mention the complementary aspects of project aimed at this question.

Also, 2 questions regarding reference to NURP data in this section:

a) In terms of overall qualitative trends in use in brake pads, the workplan seems to assume that copper in BPWD was more or less constant since the NURP data collection period of 1978-1980. But is this a valid assumption? The proceedings in Phase 1 BPP report include a summary of WCC (1994) that noted that disc brake use in cars was "increasing" at that time, and none of brake pads tested as representative of the registered vehicles in Santa Clara Co. were from model years earlier than 1985. WCC also suggested that European and Japanese imports might have more copper per vehicle at that time, but a lot of the increase in imports market shares only began after energy crisis of 1977--also the asbestos phase-out for the brake friction industry was noted as still "taking place".

b) When Ching-lin and I attended the SC meeting last fall, Jim Pendergast noted there are serious QA considerations about the NURP data (due to trace metal contamination from equipment used). Has EPA since determined that is this not an issue for Cu, or does this mean that the data is so noisy that the data can be interpreted rather loosely with the watershed model?

Comments of Jim Carleton, EPA Watershed Modeler (July 29, 2004).

I want to point out for the reviewers that I have discovered a typo in my document, with respect to one of the equations. To my chagrin, I had actually fixed this same error in my AWRA conference paper, after Betty Pun noticed it. Somehow the earlier, incorrect version of the equation made it into this document, and I missed it until now. Equation 3 should say $dM/dt = - k3RM$, where k3 is in units of inverse length (1/L), not inverse time (1/t). M is simply mass, and R is rainfall rate (L/t).

Comments of Ken Schiff, Southern California Coastal Water Research Project (September 20, 2004)

1) *In your assessment, is the proposed methodology appropriate to the task of watershed modeling for the fate and transport of copper from vehicle brake pad wear debris in the environment? Are there any other approaches or modifications to the approach described here that you recommend?*

The proposed methodology is a very reasonable approach for modeling urban and non-urban watersheds. HSPF is a well documented model and has been used abundantly both nationally and internationally. In my experience, provided the model receives accurate input data in both the appropriate spatial and temporal scales, HSPF can provide useful and reliable hydrographic and water quality results at daily time steps as proposed in the workplan. The accuracy of the input data in this application is difficult to judge, since this tends to be more site specific and I am unfamiliar with this exact location, but appears reasonable (20+ years of daily meteorological and flow data, unspecified sample size for water quality dating back to 1989). I am also impressed to see the workplan incorporate some uncertainty analysis (pg 12), an important element that is often overlooked.

My largest difficulty is specifically modeling the copper coming from vehicle brake pad wear debris (BPWD). As I understand it, the buildup and washoff components of the model are nonspecific as to source, or even mode of action (i.e. direct dep from regional air vs. air dep from resuspended particles vs. direct particle dep from the vehicle). Similarly, once buildup occurs, the model cannot discriminate differential transport of copper to the Bay between BPWD and other sources. Based on what was presented to me, I would surmise that EPA will compare the atmospheric deposition flux data to the modeled buildup coefficients, with the difference between the two being attributable to other sources, and assume the two categories of sources have equal transport efficiencies. To my knowledge, very little work has been conducted on transport efficiencies of various sources and none with BPWD.

One difference in approach the EPA may wish to consider is the use of potency factors instead of using buildup and washoff coefficients directly for copper. Potency factors rely on an underlying assumption that most copper is transported to receiving waters in the particulate fraction, an assumption we've found to be true regardless of watershed in our region. In essence, the modeler constructs buildup and washoff coefficients for particles, then uses an adjustment factor to estimate copper concentration. The approach is enhanced through the use of differential particle sizes. This approach may be useful for this application, especially since the atmospheric modelers may be estimating flux at different particle size bins. This, in turn, can be used for differential transport through the watershed because HSPF does have particle size subroutines. Furthermore, a particle-based approach should be favored by the Bay modelers. Finally, I didn't see any mention of collecting additional data to support the model. However, if empirical data does need to be collected in the future, collecting suspended solids is certainly much easier and cheaper than copper.

One element of the approach that I did not see was a rigorous validation of the model with an independent data set. Calibration in the Castro Valley watershed appeared extensive, but there was little mention of validation, especially after extrapolation to the rest of the Bay watershed (i.e. pg 4, 2nd para). Two general approaches are typically used for validating watershed models. The first is segregating the calibration data set in two, using the first to calibrate and the second to validate. As an example for the Castro Valley watershed, calibration could occur between 1971 and 1995, then validation from 1996 to 2004. A second approach is to calibrate in one watershed, then validate in a second (or more) watershed(s). Oftentimes, we do both. Regardless, both the calibration and the independent validation data set need to cover a wide range of hydrological and water quality conditions in order for one to believe that the extrapolations to unmonitored locations or time periods are reasonable.

