Appendix A

Summaries of Post-fire Effect Research in Southern California

Background Material Provided by Participants of:

WATER QUALITY EFFECTS OF POST-FIRE RUNOFF

August 18-19, 2008

Workshop Goals:

1. Summarize status of the science on post-fire water quality effects
2. Identify important elements for assessing post-fire water quality effects
3. Provide initial recommendations for development of a regional monitoring program

Numerous individuals and agencies have been conducting research on the effects of post fire runoff on storm water quality, sediment contamination, receiving water quality, and aquatic biology. The table below is a sample of some of the major recent and ongoing research activities in southern California

Table A-1. Recent research related to post-fire runoff effects.

Institute	Contact	Topic	Location	Status
CDFG	Pete Ode	benthic communities	southern California	future
City of Encinitas	Mayela Padilla	water quality	San Diego region	ongoing
CSULA	Crist Kachikian	water quality, isotope ratios	southern California	ongoing
Flow Science	Susan Paulson	water quality	Santa Susana	2003-06 fires
Geosyntec	Brandon Steets	watershed recovery, erosion control	Santa Susana, San Diego & Orange Counties	2003, 2005 fires
NMFS	Nat Sholtz	biological effects	PW northwest and S. Ca	near completion
NPS	Marti Witter	fire ecology	Santa Monica Mts.	ongoing
OC RDMD	Grant Sharp	water quality	Santiago Canyon	2007 fires
SARWQCB	Aaron Buck	water quality	Orange County	future
SCCWRP	Eric Stein	water quality	Ventura - Dry and Runkel Cyns	2003 fires
SCCWRP	Eric Stein	water quality,	Los Angeles - Ballona	2003 fires

Institute	Contact	Topic	Location	Status
		aerial deposition	Creek	
SD Co.	JoAnn Weber	water quality	San Diego County	2007 fires
SIO	Dimitri Deheyn	bioaccumulation	SD County	proposed
SPAWAR	Chuck Katz	water quality, sediment quality	Camp Pendleton	2007 fires
Tahoe Science Consortium	Zach Hymanson	water quality, air dep, ecology	Lake Tahoe	ongoing
UC Extension	Sabrina Drill	fish and benthic ecology	S. Ca. region, inland empire	ongoing
UCLA	Terri Hogue	water quality	Ventura - Piru/Pyramid	2006 Day Fire
UCLA	Terri Hogue	runoff and infiltration	Ventura - Dry and Runkel Cyns	2003 fires
UCLA	Terri Hogue	water quality	SB County - City Creek, Devils Cyn	2003 fires
US Forest Service	Pam Padgett	plant physiology	Pacific Southwest Research Station - Forest Fire Laboratory, Riverside, CA	
USDA	Pamela Padgett	air deposition		ongoing
USDA	Pete Wohlgemuth	sediment and erosion	Riverside research lab	ongoing
USFS	Robert Taylor	water quality and sediment	San Bernardino National Forest	ongoing
USGS	Dale Cox	ecology, flood response, ash	Santa Monica Mts.	ongoing
USGS	Deborah Martin	sediment, ash, water quality	nationwide	ongoing
USGS	Eric Reichardt	water quality and ash	southern California	ongoing
USGS	John Izbicki	water quality, ecology	southern California	ongoing
USGS	Jon Warrick	water quality and sediment	California	ongoing
USGS	John Moody	sediment, ash, water quality	nationwide	ongoing

Several researchers provided summaries of their research on post-fire effects on water quality. The abstracts below are intended to provide some foundational information to guide discussions during the August 18-19 workshop.

Direct Effects of Post-fire Runoff

Preliminary Analytical Results for Ash and Burned Soils from the October 2007 Southern California Wildfires. Geoffrey S. Plumlee, Deborah A. Martin, Todd Hoefen, Raymond Kokaly, Philip Hageman, Alison Eckberg, Gregory P. Meeker, Monique Adams, Michael Anthony, and Paul J. Lamothe. U.S. Geological Survey

The goal of the wildland sampling was to understand potential differences in ash and soil characteristics that may result from differences in the type of burned vegetation and underlying bedrock geology. Composite samples of ash/debris and underlying soil were collected from two burned residential areas within the Grass Valley and Harris burns. The fires occurred in October 2007. Ash analyses completed to date have focused on the residential ash and burned soil samples, and to a lesser extent on wildland samples from the same burned areas.

Water leach tests show that the residential ash samples generate high pH levels (12.5–12.7). In contrast, similar water leachates of the limited number of wildland ash samples analyzed to date generate somewhat less caustic alkalinity and lower pH (9.8–10.9). Laboratory combustion testing of vegetation indicates higher pH values in leachates are associated with higher combustion temperatures, although man-made materials in residences may have been a source of the high pH in the residential leachates.

Compared to average US soils, the two residential ash samples contained elevated arsenic (up to 140 parts per million, ppm or mg/kg), lead (up to 344 ppm), antimony (up to 32 ppm), copper (up to 1,370 ppm), zinc (up to 2,800 ppm) and chromium (up to 354 ppm).

Additional follow up studies could examine: (1) variability of ash composition within and between residences in a given neighborhood, and (2) variability in ash composition as a function of residence age, type, and setting (such as north- or south-facing slope, proximity to other residences, intensity and duration of fire, and type of construction).

Water quality parameters in post-fire runoff. *Greg Mendez. U.S. Geological Survey*

In response to the 2007 fires in Southern California, the USGS-California Water Science Center collected water-quality samples in fire-affected areas during the first two post-fire storms. This sampling was coordinated with prior ash sampling conducted other USGS scientists.

