The Effect of Wildfires on Water Quality from Watershed Systems of Southern California

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Summary

The objective of this project was to determine the effect of wildfires on water quality from watershed systems of Southern California. Specifically, the purpose of this project was to use the tools that we learned in our GIS class to determine the influence of wildfires.

Using Arc Hydro Desktop, Arc View, Arc GIS online, and topographic basemaps, this project investigated the effects of wildfires on water quality from San Diego County. Two sites were investigated within the San Diego watershed: Sweetwater Res Nr Pump Tower Upper (burned during the 2007 San Diego fires) and Loveland Res Nr Dam Site 1 Upper (not burned by the 2007 San Diego fires).

From the limited dataset of copper and lead concentrations in a burned and unburned sites, it was determined that the 2007 fires increased metals concentrations in burned areas. In addition, metals concentrations gradually increased overtime in unburned areas indicating that air deposition allows the accumulation of metals into watershed systems. Overall, this project showed that GIS tools are important to investigate how wildfires influence the surrounding environment.

Introduction

The objective of this project is to determine the effect of wildfires on water quality from watershed systems of Southern California. Wildfires can negatively affect the environment by destroying vegetation, increasing particle erosion, and contributing to pollutants in water bodies (Burke et al., 2010).

Burke et al. 2010 showed that wildfires negatively affect watershed systems by increasing the mobilization of particle-bound mercury into the water column. The same study showed that sediments had a decrease in mercury and organic concentrations due volatilization from high temperatures during wildfires. Years after the fire, watersheds also showed a recovery trend with higher mercury and organic concentrations found in post-fire sediments; this was attributed to cumulative air-particle deposition on the watershed over time. Following the conclusions made from Burke et al. 2010, the current GIS project is meant to investigate how wildfires affect other water quality parameters in watershed systems. Specifically, the purpose of this project is to use the tools that we learned in our GIS class to determine the influence of wildfires on the surrounding environment.

To investigate the effects of wildfires on watershed systems, it was first proposed to collect data from one of the following watersheds; Arroyo Seco, Piru Creek, and Malibu. These watersheds are located in Los Angeles and they suffered from multiple fire events that showed destruction of vegetation, increased erosion, and increased mercury concentrations in post-fire areas (Burke et al., 2010). After reviewing and analyzing the available United States Geological Survey (USGS) and United States Environmental Protection Agency (EPA) water quality data form Arc Hydro Desktop, Arc View, Arc GIS online, and topographic basemaps, it was determined that watersheds in San Diego County had a larger dataset on both wildfires and water quality data. As a result, this project attempts to correlate wildfire events to water quality data in San Diego County.

The acquisition and interpretation of wildfire and water quality data is discussed in the following sections.

Finding and filtering fire and water quality data for San Diego County

Fire severity and fire burn history in San Diego County

San Diego County is located in Southern California. The first step in this project was to identify the fire data available in San Diego County, including fire severity zones and fire burn history. The identification of fire severity zones in San Diego County is useful to interpret water quality data; for example, if high metals concentrations are detected in high fire severity zones, then this might be an indication that multiple fires in the area could have mobilized particle-bound contaminants. In addition, the fire burn history is also useful to interpret the data by determining where and when the fire events occurred. As a result, fire severity zones and fire burn history were identified in San Diego County by using NAD1983 Datum, Arc View, Arc GIS online, and topographic basemaps. As shown by Figure 1, San Diego County contains fire severity zone data and fire burn history from 1910 to 2007.