2. *Based on your experience with similar fate and transport of pollutant efforts, [what] kinds of advice do you have for the US EPA watershed modeler in conducting watershed modeling for the environmental fate and transport of copper?*

We have used HSPF in heavily urbanized watersheds and found that the model works extremely well. If I may offer several pieces of advice. First, the workplan relies heavily on the BASINS data sets. We have found that these data sets can be readily improved by locating updated or more detailed local data. For example, the workplan calls for using NLCD land use data from 1992. Although the more recent NLCD may not be available yet, I am sure AMBAG has more recent data than 1992.

In our experience, model applications in urban watersheds begin to lose precision under a couple of scenarios. The first is during smaller storm events, where rainfall extrapolations are less accurate. Substantial rainfall spatial heterogeneity often occurs during small events and, without spatially resolved precipitation data, hydrologic and water quality modeling results can be biased. This is important because the workplan calls for using a single rain gauge and extrapolating rainfall to unmonitored areas using isohyets based on long term averages. I recommend looking for additional rain gauges, if not in the Castro Valley watershed, then for the Bay wide area modeling. Once again, moving beyond the BASINS data sets and acquiring local agency data will help. The second area of model failure is during dry weather. This occurs when nonpoint sources of water, say from lawn overwatering or car washing, begins to overwhelm groundwater exfiltration. From a modeling perspective, nonpoint sources of water are virtually impossible to estimate because they are highly variable and unpredictable. To make things even more difficult, nonpoint source water quality is also highly variable and unpredictable. This may be less of an issue in the San Francisco Bay region where groundwater may be a significant fraction of the dry weather flow. However, I would recommend that EPA consider relative contributions of dry weather flows and quantify them to the extent possible.

3) *Will the data generated by the planned modeling efforts be appropriate inputs for the Bay Modeling? Would you recommend any modifications to the procedures to improve the usefulness of the model data for the Bay Modeling?*

This is a difficult item for me to judge because I have not used MIKE 21 and the workplan is almost completely silent on data export for the Bay modelers. That being said, post-processing algorithms can likely be used to map most of the loading data to the MIKE 21 input decks. MIKE 21 is a proprietary model, though, and any tweaking of MIKE 21 to accept the data might be costly. The workplan does call for communication among modeling groups, so good intentions are there. It will be prudent of the contract managers to ensure that early and frequent communication occurs. One area of concern is the time scale of Bay model inputs. The workplan currently calls for average daily watershed loading. However, daily loads may not be sufficient for the Bay modelers who, I assume, may be operating at finer (i.e. tidal) temporal scales. The temporal resolution among modeling groups should be explored. Also, the workplan specifically avoids the Bays two largest watersheds, the Sacramento and San Joaquin Rivers. Obviously, the Bay modelers will need to incorporate these two large inputs and ensure the watershed modelers are working on similar time scales and periods.

> *4) Will the data generated by the air deposition model provide appropriate inputs for the watershed modeling approach described in this work plan?*

The atmospheric deposition modeling is one of the most intriguing elements of the study and I would love to hear more. Based on my experience, the atmospheric deposition modeling may be one of the greatest areas of uncertainty. This is because the source emissions are often imprecise. So, even if enormous effort is spent assessing the atmospheric emissions of BPWD, the emissions inventory for other sources may be largely inaccurate. Moreover, our studies have shown that the major component of atmospheric emissions for copper (and many other trace metals) is dusts, which are a composite of multiple sources (including BPWD) that are continually being resuspended in the urban environment. Thus, if the goal is to estimate the fraction of atmospheric deposition due to BPWD, beware of uncertainty. Finally, the deposition flux rates can be readily used by the watershed modeler for interpreting buildup coefficients. These rates are often averaged in both space and time, which may be adequate for your atmospheric modeling purposes, but not your watershed modeling needs. In our experience from measuring empirical deposition, flux rates are typically very heterogeneous and often highly variable.

Comments of Wayne C. Huber, Water Resources Engineering, Oregon State University, (September 22, 2004)

Specific review questions are addressed subsequently. First, some general reviewer's comments will be made.