The main fires affecting San Diego County were the Harris and Witch/Poomacha fires. The Harris fire burned a large percentage of the Otay and Tijuana River drainages. The Witch/Poomacha fire burned a portion of the upper San Diego River drainage and a large portion of the San Dieguito River drainage. Two sampling sites were selected in the area of the Harris fire. One site was located in a rural area on Cottonwood Creek below Barrett Lake. The site is at the head of the Tijuana River, downstream of a mobile home park that burned. The other site is located on the Otay River upstream of a drinking-water reservoir (Otay Reservoir). This second site was not sampled, because there was no flow at this site during the storms. One location was sampled in the area affected by the Witch/Poomacha fire. The site is in a residential area (Rancho Bernardo) in the San Dieguito River drainage, which flows into Lake Hodges (a drinking-water Reservoir). One sample was collected in Orange County, below Harding Canyon.

During the first two post-fire storms (11/30/07 and 12/7/07), we collected several samples over the storm hydrograph for field parameters, DOC, and optical properties. In addition, we collected several samples from each site for a full suite of constituents, including trace metals, nutrients, organic carbon, suspended sediment, and DOC fractionation. We are assessing the differences in the results between the sites, and comparing the trace metal data from the storm samples with the data from the ash samples.

<u>Pre- and post-fire contaminant concentrations in stormwater, soil and ash.</u> Susan Paulsen and Alexander Anderson. Flow Sciences, Inc.

Post-fire contaminant concentrations in storm water runoff, soil and ash from a largely undeveloped area containing some industrial activity were assessed by comparison with concentrations in pre-burn samples, as well as post-fire runoff samples collected from off-site undeveloped areas with no industrial activity. The sampling sites that had a limited amount of industrial activity was The Boeing Company's Santa Susana Field Laboratory (SSFL) area, which burned during the September/October 2005 Topanga Fire. The off-site locations were other areas that burned during the Topanga Fire, as well as undeveloped areas that burned in the Harvard Fire (also September/October 2005).

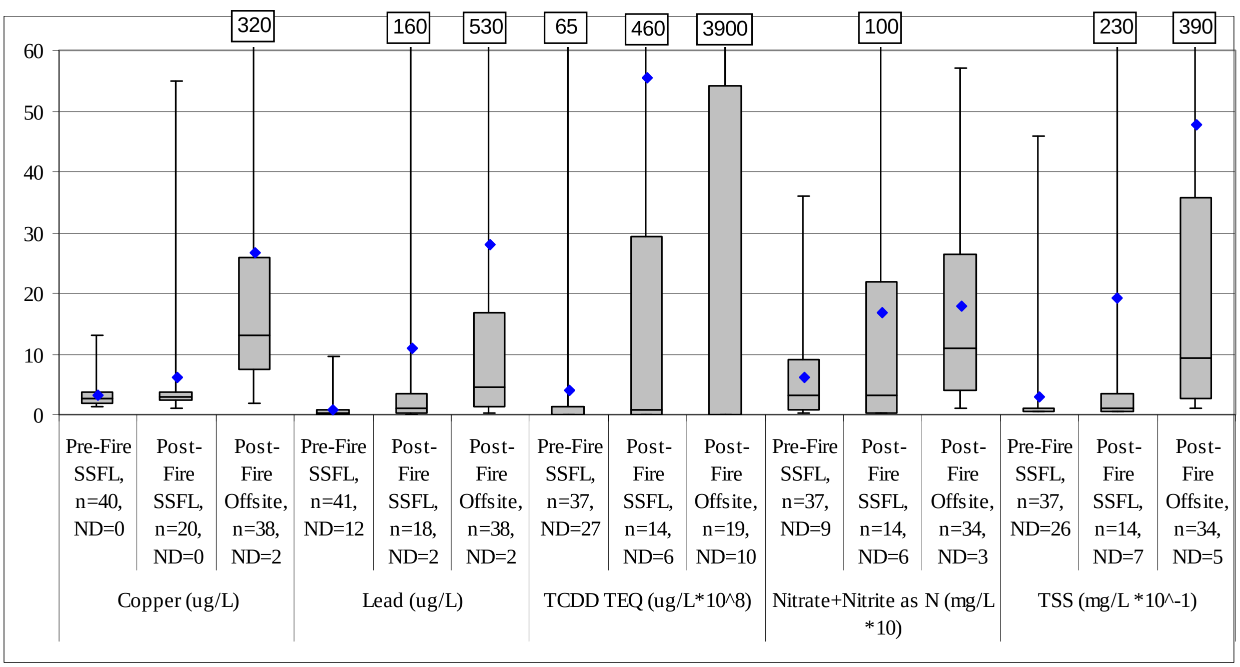


Figure A-1. Pre- and post-fire concentrations in stormwater from primarily undeveloped areas of The Boeing Company's Santa Susana Field Laboratory (SSFL), and post-fire concentrations from undeveloped burn areas outside the SSFL study area. The box plots show the minimum, 2nd quartile, median, 3rd quartile, and maximum (and mean, shown by diamond) of the dataset. Non-detects plotted as 0.5*detection limit. The total number of available samples (n=#) and the number of those samples that were below analytical detection limits (ND=#) are indicated in the figure.