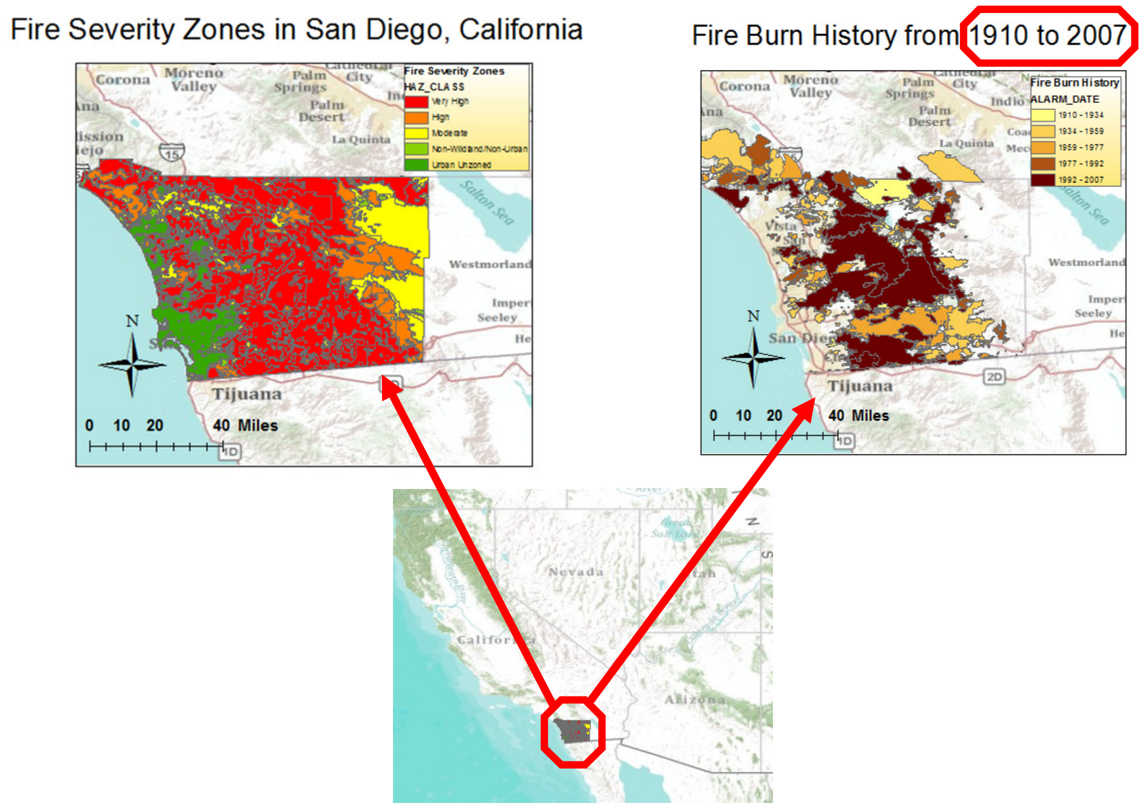

Figure 1. **Map of study area showing fire severity zones and fire burn history in San Diego County, California.**

The classification of "very high" severity zone shows that San Diego County is prone to suffer from multiple wildfires (illustrated by the various sections shown in red [Figure 1]). As expected, the fire severity zone also corresponds directly to the fire burn history. Specifically, the 1992 to 2007 fire burn history shows that fires were significantly centered in the "very high" severity zone of San Diego County. Now that the fire severity zones and fire burn history have been identified, the next step is to relate this fire data to USGS and USEPA water quality data.

Water quality data in San Diego County

USEPA regulates various water quality parameters to insure public health (USEPA [2010]). To analyze how wildfires affect water quality, each water quality parameter was selected based on whether or not it appeared on the USEPA regulation website and accessibility to the data from Arc Hydro Desktop for San Diego County. The water quality parameters that were selected are as follows: atrazine, mercury, lead, copper, arsenic, total organic carbon, and turbidity.

According to the USEPA website (USEPA, 2010), atrazine is an organic compound used as an herbicide for agricultural purposes; it is also a source of contamination in urban runoff that causes cardiovascular and reproductive problems in humans; at elevated metals concentrations, mercury, lead, copper, and arsenic can be toxic and cause internal tissue damage in humans; turbidity is attributed to soil runoff and it is regulated to decrease bacteria and metals concentrations that are adsorbed onto particle surfaces.

Although total organic carbon is not regulated by USEPA, it was included in this study to make temperature correlations. For example, Stronach and McNaughton (1989) reported temperatures of 407 to 830 °C in fire-burned soils; since TOC is volatile at 550°C (APHA, 1998), a decrease in total organic carbon concentrations in watershed systems could be linked to the fire burn severity. As a result, a total of 7 water quality parameters were selected.

Using Arc Hydro desktop and topographic basemaps, the water quality data for the 7 water quality parameters was searched on the database from 1920 to 2010 to correlate to the fire burn history data available in San Diego County. Based on the database, the range of dates that had data were from 1980 to 2010 (Figure 2; turbidity not shown). All water quality parameters were characterized as sporadic observations in San Diego County from the Arc Hydro Desktop archive; that is, the observations were not continuously measured (e.g. hourly, daily, or monthly). As a result, the main problem with the data set of interest was availability of water quality information; this might inhibit data interpretation.