GENERAL COMMENTS

This is a difficult and challenging project. Overall, the goal is to understand the impacts of brake pad wear debris (BPWD) of copper on the water quality of San Francisco Bay, with an implied goal of eventually mitigating negative impacts to the degree that mitigation can be achieved. Implicit in this goal is 1) the assumption that loadings to the Bay from BPWD can be quantified enough so that the linkage between Bay water quality and BMWD can be confirmed, and 2) effects of a reduction in BPWD can be demonstrated. Confirmation of one or both assertions will be a difficult technical task

<u>The overall Work Plan cries out for a mass balance analysis</u>. For the Castro Valley Watershed, how many kilograms of copper per year are discharged through the USGS gage? What does this loading to the Bay translate to in terms of kg/area-period, where "area" could be the whole 5.5 mi^2 watershed or perhaps just the impervious portion? "Period" could be the whole year, especially if Castro Valley Creek is perennial, or perhaps just the wet season. If a Cu loading is derived from the flow data, does it bear any resemblance to the 0.0013 – 0.0015 lb/ac-day values cited on page 12 of the Work Plan? (There is no reason that it should.) Or perhaps, the 0.0013 value was itself derived from annual flow data? If so, we don't know that it came from BPWD.

Let's say a Cu loading is derived from flow data. Can it be disaggregated into atmospheric and other sources? On what basis? If the atmospheric deposition effort is conducted without using the stream gaging data, can a ballpark loading be found that corresponds in any way to the flow-derived loading? My suspicion is that the atmospheric loading will be much smaller than the flow-based loading, in which case where is the copper coming from? How much of it can be attributed to BPWD? <u>What are all the sources of copper, not just BPWD?</u> Such sources include anthropogenic sources but also any natural leaching that might occur. Has such an order-of-magnitude mass balance analysis been performed as part of ongoing TMDL efforts? If so, have copper sources to the Bay been sufficiently quantified to justify the more detailed modeling?

Can a similar mass balance be performed for the Bay itself, that is, to break down the loadings between surface inflows and atmospheric deposition, and accounting for ocean exchange and possible internal loadings? No matter which loading is greater, what contribution to the loading can be attributed to BPWD? Can we then see the effect of reducing BPWD by some means? And is there enough Cu in Bay sediment such that the "reservoir" of particulate Cu can be resuspended during high winds and overwhelm any effort to reduce loads? (This is a common problem in lake eutrophication studies, wherein the efficacy of phosphorus or nitrogen removal in inflows must be evaluated against internal nutrient recycling.)

The danger I'm trying to articulate is that we may not be able to measure, let alone model, the most significant sources and origins of copper to the San Francisco Bay. If we can't do this, then it seems to me that the overall project is flawed at best and futile at worst. If such mass balances have already been performed, it would have helped to learn about them in the material sent to reviewers.

And in a sense, the watershed modeling is overkill. HSPF will be used with an hourly time step (15 min rainfall data might be better but unavailable for this locality), but there is little chance – or need – to simulate accurately a detailed storm runoff pollutograph. The need for the Bay is most likely seasonal or annual loadings of copper. Certainly air deposition data can't be provided reasonably on a storm event basis (or am I wrong?). And for that matter, MIKE-21 is probably overkill as well; a simple "box model" might serve adequately, if exchange rates to the ocean could be well enough defined. (Several models of SF Bay have been developed over the years; why is MIKE-21 being used? I acknowledge, it is a good circulation model.)

Incidentally, a quick review of the National Climatic Data Center (NCDC) web site reveals that there appear to be hourly precipitation data at other than just the San Francisco airport. For example, hourly data are listed for the Oakland Airport, Berkeley, and San Leandro in Alameda County. However, coverage may not be continuous enough at these other sites for the continuous modeling (good idea) planned for the study.

A spreadsheet would suffice for an overall mass balance analysis. All the BASINS-HSPF and Bay models do is distribute loadings in space and time. It is a little hard to believe that the Bay is sensitive enough (to short term spatial and temporal variations) to warrant this. Moreover, the temporal and spatial scale for atmospheric deposition will be much larger (both temporally and spatially) than the detailed temporal and spatial scales that can be employed by the watershed and Bay models. If there is a demonstrable basis for believing that BPWD contributes a high portion of the Cu load to the Bay, and if this loading is mainly from dry and wet deposition onto impervious surfaces, a seasonal or annual spreadsheet-based analysis might well suffice.