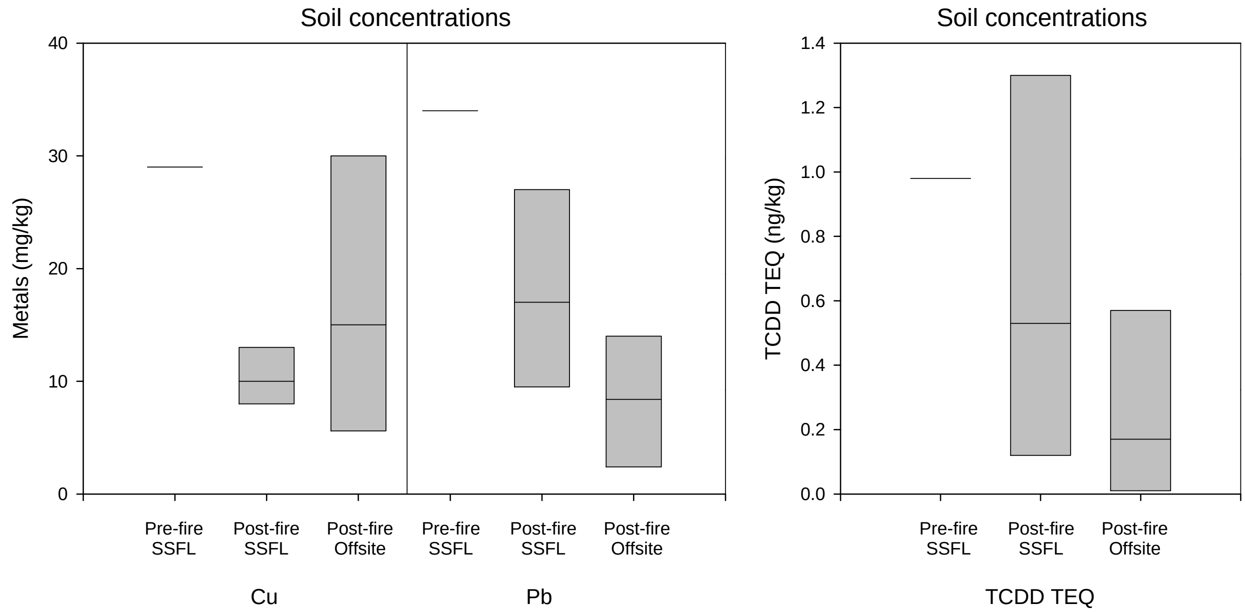


Figure A-2. Pre- and post-fire concentrations in soil from The Boeing Company's Santa Susana Field Laboratory (SSFL), and post-fire concentrations from undeveloped burn areas outside the SSFL study area. Data from the pre-fire samples are represented by a single value, while box plots for the post-fire sample data represent the maximum, mean, and minimum values.

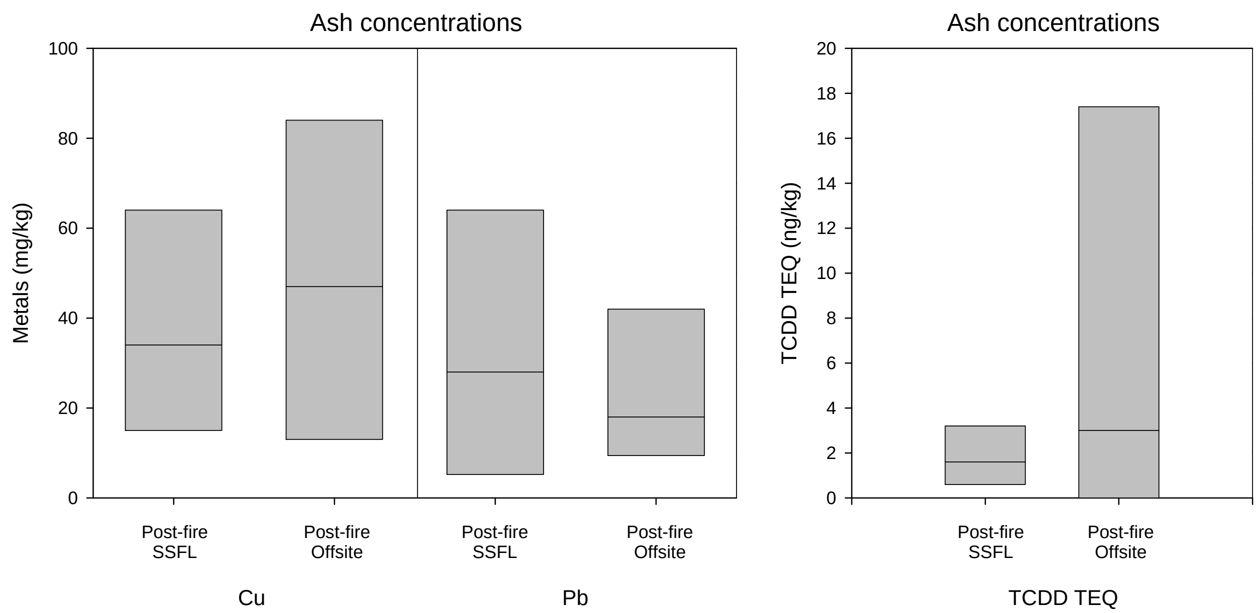


Figure A-3. Pre- and post-fire concentrations in ash samples from The Boeing Company's Santa Susana Field Laboratory (SSFL), and post-fire concentrations from undeveloped burn areas outside the SSFL study area. The box plots for the post-fire sample data represent the maximum, mean, and minimum values.

Results show that concentrations of many constituents, including copper, lead, dioxins, and nitrogen compounds, are elevated in post-fire storm water samples and in soil and ash. Storm water runoff flow rates from burned areas were several times larger than flow rates from similar, unburned drainages.

Geochemical and metal transport studies in burned watersheds in southern California.
Terri Hogue. UCLA

An extensive geochemical dataset has been used to determine the distribution of water and solutes within watersheds in the San Bernardino Mountains that were burned during the Old Fire of 2003. End-member observations (groundwater, overland flow, subsurface flow), as well as numerous streamwater samples, were collected to constrain and develop a catchment mixing model. Results showed significant changes in geochemical fluxes in post-fire catchments, corresponding to alterations in subsurface flow components in faster responding systems (increased baseflow and reduced soil water). The fires appear to have less impact on flow partitioning in baseflow-dominated systems (Jung et al., 2008). Quantified source water contributions are currently being used to optimize model simulations of post-fire runoff. More recent work has focused on post-fire nutrient and metal transport within the Piru Creek watershed, affected by the Day Fire of September, 2006. A network of soil, sediment and streamwater sampling sites is being utilized to investigate the evolution of contaminants in soil horizons and the subsequent degradation in stream water quality during runoff events. Findings show burned soils exhibited an initial significant loss of Hg at the surface followed by a sharp increase in surface Hg concentrations over the following year in comparison with the unburned soil profiles. Analysis also showed increased levels of Hg in storm runoff in unfiltered samples which correlated with TSS measurements, supporting increased erosion and related metal transport (Burke et al., 2008). Ultimately, collected data will be used to develop coupled metal-sediment transport models for post-fire watersheds.