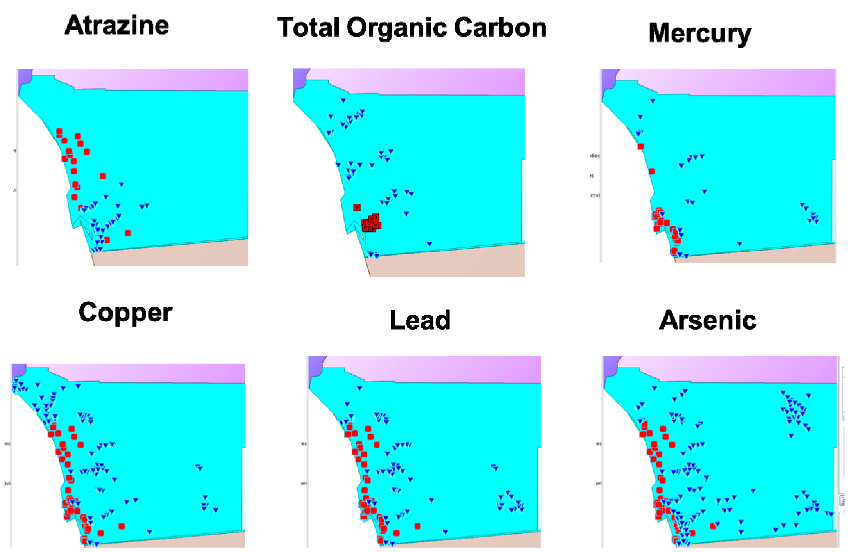

Figure 2. **EPA (shown in red squares) and USGS (shown in blue triangles) data available for water quality parameters of interest from 1980 to 2010 (turbidity not presented).**

To better correlate the fire burn history to the water quality data available in San Diego County, the water quality data was filtered by zooming into a smaller date range. As a result, the water quality data was filtered by choosing observations between 2005 and 2010 (Figure 3). The smaller date range of 2005 to 2010 was chosen according to the available fire burn history which extends to 2007 (Figure 1). From the attribute table of the fire-burn history, there are more than 10 descriptions for fires that occurred in 2007; it is also most convenient to concentrate on data that is most recent due to up-to-date sampling and analysis of water quality parameters. As a result, to assess pre- and post-fire effects, it is imperative to choose a date range for the water quality data that extends before and after 2007 (i.e. 2005 to 2010).

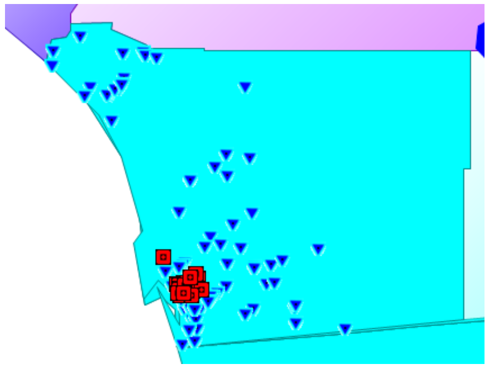

Figure 3. EPA (shown in red squares) and USGS (shown in blue triangles) data available for atrazine, mercury, lead, copper, arsenic, total organic carbon, and turbidity between 2005 to 2010.

Once all of the 2005 to 2010 water quality data was collected for San Diego County, the next step was to use the attribute table of "Search Results" to choose the sites of interest. There were many observations at various locations within San Diego County, however, the consistency of the observations also was limited. For example, atrazine, mercury, arsenic, and total organic carbon data only was available between 2008 to 2009. The data that extended from 2005 to 2010 only belonged to copper and lead. Therefore, the data was filtered by the choosing those sites that had observations for lead and copper between the years of 2005 to 2010. In doing so, 4 sites were chosen within San Diego County (Figure 4). The 4 sites chosen were 1) Loveland Res Nr Dam Site 1 Upper, 2) Sweetwater R A Low Flow Div Dam ABV Sweetwater, 3) Sweetwater Res E End Res Fill Bndry Upper, and 4) Sweetwater Res Nr Pump Tower Upper.