In order to achieve credibility, the overall study must include an overall mass balance that lists all sources of copper and their ballpark loading rates, either in terms of mass/area-time for diffuse sources, or in terms of mass/time and/or concentration x flow for industrial, institutional and natural ("upstream") sources. What kind of closure can be achieved when loadings are estimated <u>independently</u> from monitored Cu values at the outflow of Castro Valley Creek?

RESPONSE TO SPECIFIC REVIEW QUESTIONS

1. *In your assessment, is the proposed methodology appropriate to the task of watershed modeling for the fate and transport of copper from vehicle brake pad wear debris in the environment? Are there any other approaches or modifications to the approach described here that you recommend?*

a. As explained above, a mass balance analysis should first demonstrate that it is necessary and useful for short-time and small spatial scale watershed modeling, of the type of which HSPF is capable. Let us assume that HSPF-type modeling is justified:

b. Then I have no problem with HSPF in place of SWMM (or other choice) if regional studies have already used it and a calibrated (for quantity) version is in place. The BASINS-

GIS connection is very useful, and the overall BASINS model very usefully incorporates spatial data.

2. *Based on your experience with similar fate and transport of pollutant efforts, kinds of advice do you have for the US EPA watershed modeler in conducting watershed modeling for the environmental fate and transport of copper?*

One issue that I hope Prof. Sansalone will discuss more intelligently than I am able to do is that of copper speciation. How much of the Cu is soluble, vs. insoluble? What is the nature of the particulate Cu in terms of particle size distribution? This kind of information directly impacts the treatability of stormwater for removal of Cu and might also lead to implications regarding the origin of the copper. Are there chemical characteristics (nuclides?) of the copper that can be traced back to BPWD? We need all the help we can get to make the link between BPWD (and other sources!) and Cu in stormwater and the Bay.

My experience with the SWMM model is that the only practical method for calibrating water quality estimates, both for long-term loads and even more, for short-term pollutographs, is "simply" to adjust buildup and washoff rates so that measured effluent concentrations and loads correspond to simulated concentrations and loads. Sometimes a constant event mean concentration (EMC) is all that is warranted on the basis of sparse data. That leads to constant concentrations in the flow, with loads varying only because of flows (load = concentration x flow). It is extremely difficult to find (read this to mean, "I haven't seen any") modeling studies in which independently derived loading rates can be found to produce watershed loads that correspond to monitored stream loads (from USGS or other gaging). Virtually always, buildup and washoff parameters are adjusted to get the model to agree with monitored watershed loads – this is not hard to do, and the study will use good PEST software to help in this regard. But in this case, it is tenuous to assign a cause and effect to the imputed surface loads. This has been one of the difficulties in simulating the effectiveness of street sweeping, for instance. I wish the modeling team great success, but a compilation of independent surface loading rates for input into HSPF that includes all potential sources and that results in simulated watershed effluent loads in the same ballpark as monitored stream gaging loads is highly unlikely. This leads back to the simpler mass balance study to justify a more detailed modeling study.

Whether or not HSPF or a spreadsheet is used to provide Cu loadings, land use might well be a factor, in addition to imperviousness. Broad land use categories should be obtained and used in the model. If Castro Valley Creek is perennial, that is, if it has baseflow throughout the year, which is very common in urban streams even in arid areas, then that dry-weather flow loading must be accounted for. And what is the source of any copper in the baseflow? Can it be controlled?

3. *Will the data generated by the planned modeling efforts be appropriate inputs for the Bay Modeling? Would you recommend any modifications to the procedures to improve the usefulness of the model data for the Bay Modeling?*

I have already commented on the spatial and temporal scales at work in both the watershed and the Bay. It is not necessary that the deposition and watershed and Bay models all three correspond in their scales. For instance, even if seasonal copper loads would suffice for analysis of Bay water quality, it might well be easier and more accurate to provide these from a continuous simulation of storm events. I envision atmospheric deposition at the air-shed scale. Hence, there will likely be one atmospheric loading rate for the whole Castro Valley watershed (and maybe for the whole Bay area). The minimum watershed modeling spatial resolution that supports other possible Cu sources, including variations based on land use and point sources, should be used in the modeling.

4. *Will the data generated by the air deposition model provide appropriate inputs for the watershed modeling approach described in this work plan?*

Again, this relates to earlier discussion regarding scale. I would be most concerned about the mass balance of copper for the air-shed. Air transport out of the watershed is shown in Figure 1. What about air transport into the air-shed? What if BPWD were reduced in the Bay area and the same copper deposition was still experienced? All sources and sinks must be identified, or at least suggested. Then data needs for the overall mass balance can be more easily recognized. But the key issue for this study, I believe, is whether or not atmospheric deposition provides the principal source of copper from the watershed, through buildup and washoff, and its relative importance to the Bay. And if atmospheric deposition of copper is the principal source of copper, how much of that copper is due to BPWD?

