PBT Trend Monitoring: Measuring Lead in Suspended Particulate Matter, 2014 Results

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2014 Highlighted Findings

- The highest lead concentrations in suspended particulate matter (SPM) were found at the Spokane River sites, followed by urban streams in the Seattle and Tacoma areas, and Upper Columbia River site.
- No significant temporal trends in lead concentrations were detected at any of the monitoring sites for the past four to seven years, except for a significant decreasing trend at Thornton Creek.
- The Spokane and Columbia River sites continue to have high loads of SPM-bound lead.

Why Monitor Lead?

Ecology monitors lead in Washington rivers and streams because of concern over its toxic and persistent properties. While lead is a naturally occurring element, human activities have resulted in widespread environmental contamination.

Lead affects humans and wildlife by harming developing nervous systems and other bodily systems. There are many sources of lead from the indoor and outdoor environment, and even minor exposures may cause harm.

Project Overview

In 2009, the state Department of Ecology (Ecology) and the state Department of Health developed a chemical action plan (CAP) for lead (Davies, 2009). The plan identified the toxic effects of lead, described lead's occurrence in the environment, and recommended ways to reduce human and wildlife exposure to lead. Roberts et al. (2011) also discusses potential lead sources in the Puget Sound region.

In 2008, Ecology began a long-term monitoring program to assess temporal changes in lead levels in Washington rivers and streams. Suspended particulate matter (SPM) samples were collected from 15 sites for analysis of total lead (Figure 1). Samples were collected twice in the spring and twice in the fall at each site. Monitoring sites covered a range of watershed size, land use, and potential lead sources.

The primary goal of this program is to provide a baseline for lead concentrations in the environment and evaluate temporal trends as CAP reduction strategies are implemented.

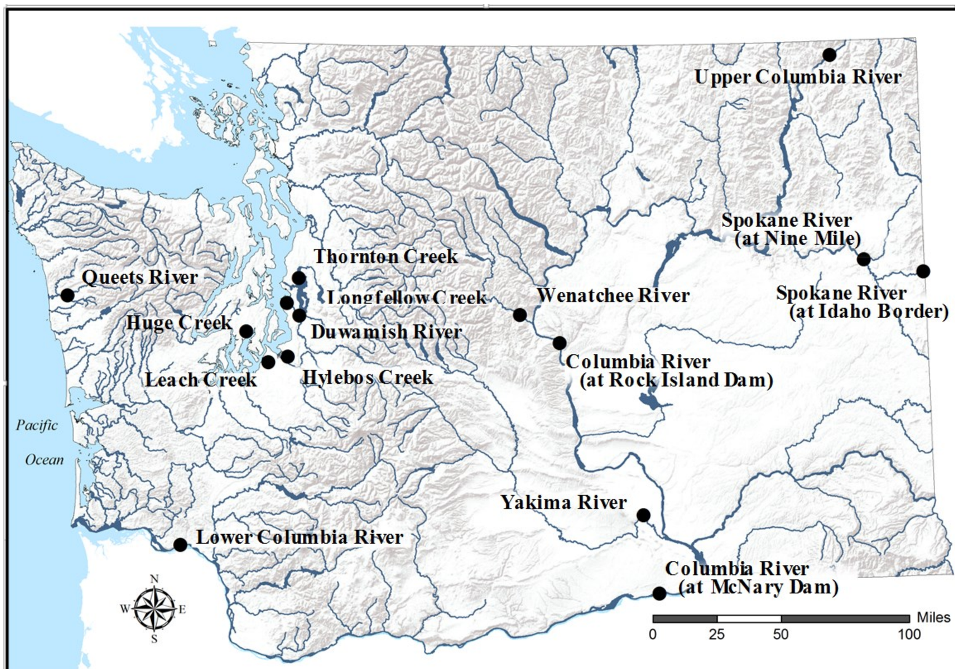

Figure 1. SPM Lead Monitoring Sites in Washington, 2014

For More Information

PBT Monitoring Program website: http://www.ecy.wa.gov/programs/eap/toxics/pbt.html

Lead Chemical Action Plan website: http://www.ecy.wa.gov/programs/hwtr/RTT/pbt/lead.html

Complete 2014 data set in EIM (search Study ID: PbTrends14): www.ecy.wa.gov/eim

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Methods and Data Quality

SPM samples were collected following Ecology's standard operating procedure (SOP) for collection of suspended particles using in-line filtration (Meredith, 2008). Ambient water temperature, pH, and conductivity were measured following Ecology's SOP for collection and analysis of pH (Ward, 2007). Ecology's Manchester Environmental Laboratory analyzed total lead in the SPM samples following EPA Methods 3050B and 200.8.

All quality assurance samples and analyses met measurement quality objectives (MQOs) set for this project (Meredith and Furl, 2008), with one exception: One set of field replicates collected at McNary Dam had a difference of 55%, beyond the MQO of 50%. However, these samples also had detected lead results below reporting limits, where meaningful measurements of precision are constrained.