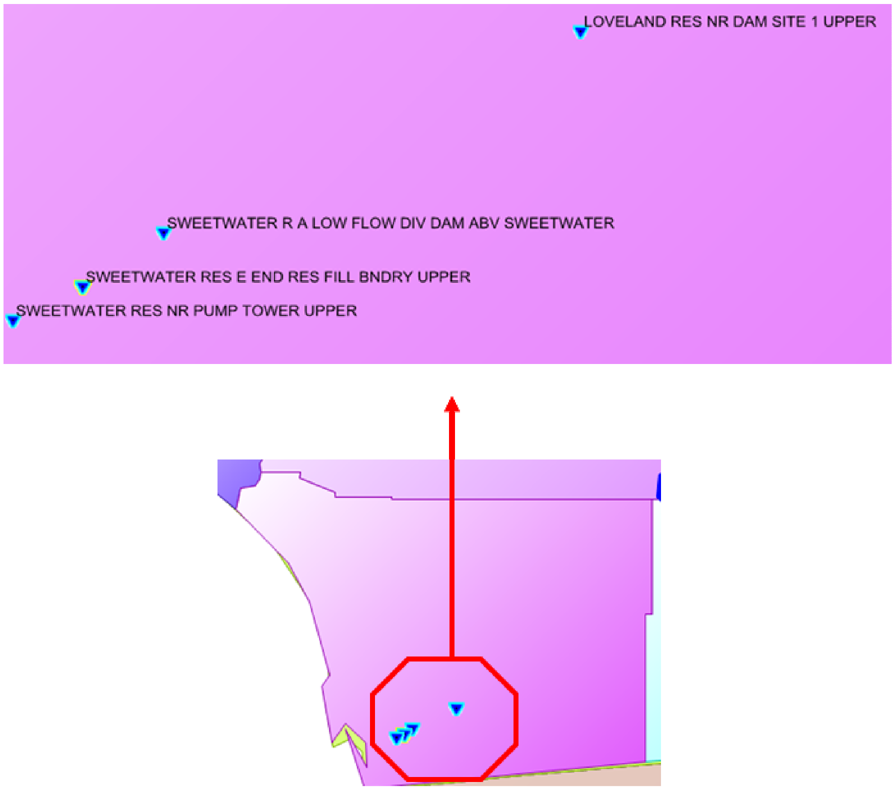

Figure 4. The 4 observation sites containing copper and lead data between 2005 to 2010.

Once the water quality data and sites were chosen for 2005 to 2010, the next step was to plot the copper and lead data at the four sites (Figures 5 and 6). Notice that these data plots show that there is paucity in copper and lead observations for two of the four sites: Sweetwater Res E End Res Fill Bndry Upper and Sweetwater R A Low Flow Div Dam ABV Sweetwater only show 3 copper and 3 lead observations between 2005 to 2010. For the two other sites, Loveland Res Nr Dam Site 1 Upper and Sweetwater Res Nr Pump Tower Upper, more than 10 copper and lead observations are shown between 2005 to 2010.

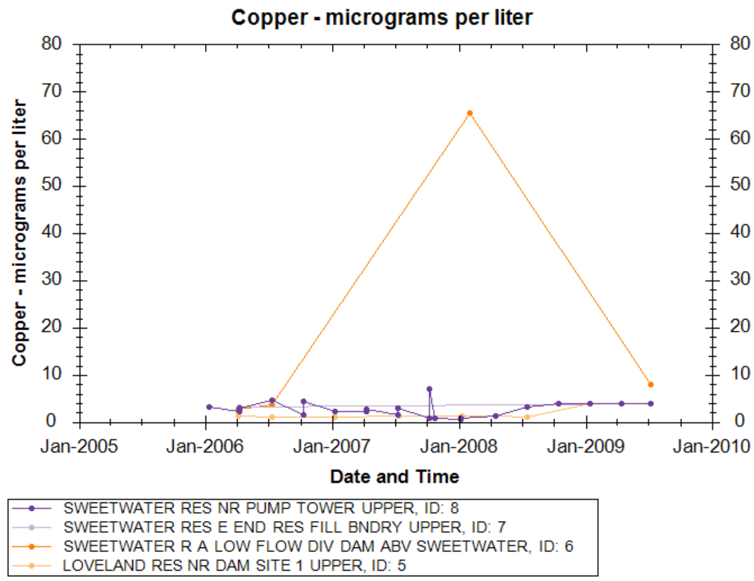

Figure 5. **Copper concentrations between 2005 to 2010 for the 4 observations sites in San Diego County.**