A very cursory review of the air deposition modeling work plan available on the web indicates a link of air quality to traffic intensity, e.g., Equation 1. This also suggests higher loadings as a function of land use, i.e., higher loadings in areas of high average daily traffic, which might also be justified on the assumption of direct deposition (loading) onto roadways from vehicles. If such a connection can be made (spatially variable deposition), this lends additional justification to a distributed watershed model, like HSPF. What I do not see in my quick review is an emphasis on the source of copper in the wet and dry deposition. I'm still missing the justification of the highly implicit assumption that most or all copper comes from brake pads.

SUMMARY COMMENTS

The overall purpose of this study is laudable: to lead to clean up of San Francisco Bay with regard to heavy metals in general and copper in particular. But my feeling is that the modeling cart may be coming before the horse. While it is certainly possible to calibrate a watershed model (HSPF) to reproduce measured copper concentrations in Castro Valley Creek, making the connection with brake pad wear debris (BPWD) is another matter. For the latter purpose, I summarize my suggestions as follows:

1. Perform a mass balance analysis for the air-shed, watershed, and Bay using current best available copper data from all suspected sources, sinks, inflows, and outflows. Is it possible to identify BPWD as a significant source? If so, are BPWD sources large enough so that a reduction will be observable in the Bay? This kind of analysis is

basically spreadsheet-based and need not employ continuous simulation watershed models or detailed Bay circulation models. It will most likely result in estimates only of seasonal or annual loads.

2. If the link to BPWD can be made quantitatively then some model that relates the sources, sinks, inflows and outflows of copper for the watershed and Bay can be used. If only seasonal or annual loads are important, then HSPF may be more than is needed, although the link to the spatial databases inherent in BASINS makes HSPF an attractive model to use. But the fear is that HSPF can only be calibrated through matching of surface loadings to monitored stream loads at the watershed outlet. If this were to occur, it is hard to see how the model can simulate the impact of any reduction in BPWD since we do not know the relative magnitude of all diffuse and point sources to the Bay – again, reverting to the mass balance issue.

3. The difference between this brake pad study and other urban nonpoint source runoff control studies is the emphasis here on source control, in particular, control of BPWD. When a study will result in direct treatment of the stormwater, e.g., through so-called best management practices (BMPs) such as ponds or swales, then an estimate of stormwater loads derived from calibration against monitored stormwater loads is fine. The stormwater will be treated in order to reduce stormwater loads, and no reliance on source control is presumed (although certainly source control plays an important part in improving stormwater quality; removal of lead from gasoline is a huge success story). In the stormwater arena, it has been hard to demonstrate that source control has been effective in reducing stormwater loads, through practices such as "good housekeeping," public awareness (e.g., storm drain stenciling), K-12 programs, etc. Paired watershed studies are generally inconclusive statistically, although everyone would agree that source control is a good idea.

4. I fear I am being too harsh with regard to the watershed modeling plan, but it is not a criticism of the proposed modeling per se, but rather where the HSPF modeling fits into an overall analysis. Before initiating a study of this magnitude, there should be an up-front demonstration of the magnitudes of the loadings involved and their connection with copper concentrations in San Francisco Bay. In my opinion, only then are more detailed modeling studies justified. Maybe such an analysis has already been performed to justify the more extensive modeling that is proposed, perhaps through the related TMDL studies. If so, go for it! If not, do the order-of-magnitude mass balance analysis first.

Comments of John Sansalone, Associate Professor & Louisiana Land and Exploration Professor Civil and Environmental Engineering Department, Louisiana State University, (September 24, 2004)

1. In your assessment, is the proposed methodology appropriate to the task of watershed modeling for the fate and transport of copper from vehicle brake pad wear debris in the environment? Are there any other approaches or modifications to the approach described here that you recommend?