References/Publications:

Burke, M., T. S. Hogue B. Navarro, C. Mendez, M. Ferreira, S. Lopez, C. Lin, and J. Jay, 2008: The Effects of Wildfire on Mercury Profiles and Partitioning in Soil Horizons in Southern California, *in preparation, Science of the Total Environment*

Jung, H., T.S. Hogue, L. Rademacher, and T. Meixner, 2008: Impact of Wildfire on Source Water Contributions in Devil Creek, CA: Evidence From End-member Mixing Analysis, *in press, Hydrologic Processes*

<u>Effects of wildfire on storm water metals and PAHs.</u> *Eric Stein and Jeff Brown. S. Ca. Coastal Water Research Project*

This study assessed metals and PAH loading from catchments subject to severe wildlfire. Two sets of analysis were conducted. The first consisted of paired watersheds (1 burned and 1 unburned) that were sampled following the 2003 Cedar Fire and the 2006 Day Fire to investigate the direct effects of post fire storm runoff. During the second study, pre- and post-fire storm water runoff samples were collected from the undeveloped portion of Santiago Canyon in Orange County, California. Pre-fire samples were collected during 2005 and 2006 as part of a separate study on background water quality. Post-fire samples were collected from the same locations after the October 2007 Santiago Canyon fire, in which 28,400 acres burned. For both studies, storm water runoff samples were collected using a "pollutograph" sampling approach, in which multiple discrete samples were collected throughout the storm. Samples were analyzed for metals and polycyclic aromatic hydrocarbons (PAHs) in order to estimate event mean concentrations and mass loading. Because the data are represented by few data points, the results are considered preliminary.

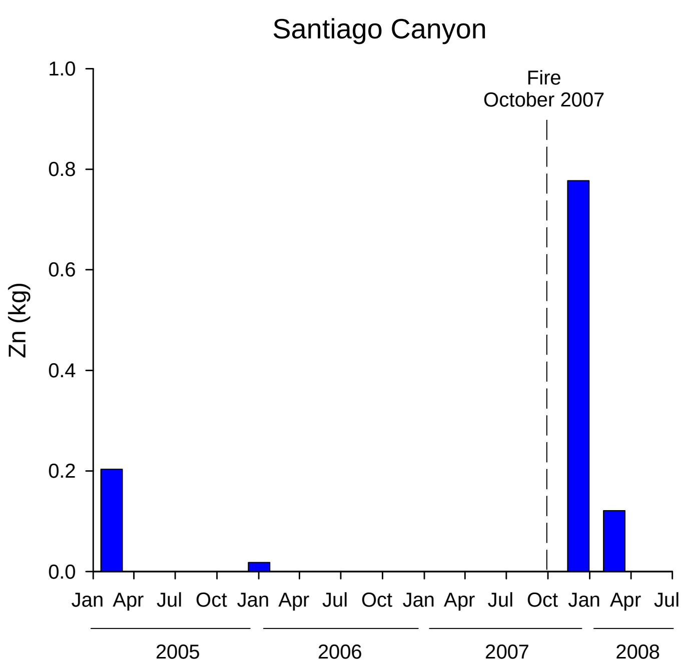


Figure A-4. Mass of zinc in storm water runoff collected from Santiago Canyon, following the October 2007 wildfire.

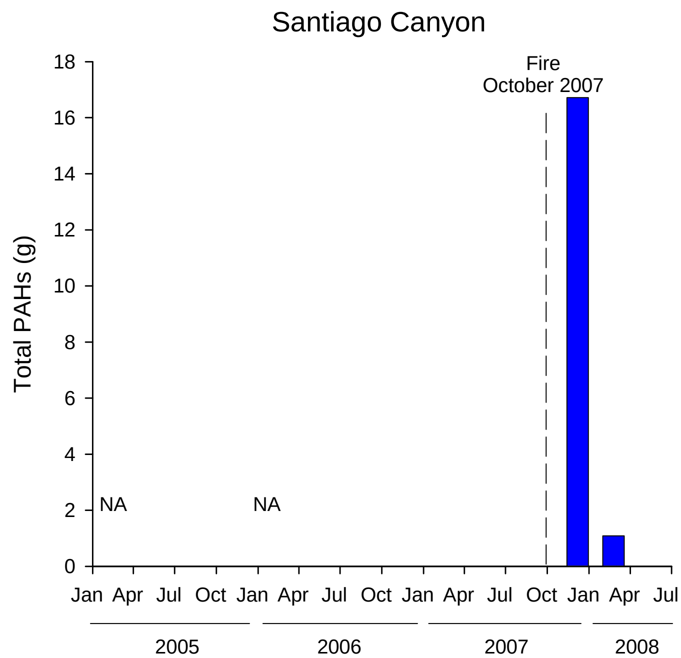


Figure A-5. Mass of PAHs in storm water runoff collected from Santiago Canyon, following the October 2007 wildfire. NA = not analyzed.

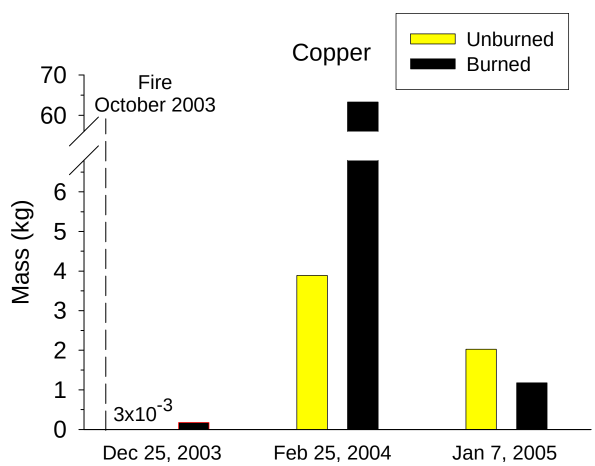


Figure A-6. Post-fire sampling from burned and unburned sites in Simi Valley.

Initial data from these studies suggests that concentrations of metals and PAHs may be 2-5 times higher in runoff from burned areas than in comparable unburned catchments.