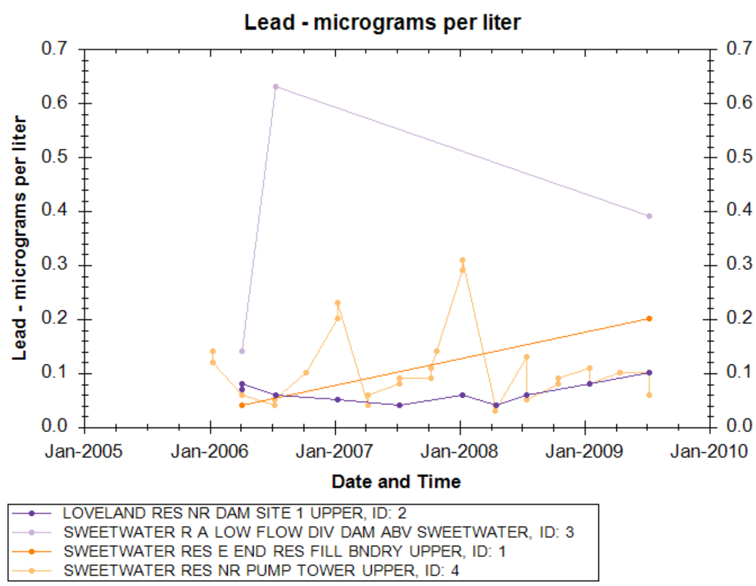

Figure 6. **Lead concentrations between 2005 to 2010 for the 4 observations sites in San Diego County.**

Copper and lead concentrations in San Diego County (2005-2010)

Water quality data was assessed by choosing two of the four sites that had a larger range of copper and lead observations in San Diego County. The two sites selected, Loveland Res Nr Dam Site 1 Upper and Sweetwater Res Nr Pump Tower Upper, were plotted on San Diego County and both locations are located within the San Diego watershed (Figure 7).

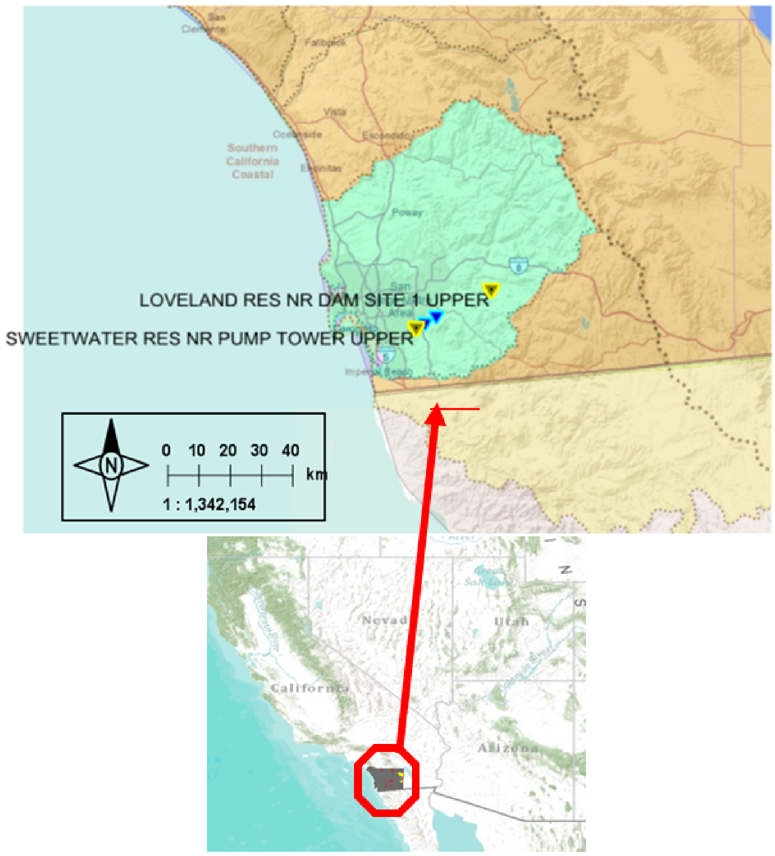

Figure 7. **San Diego watershed (shown in green) and 2 observation sites (highlighted in yellow) selected for water quality analysis. Note: The other 2 observations sites (highlighted in blue) were not chosen due to limited copper and lead data.**

The copper and lead data for Loveland Res Nr Dam Site 1 Upper and Sweetwater Res Nr Pump Tower Upper are summarized in Figures 8 and 9. The Sweetwater Res Nr Pump Tower Upper site shows the highest concentration of copper in October 2007 and the highest concentration of lead in January 2008; the site also shows multiple spikes for copper and lead between 2005 and 2010. The Loveland Res Nr Dam Site 1 Upper site shows a slight increase in lead concentration in January 2008 and an increasing trend of copper and lead concentrations after June 2008; the highest copper and lead concentrations were observed after January 2009.