Given the constraints of the plan, the plan is a reasonable first-order attempt to model the fate and transport of copper in an urban watershed. However, I do not know that you can specifically identify vehicle brake pad wear debris as the only major source of copper from which the project is modeling fate and transport. The sites identified for deposition sampling (in particular the open space land use) will receive copper from a variety of sources. While brake pad wear debris may be a major source, this source would require a specific fingerprint in order to state and illustrate a relationship between the source and the fate/transport in the environment. Particle size (and density) from the dynamometer produces a particle number distribution (PND) that is tied to a specific source, directly at that source. There are many urban sources that generate specific but overlapping PNDs of either copper or copper associated particles. The question is, can the PND from the brake pad wear debris source be linked to the dry deposition particles retrieved from the samplers by a physical or chemical link? It may be very difficult to illustrate a PND or gravimetric balance between mobile fluxes and fluxes obtained by the dry deposition samplers; but it is worth the attempt.

Understanding that there are time and financial constraints, given the watershed size and the spatial/temporal variability of precipitation across the watershed, is there access to another meteorological station in addition to SFO? This is not a small watershed and the watershed is a three-dimensional watershed.

The linkage between constitutive properties and relationships (partitioning, PND, partitioning, dissolution, distribution, wash-off) for different model components and inputs could use some strengthening; or at least identification of the uncertainties associated with these linkages, given the project constraints. These may be beyond the project scope.

2. *Based on your experience with similar fate and transport of pollutant efforts, what kinds of advice do you have for the US EPA watershed modeler in conducting watershed modeling for the environmental fate and transport of copper?*

Recognize that build-up and wash-off processes are not always exponential processes, even in source area watersheds. For instance, wash-off is a function of particle supply limitations, availability and PND at the point of wash-off. Tied to hydrology, these relationships can be complicated; and an exponential wash-off process represents one limiting transport behavior. Having said this, such behavior is rarely ever measured. Unless I have missed the specific methods for association between source characterization, such as brake pad wear debris fluxes, PND and similar quantities determined in the watershed, the plan may be able to infer fate and transport for a specific source of copper, and is more of an overall fate and transport model for copper in an urban watershed.

3. *Will the data generated by the planned modeling efforts be appropriate inputs for the Bay Modeling? Would you recommend any modifications to the procedures to improve the usefulness of the model data for the Bay Modeling?*

See comments from questions 1 and 2. The data generated can be helpful to the modeling effort. However, the appropriate linkages between the source characterization data and how these data will be used in the specific modeling efforts needs to be made – this linkage is not clear. It would be helpful to identify the likely range of uncertainties with respect to the data inputs and in the modeling results illustrate the impact of the uncertainties. It is not well defined in the plan how the components of the brake pad wear debris data collection are serving as specific inputs to the modeling effort. The linkage between source characterization and atmospheric deposition modeling is stronger than linkages where watershed modeling assesses the fate and transport of copper – this is more tenuous. It would be helpful to illustrate that the approach to data collection is based on what data are needed for desired modeling deliverables.

With respect to the watershed modeling effort there are 4 challenges. These challenges may not be resolvable within the scope of the project; but they provide insight into the modeling effort and future watershed fate and transport efforts. First, the kinetics of dissolution requires quantification. Second, partitioning between the dissolved and particulate phase requires quantification. Third, distribution of copper across the particulate phase requires quantification. Once copper has partitioned back to the particulate phase (to anthropogenic urban sediments transported in rainfall-runoff) copper distribution can be predominately towards the coarser fraction depending on hydrologic, chemical, granulometric, and watershed characteristics. Finally, the equilibrium speciation of aqueous copper requires quantification. These are illustrated in Figure 1. Figure 2 illustrates such copper distributions for a number of urban areas where predominate sources of copper are transportation. Figure 2 results are controversial (but accurate) because the results go against conventional wisdom and sampling/analysis of the entire gradation is rarely carried out.

4. *Will the data generated by the air deposition model provide appropriate inputs for the watershed modeling approach described in this work plan?*

See comments from questions 1, 2 and 3.