Angora post-fire water quality monitoring. *Alan Heyvaert, Ralph Townsend, Andrea Parra, Collin Strasenburgh, Todd Mihevc, Russ Wigart, Brendan Ferry, Kim Gorman. Desert Research Institute, UCD Tahoe Environmental Research Center, El Dorado County, Lahontan Regional Water Quality Control Board*

Hydrology, soil and water quality parameters were assessed following the June/July 2007 Angora fire, in which 3,100 acres were burned. Water quality samples were collected from six sites, with two samples collected each from Angora Creek, Angora Urban, and Upper Truckee River. Analysis included TP, TDP, SRP, TKN, TN, NO3-N, NH3-N, TSS, PSD, EC, pH, turbidity. Samples for analysis of CA priority pollutants and metals will be collected during the first storm runoff event to occur. Flow rates and concentrations remain very low at both of the Angora Creek monitoring sites to date (August 2007).

Neither the Lake Tahoe Basin Management Unit Forest Plan nor the Water Quality Control Plan for the Lahontan Region of the California Water Quality Control Board has a water quality threshold value designed for wildfire.

Indirect Effects (Aerial deposition)

<u>*Indirect effects to water quality in pre- and post fire samples from Ballona Creek*</u> *Eric Stein and Jeff Brown. S. Ca. Coastal Water Research Project*

Indirect effects of fire associated with ash fallout were evaluated by collecting storm water samples from the Ballona Creek watershed following 2003 fires in nearby watersheds. Although the Ballona Creek watershed did not burn, it did receive substantial ash fallout. Storm water runoff samples were collected using a "pollutograph" sampling approach, in which multiple discrete samples were collected throughout the storm. Samples were analyzed for metals and polycyclic aromatic hydrocarbons (PAHs) in order to estimate event mean concentrations and mass loading. Results were compared to samples collected by SCCWRP at the same location in previous years in which no fire occurred. Because the data are represented by few data points, the results are considered preliminary.

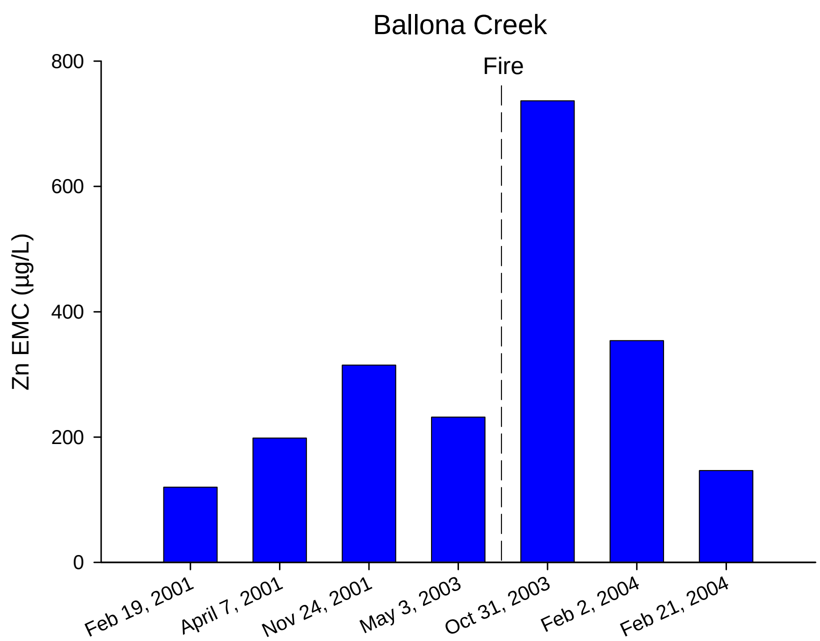


Figure 7. Concentration of zinc in storm water runoff collected from Ballona Creek pre and post-fire.

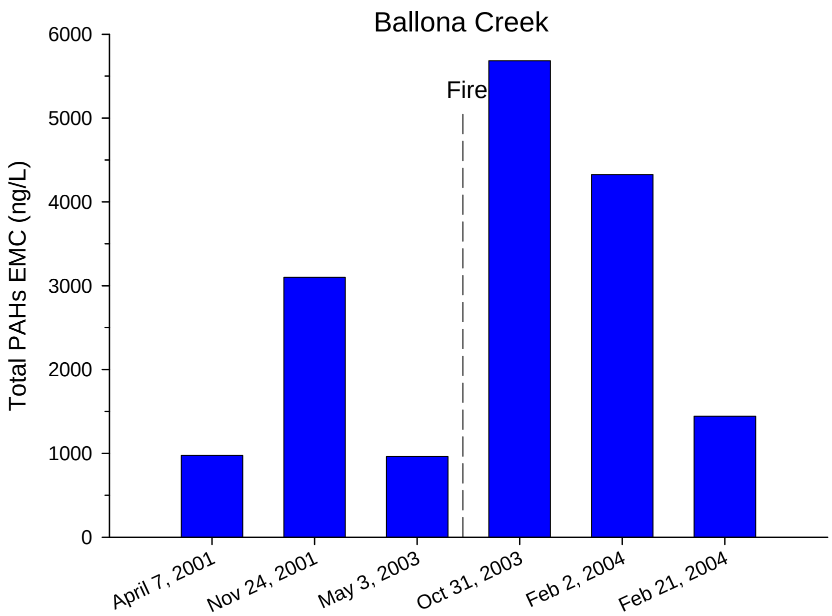


Figure A-8. Concentration of PAHs in storm water runoff collected from Ballona Creek pre and post fire.

Results of this study suggest that ash fallout onto unburned urban landscapes may increase storm water metals and PAH concentrations by 4 to 8 times levels typically observed.

<u>Effect of fire on dry deposition rates in Los Angeles</u>. Lisa Sabin. S. Ca. Coastal Water Research Project.

Dry deposition flux of metals were measured at the Tillman Wastewater Treatment Plant in Los Angeles over a one year period between June 2003 and April 2004. The October 2003 fires occurred coincident with this sampling. Results show a marked increase on dry deposition flux immediately following the fires.