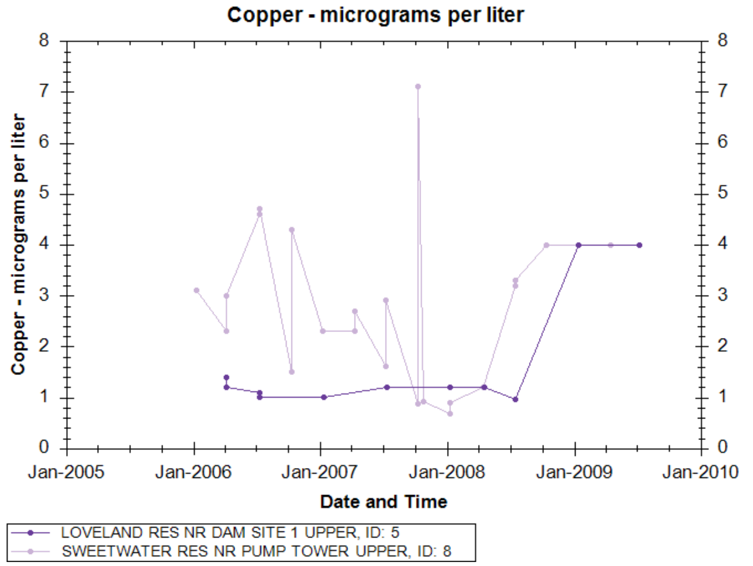

Figure 8. **Copper concentrations between 2005 to 2010 at 2 observations sites in San Diego County.**

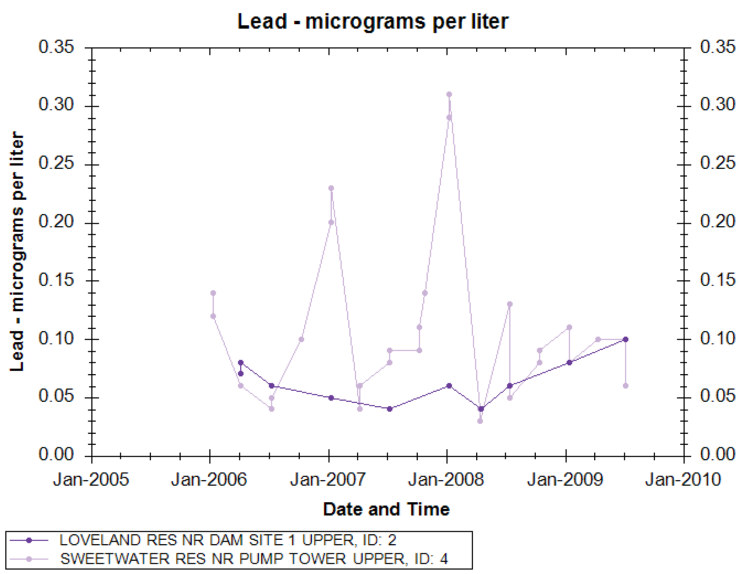

Figure 9. **Lead concentrations between 2005 to 2010 at 2 observations sites in San Diego County.**

Based on the copper and lead data of the two sites selected, it can be concluded that the Sweetwater Res Nr Pump Tower Upper site is more susceptible to increases in copper and lead concentrations as compared to the Loveland Res Nr Dam Site 1 Upper site; this is shown by the multiple copper and lead spikes observed in the Sweetwater Res Nr Pump Tower Upper site between 2005 to 2010. Also, it is apparent that water quality was most affected in October 2007 and January 2008 for the Sweetwater Res Nr Pump Tower Upper site, as shown by the highest copper and lead concentrations. In addition, the Loveland Res Nr Dam Site 1 Upper site shows that the water quality was most affected after June 2008, as shown by the increasing copper and lead trends. To determine whether wildfires might have influenced these water quality observations, it is important to go back to the fire history data to investigate possible correlations to the water quality data.