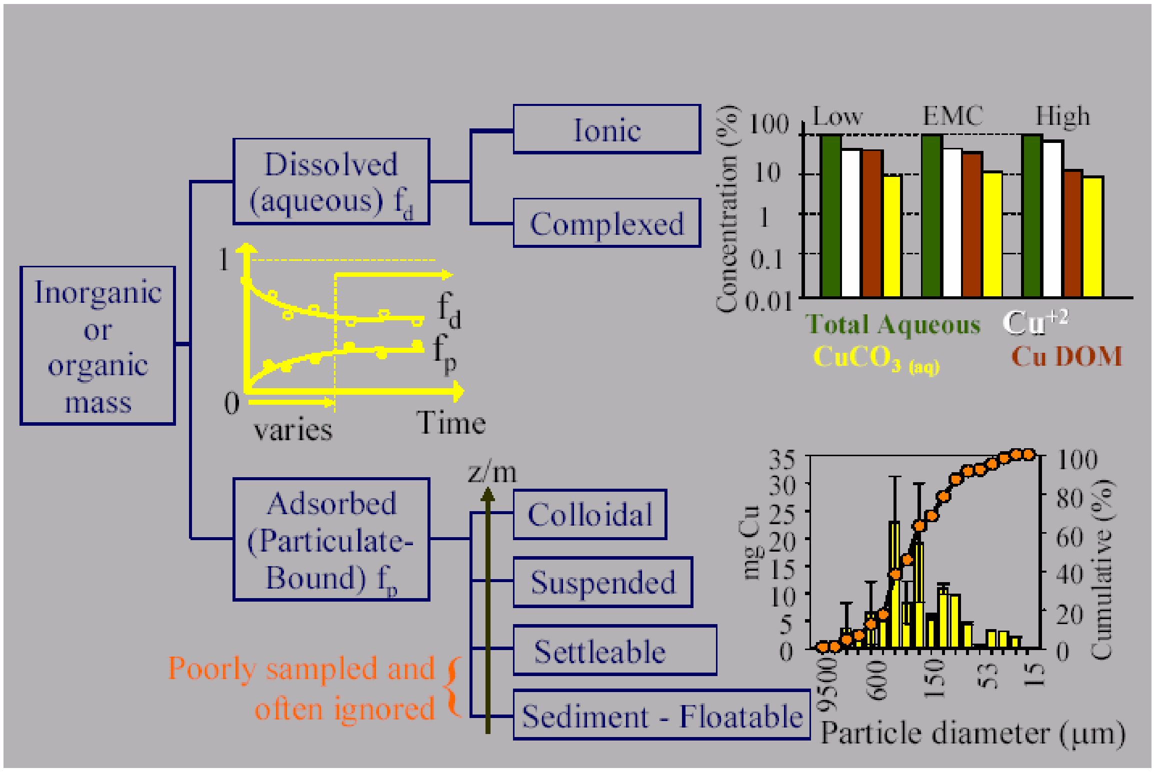

Figure 1. Conceptual illustration, with actual copper data shown, of constitutive relationships for copper in rainfall-runoff.