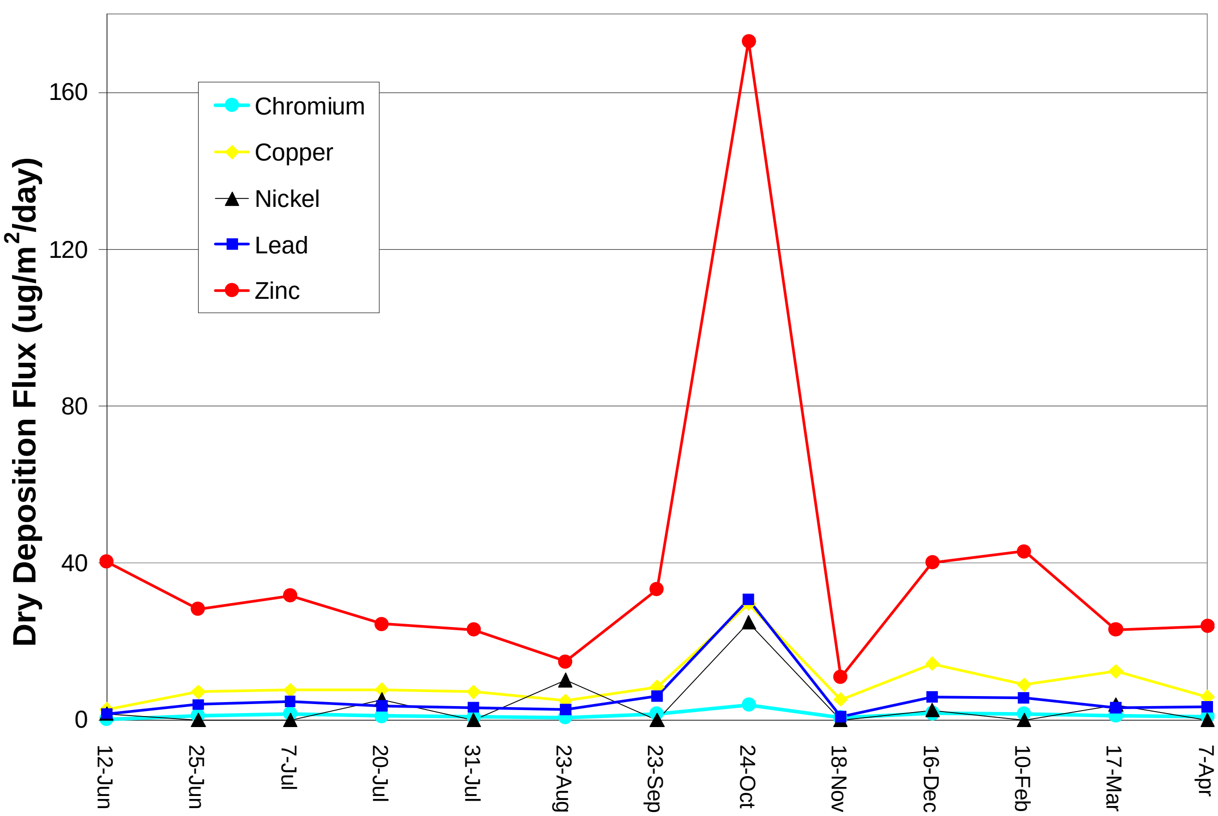


Figure A-8. Effect of ash fallout on metals dry deposition flux at the Tillman Wastewater Treatment Plant.

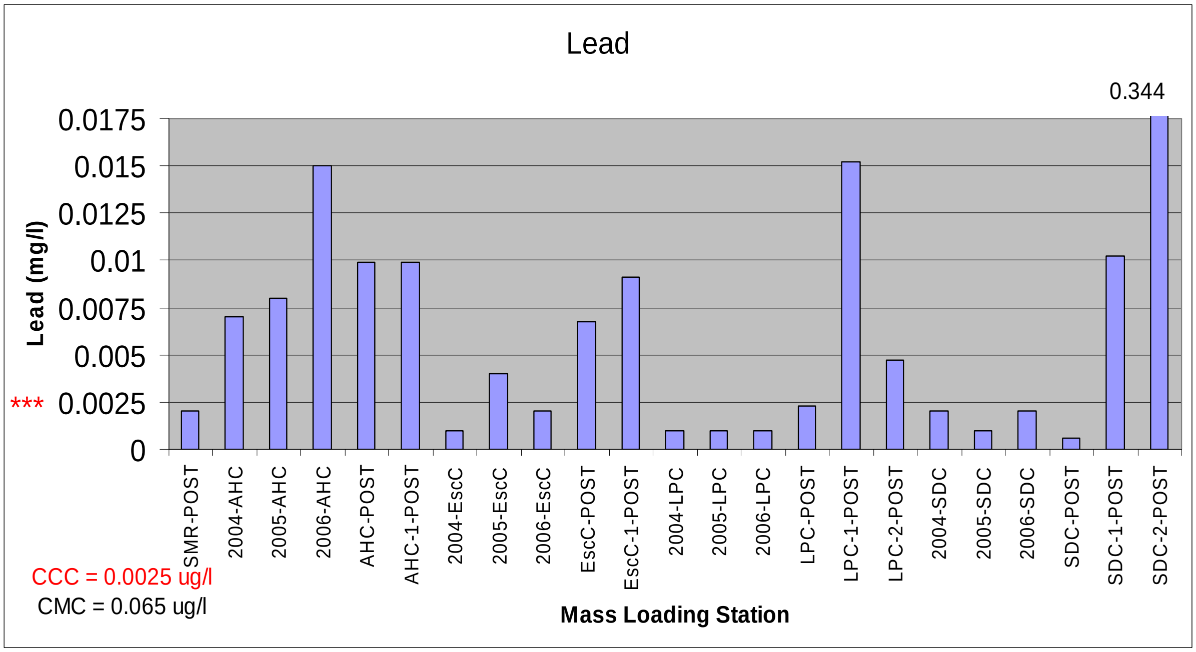
<u>The Effects of Wildfires on Water Quality in San Diego Streams</u>. Cynthia Gorham-Test, Regional Water Quality Control Board, San Diego

I appreciate the San Diego County Stormwater Co-permittees allowing the San Diego Water Board to have early access to the data for analysis and review. I would especially like to thank Dave Renfrew of Weston for his help during this analysis.