Correlation of copper and lead concentrations to fire events in San Diego County

Since the copper and lead data show that the concentrations are affected in early 2008, it is apparent that a fire event in 2007 might have affected the water quality parameters. As a result, the fire burn history in San Diego County was investigated further for 2007. Using the attribute table of the copper and lead data from ArcHydro Desktop (Table 1), the highlighted sites were used to export the latitude and longitude information into ArcGIS.

Table 1. **Attribute table for copper and lead data acquired from ArcHydro Desktop. Note: The 2 highlighted rows represent information for the 2 sites in San Diego County, including latitude, longitude, data type, and begin and end date times.**

SiteName	Latitude	Longitude	VariableName	DataType	BeginDateTime	EndDateTime
SWEETWATER R A LOW FLOW DIV DAM ABV SWEETWATER	32.71977615356...	-116.950584411...	Lead	Sporadic	2006-04-06 01:20	2009-07-08 11:00
SWEETWATER RES NR PUMP TOWER UPPER	32.69171905517...	-117.007804870...	Lead	Sporadic	2006-01-10 11:20	2009-07-07 10:43
LOVELAND RES NR DAM SITE 1 UPPER	32.78422164916...	-116.792800903...	Copper	Sporadic	2006-04-06 11:10	2009-07-08 01:03
SWEETWATER R A LOW FLOW DIV DAM ABV SWEETWATER	32.71977615356...	-116.950584411...	Copper	Sporadic	2006-04-06 01:20	2009-07-08 11:00
SWEETWATER RES E END RES FILL BNDRY UPPER	32.70255279541...	-116.981414794...	Copper	Sporadic	2006-04-07 12:20	2009-07-07 11:50

Latitude and longitude information for the two sites were imported into ArcGIS and plotted on top of the 2007 fire data (Figure 8); the copper and lead data file was projected on the NAD 1983 Datum. As shown by the 2007 fires, it is evident that the Sweetwater Res Nr Pump Tower Upper site was directly affected by the fires because its location was in the proximity of the fires. On the other hand, the Loveland Res Nr Dam Site 1 Upper site was not affected by the fires because its location was not in the proximity of the fires.

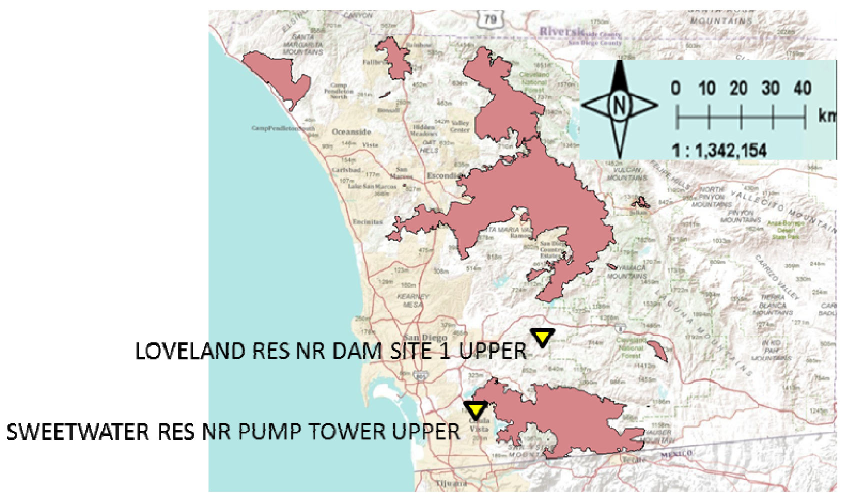

Figure 10. **The 2 observations sites (yellow triangles) projected onto the 2007 fire burn data of San Diego County (shown in red).**

In 2007, the wildfire season in Southern California was responsible for the destruction of more than 500,000 acres (Palen, 2008). The severity of the fires was intensified by the 2006-2007 droughts which yielded high loads of dead fuel throughout

Southern California; the Santa Ana winds also contributed to the rapid spread of the fires throughout San Diego County (Keeley et al, 2009). The fire started on October 20 2007, lasted 19 days, and resulted in the destruction of more than 1500 homes (Palen, 2009).