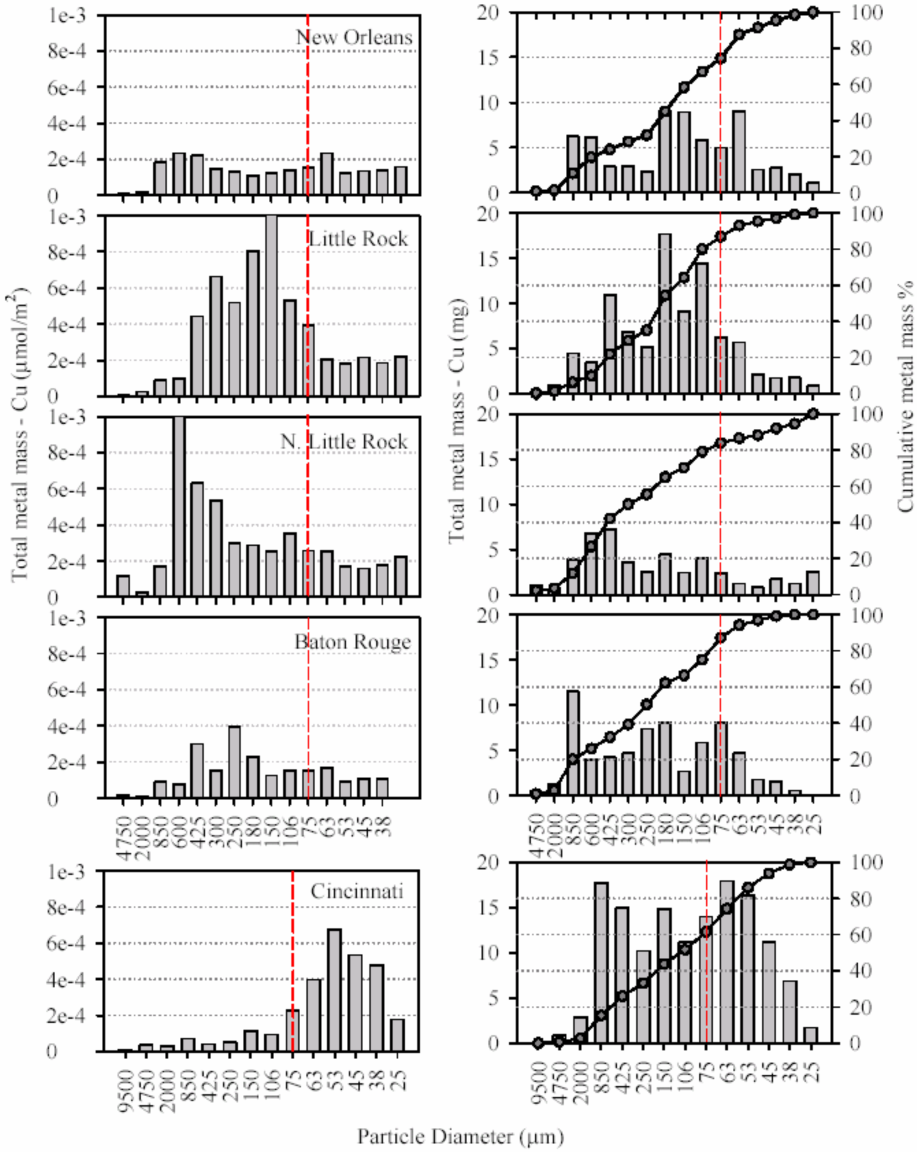

Figure 2. Plots of gradation-based Cu concentration in µmoles/m2 and mass (mg) for accumulated particulate matter at five urban land use sites impacted primarily by transportation.

Metal mass (mg) was based on 1000-g of dry granulometric mass.

Comments of Bob Ambrose, Environmental Engineer, U.S. EPA, Ecosystems Research Division (October 2, 2004)

I have reviewed the draft work plan for modeling the watershed loading of copper from brake pad wear. This multimedia pollutant fate modeling problem is by nature difficult, and procedures to properly link individual media models are still being developed and tested. While this plan has general merit, there areas of concern that need to be addressed. These deal with pollutant mass balance, model calibration, intermedia mass transport.

First, the study plan rightly emphasizes the buildup and washoff of air-borne copper from impervious surfaces. Because pollutant delivery from these surfaces is so efficient, this should constitute the largest load category to the Bay (along with, perhaps, direct atmospheric deposition to the Bay). While pervious segments are mentioned, no details are given about modeling the fate of copper deposited to pervious surfaces. I assume that these surfaces would use the same buildup and washoff equations that are used on impervious segments, but with different parameters. Will partition coefficients be used to calculate the dissolved copper fraction available for runoff and leaching?

I am concerned about one aspect of the calibration procedure, namely the proposal that the deposition parameter k_1 be calibrated along with the removal parameters k_2 and k_3. The deposition rate, however, is calculated by the atmospheric model based on source loading estimates and the calibration of local atmospheric fate processes. Not using the atmospheric model's deposition rate (as averaged properly over space and time) introduces mass balance discrepancies into the modeling system. Mass balance should be enforced as rigorously as possible. If stream data are used to calibrate k_1 in the watershed model, then the atmospheric model should be recalibrated to give this same deposition rate. This would be tantamount to using tributary data to calibrate parameters in the atmospheric model. While that might be ok if there is a lack of data to directly calibrate and confirm the atmospheric model, I don't think that this would be optimal use of the observed datasets. In any case, however, calibration procedures should at least assure mass balance in this intermedia transfer.

Another mass balance issue is that non-washoff removal, k_2M, which represents wind-erosion from the watershed surface, is not a source term to the atmospheric model. This mass is effectively lost from the system. I don't know whether this mass balance error will be significant, but it must be acknowledged and checked out. If this mass release from the watershed is a significant fraction of the total break pad discharge to the atmosphere, then an iterative modeling procedure would need to be implemented. It might be possible to arrange for a parallel application of a true multimedia model, such as TRIM or MEND-TOX, to address this and other potential mass balance issues on the Castro Valley subwatershed. The EPA contact for TRIM is Deirdre Murphy at OAQPS in RTP, North Carolina.

Finally, it would be nice to present the final results in a mass balance summary diagram much like Figure 3 in the August 2004 Break Pad Partnership Update. I would like to see the long-term average mass fluxes for each of the arrows in that diagram, and the total masses and concentrations in each of the media depicted. You may already have plans to do this, but I do want to encourage your efforts to fill in “The Big Picture.”

I will be glad to discuss these comments with you, your reviewers, and your partners in this study.