The stormwater data were collected at four mass loading stations were analyzed for heavy metals and nutrients. Mass loading stations were located in freshwater streams at the bottom of the watersheds, but upstream of tidal influence. Mass loading stations were located on Agua Hedionda Creek, Escondido Creek, Los Penasquitos Creek, and San Dieguito Creek. Tributary mass loading stations also were sampled in each watershed and are included in the analysis. Data are from 2004, 2005, 2006, and 2007.

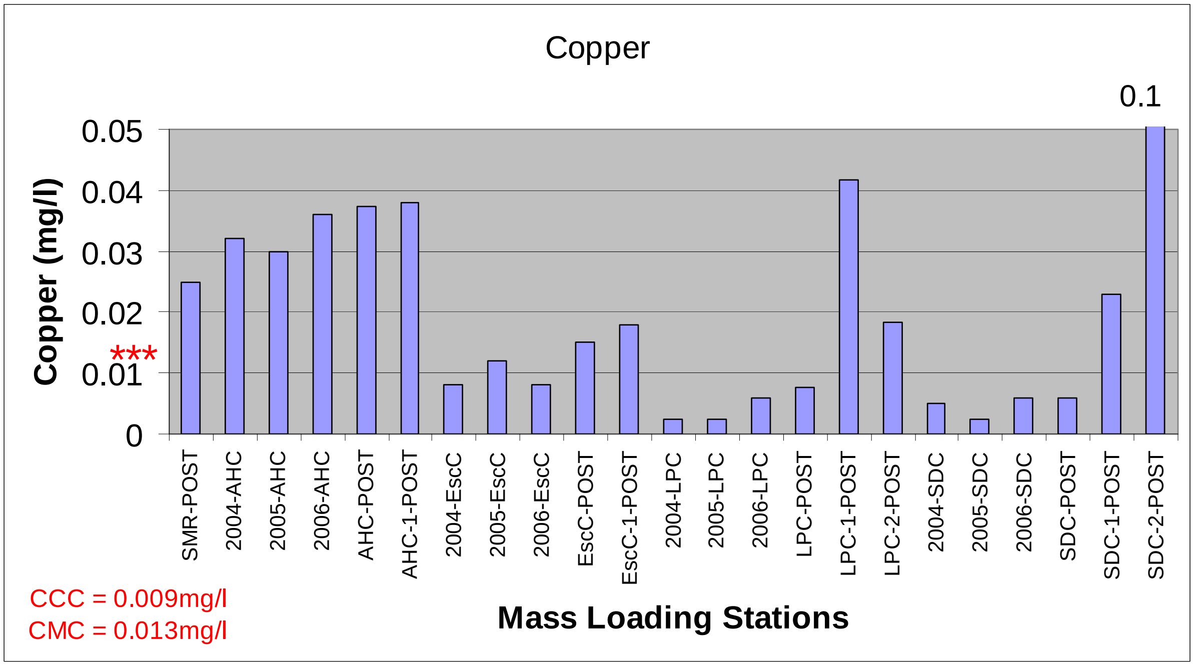
Post-fire are included in the analysis at the mass loading stations. Tributary stations only have the Post-fire data, but will be sampled in the future. A 2007 sample from the Santa Margarita River mass loading station is included as a control, since this watershed only had a small amount of area that burned.

Lead and copper show a pattern with overall higher concentrations with post-fire conditions. Exceedences for lead occur for the chronic CTR, and in one case the acute CTR is greatly exceeded at the San Dieguito River tributary station where burning occurred at the site itself. The SDC-2 site can provide great insight to what water quality conditions we can expect at or near a wildfire burn location.



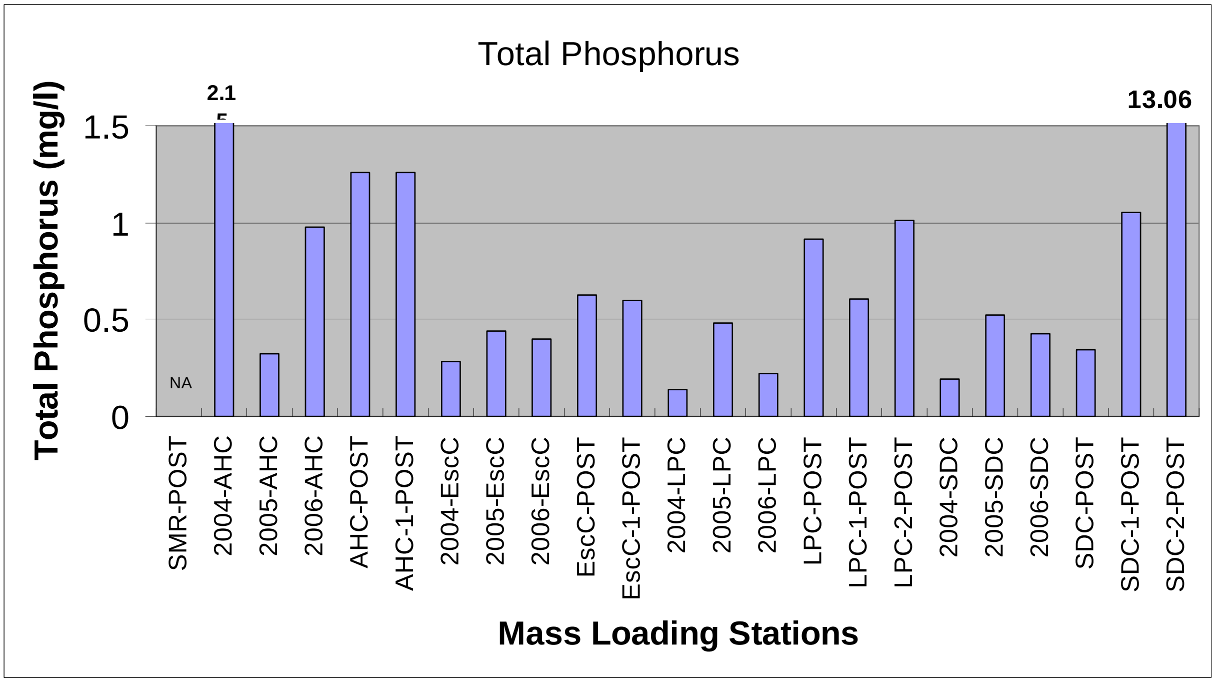
Concentrations of copper exceed the acute CTR value across the sampling years at the Agua Hedionda mass loading station and at the tributary site, but concentrations are measurably higher for post-fire samples. Post-fire samples were higher at Escondido Creek and Los Penasquitos Creek sites. The San Dieguito River mass loading station sample was not higher than the previous three years. This may be due to Lake Hodges acting as a huge sediment detention basin. The two tributary sites (SDC-1 and SDC-2) sampled on San Dieguito Creek had concentrations of copper higher than the other San Dieguito samples and both exceeded the acute CTR value. Actually, the acute CTR values were exceeded at all the tributary stations during post-fire sampling. Once again, the SDC-2 site results were off the charts.