The projection of the observations sites onto the 2007 fire burn data from San Diego County is in accordance with the water quality data observed for copper and lead (Figure 8 and 9). As previously mentioned, the Sweetwater Res Nr Pump Tower Upper site had the highest concentrations of copper and lead in October 2007 and January 2008, indicating that the 2007 October to November fires influenced the water quality by increasing the metals concentrations immediately or within a couple of months after the fire. This was expected since particle bound metals can be mobilized in watershed systems after a fire event (Burke et al., 2010); in this case, the spike in copper and lead concentrations was seen after the 2007 fire event in January 2008 for the Sweetwater Res Nr Pump Tower Upper site, which is consistent with the mobilization of particle-bound metals into watershed systems. The Sweetwater Res Nr Pump Tower Upper site did show multiple spikes in copper and lead concentrations. This might be attributed to the close proximity to the 2007 fires which could have drastically destroyed soil and vegetation. As a result, the consistent spikes in metals concentrations are an indication that fires do increase particle mobilization and concentrations of particle-bound metals.

The fire burn data is also consistent with the observations seen for the Loveland Res Nr Dam Site 1 Upper site. As shown in Figure 10, the Loveland Res Nr Dam Site 1 Upper site was not in the proximity of the 2007 fires, which is consistent with the water quality data that showed no drastic spikes in the proceeding months after the 2007 fires (e.g. January 2008). However, after June 2008, the Loveland Res Nr Dam Site 1 Upper site did show an increasing trend in copper and lead concentrations, indicating that airborne metals could have deposited back onto the watershed; this is probable because the 2007 fires might have volatilized metals into the air which could have deposited back onto the watershed overtime. This is in accordance with Burke et al. 2010, which showed that air deposition increased metal concentrations on watershed systems 1 to 2 years after the fires occurred.

Comparison of copper and lead concentrations to USEPA standards

According to the USEPA drinking water standards, copper concentrations should be less than 1.3 mg/L and lead concentrations should be less than 0.015 mg/L (USEPA, 2010). Figures 8 and 9 show that copper and lead concentrations were exceeded at both burned and unburned sites between 2005 to 2010, with copper concentrations ranging between 0.8 to 7.3 mg/L and lead concentrations ranging from 0.04 to 0.33 mg/L. In particular, the USEPA standards were most often exceeded by the burned site, indicating that wildfires have a negative effect on water quality parameters. As a result, this is an indication that water quality should be stringently monitoring during and after a fire event to protect drinking water sources.

Limitations in study and recommendations

The main limitation of this project was the accessibility to water quality data. As previously mentioned, out of the initial 7 water quality parameters that were considered, only two of the parameters had data ranging from 2005 to 2010. In addition, the observations were sporadic, with inconsistency in sampling time of hourly or daily values. As a result, the interpretation of the water quality data in this project was limited to the data that was available online.

To make the water quality dataset more robust, it is recommended that ARC Hydro Desktop should be more accessible to other users. Although government agencies like USEPA and USGS provide water quality data, it might be more helpful to include observations done by universities or consulting firms. This might be an option that is already provided by ARC Hudro Desktop, but it is apparent that a better incentive should be advertised to publish water quality data from other users. This could reduce the paucity of observations by allowing the uploading and sharing of various water quality data.

Although not assessed in this study, non-point and point sources could be included to show how they influence water quality before, during, and after a fire event; industries might be destroyed during a fire and could decrease the discharge of metals into streams. Vegetation maps also could help to interpret the extent of the fire severity; if less vegetation is seen, then this could be an indication of a destructive fire. Lastly, it is recommended that air quality data should be analyzed to show how fire events affect the transfer of pollutants from watersheds to air, and vise versa.

Conclusions

This project correlated wildfire events to water quality data in San Diego County. From the limited dataset of copper and lead concentrations in a burned and unburned site, it was determined that the 2007 fires increased metals concentrations in burned areas. This was consistent with previous studies which showed that particle mobilization during and after a fire event increases metals concentrations in watershed systems. In addition, metals concentrations increased gradually overtime in the unburned area indicating that air deposition allows the accumulation of metals into watershed systems. To further investigate the effects of wildfires on water quality from watershed systems, it is imperative to collect more fire burn and water quality data. The main limitation in this project was the non-continuous water quality data; this limited the amount of water quality parameters that could be correlated to the fire burn data. Overall, this project showed that GIS tools are important to investigate how wildfires influence the surrounding environment.

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