Results

Sixty SPM samples were analyzed for lead in 2014. Lead concentrations ranged from below reporting limits (7-31 mg/kg) to 1,607 mg/kg. Samples collected from the Spokane River at the Idaho border contained the highest lead levels, followed by the Spokane River at Nine Mile. Lead concentrations were consistently higher than 100 mg/kg at the three urban streams and the Upper Columbia River. These six sites have consistently had the highest lead concentrations since their inclusion in the study.

One sample from the Wenatchee River also had a comparatively high lead concentration (358 mg/kg). Samples from all other locations not previously mentioned were below 100 mg/kg during all four sampling events.

A summary of the 2014 lead results is shown in Table 1, and individual concentrations are displayed in Figure 2.

Table 1. Statistical Summary of Lead in Suspended Particulate Matter, 2014 (mg/kg).

Season	n	FOD	Min	Max	Median	Mean	SD
Spring	30	90%	ND	1,607	78	232	398
Fall	30	67%	ND	1,090	129	185	254
2014	60	78%	ND	1,607	108	212	342

n = number of samples. FOD = frequency of detection.
ND = not detected above reporting limit of 0.05 µg lead/filter.
SD = standard deviation.

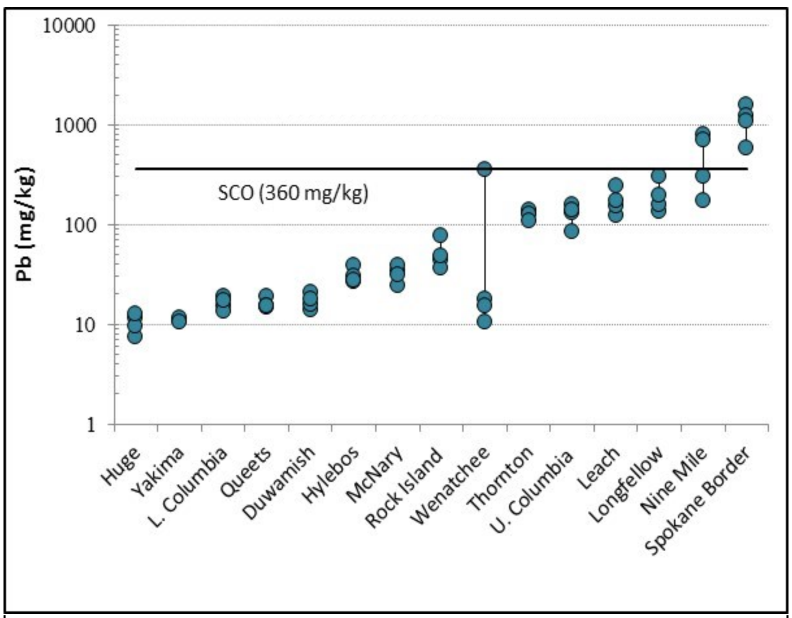


Figure 2. SPM Monitoring Locations Ranked by Mean 2014 Lead Concentrations.
SCO = Sediment Cleanup Objective.

Comparison to Guidelines

Currently, no regulatory criteria exist for lead in SPM. The Sediment Management Standard rule, which includes a freshwater Sediment Cleanup Objective (SCO) for lead, took effect September 1, 2013 (WAC 173-204). Although the SCO is applicable to bottom sediments only, it is a useful threshold to assess levels of lead in SPM since some of the particulate matter will presumably settle to the bottom of the sampled stream or a receiving waterbody.

Ten percent of samples (six of 60) contained lead concentrations above Washington's freshwater SCO of 360 mg/kg (Figure 2). All four samples collected from the Spokane River at the Idaho border and both spring samples from the Spokane River at Nine Mile were above this threshold.

Loading

Daily particulate lead loads were estimated for each sampling site, except Hylebos Creek, using lead concentrations calculated from SPM sampling and daily mean stream-flow. Streamflow data were provided by the U.S. Geological Survey, U.S. Army Corps of Engineers, and the City of Seattle. Figures 3 and 4 display the seasonal mean lead loads for the river and small stream monitoring sites, respectively.

The Upper Columbia River site contained the highest average lead loads (20 - 230 kg/day), followed by the Lower Columbia River site, Spokane River sites, and the mid-Columbia River sites (McNary and Rock Island). Other rivers contained lead loads one-to-two orders of magnitude lower than the Columbia and Spokane Rivers.

All river sites had much higher lead loads during spring compared with fall loads. Sampling events generally captured high-flow spring conditions and low-flow fall conditions at all river sites. A cursory examination of the data suggests that higher flows drive the lead loads more than SPM lead concentrations or total suspended solids (TSS), although TSS may also be a function of flow at many sites.