Unfortunately, this is the first year that these tributary stations were sampled, so we do not have any historic data for comparison. However, we will have data for future comparison.



Total phosphorus concentrations generally show an increase in the post-fire years as opposed to previous years in Agua Hedionda Creek and Los Penasquitos Creek. The other two creek tributary post-fire samples vary in previous years' samples. All the tributary post-fire samples exceed the previous years' samples for their watersheds, except for one case in Agua Hedionda Creek. Once again, the SDC-2 tributary site that burned is extremely high.

It appears that each watershed has its own pattern of chemical concentration. Agua Hedionda Creek has the higher concentrations of metals and phosphorus with all years around the same concentration. Escondido Creek metals and phosphorus are high across years, but not as high as Agua Hedionda Creek. Los Penasquitos Creek and San Dieguito River have much lower concentrations of metals and nutrients, except at the tributary stations during the post-fire storm event.



NOTE

Heavy metals were not adjusted for hardness. This calculation is needed to complete the analysis. Loading estimates also would benefit this analysis.

FURTHER ANALYSIS

To further determine what impact the fire has had upon the stream and its receiving waterbody, we could calculate the volume of the runoff from the area that has been burned. Then the SDC-2-POST Station concentration value for each constituent of concern could be used as an average value for the runoff volume for a given flow period and multiplied by the flow volume. That total could be compared with the total volume of water and total calculated mass load for the watershed to see what the effect of the loading from the fire has been. Estimates of instream losses also should be considered. No doubt these values would be very rough estimates, but they would provide some insight.

CONCLUSIONS

The post-fire pollutants at the mass loading stations are the same pollutants we see in stormwater, only in some cases they are higher and they exceed WQ standards more often. In San Dieguito we don't see as much exceedances due to Lake Hodges acting as a giant BMP.

The tributary site in San Dieguito that has measurements "off the charts", and burned during the wildfires is probably a good indicator site for what does occur at sites that burn as opposed to measurements of what happens at the most downstream portion of the watershed at the mass loading stations. The heavy metals at the tributary stations are “off the charts” for almost all metals and nutrients. However, by the time the pollutants reach the mass loading station at the base of the San Dieguito Watershed, the signal is lost. How can a signal as large as that of a major wildfire be lost in relatively small watersheds? Is it just a matter of dilution, or is the signal lost amongst the day to day pollutants loaded from our streets, lawns, and industrial sites?

Biological Effects

No study summaries submitted

Existing fire monitoring programs

BAER Fire Program *http://www.nps.gov/fire/fire/fir_baer.cfm*

The Burned Area Emergency Response (BAER) program has the goal of protecting life, property, water quality, and deteriorated ecosystems from further damage after the fire is out. Concern for possible post-fire effects on fish, wildlife, archeological sites and endangered species is often a primary consideration in the development of a BAER plan.

BAER objectives are to:

1. Determine if an emergency condition exists after the fire.
2. Alleviate emergency conditions to help stabilize soil; control water, sediment and debris movement; prevent impairment of ecosystems; mitigate significant threats to health, safety, life, property and downstream values at risk.
3. Monitor the implementation and effectiveness of emergency treatments.

BAER is 'first aid' - immediate stabilization that often begins even before a fire is fully contained. BAER does not seek to replace what is damaged by fire, but to reduce further damage due to the land being temporarily exposed in a fragile condition. In most cases, only a portion of the burned area is actually treated: severely burned areas, very steep slopes, places where water runoff will be excessive, fragile slopes above homes, businesses, municipal water supplies, and other valuable facilities. Treatments are installed as soon as possible, generally before the next damaging storm. The spending authority granted for each BAER project covers only the most urgent treatments that cannot await normal funding processes. Special funds are authorized for these activities and costs vary with the severity of the fire season. On average, BAER expenses have been about 12% of the cost of fire suppression.

Professional hydrologists, soil scientists, engineers, biologists, silviculturalists, range conservationists, archeologists, and others evaluate the burned area and prescribe treatments to protect resources quickly and effectively staff BAER teams. The National

Park Service coordinates rehabilitation plans with private landowners and other federal and local agencies, such as the Natural Resources Conservation Service (NRCS), the USDA Forest Service (USFS), the Bureau of Land Management (BLM), and local forestry departments.

State Emergency Assessment Teams (SEAT)

The State of California is in the process of developing interagency assessment teams to address impacts to resources from fire (as well as other emergencies in the future). These SEATs (State Emergency Assessment Teams) will be utilizing the federal BAER team system as a template. The Regional Water Boards have dedicated staff to these teams.