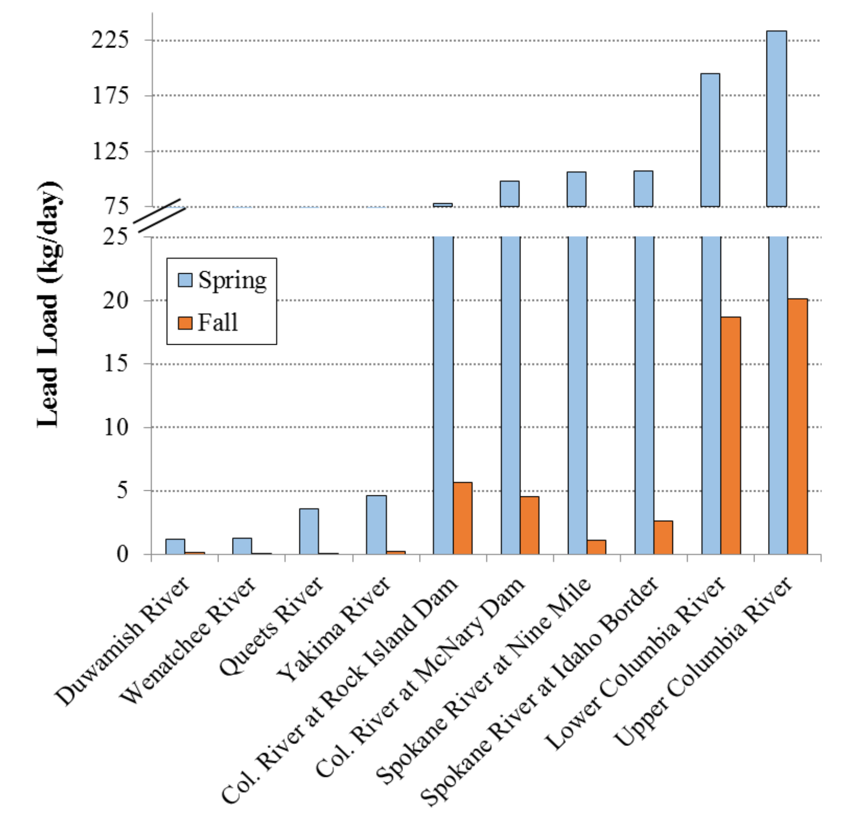


Figure 3. Estimated Mean Particle-bound Lead Loading at River Monitoring Sites, Spring and Fall 2014 (kg/day).
Values show the average of two samples per season.

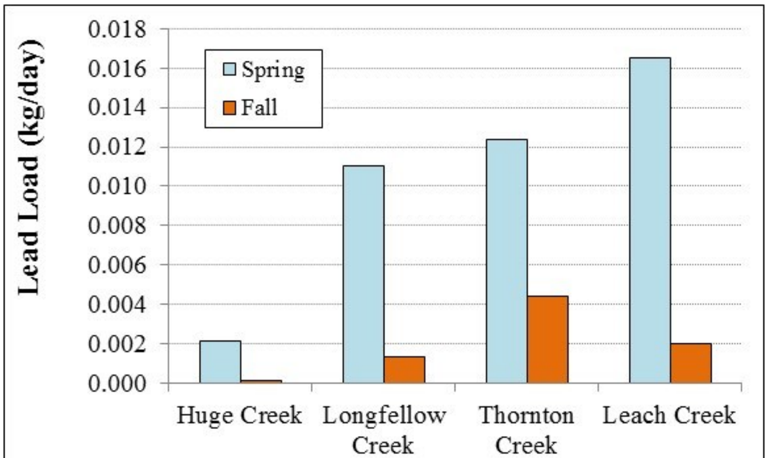


Figure 4. Estimated Mean Particle-bound Lead Loading at Small Stream Monitoring Sites, Spring and Fall 2014 (kg/day).
Values show the average of two samples per season.

Much lower lead loads were found in the small streams (0.0002-0.016 kg/day), with the rural reference stream (Huge Creek) ranking lowest. These low lead loads correspond to lower flows in the small streams compared with the large and mid-sized rivers.

Spring loads in the small streams were much higher than those in the fall, similar to the pattern observed for the large and mid-sized rivers. Lead loads were an order-of-magnitude higher in the spring, although it is noteworthy that these loads are based on instantaneous measurements of lead and average flow for the day of sampling. These instantaneous loads, particularly in small streams, can be heavily influenced by antecedent rainfall. This effect was observed in the first round of spring sampling for small streams, when two inches of rain fell during the two days prior to sampling[1], leading to a large increase in flows and resulting lead loads.

[1] Seattle-Tacoma Airport, May 3-4, 2014

Temporal Trends

Sampling conducted in 2014 was the seventh year (2008-2014) of monitoring at 11 of the study sites and the fourth year (2011-2014) for those added to the program later (Thornton, Longfellow, Leach, and Huge Creeks). The Seasonal Kendall Test — a non-parametric rank test for identifying trends in seasonal time series data — was used to evaluate the SPM lead data for trends during these periods. Separate slope estimates were also calculated for spring and fall seasons. Huge Creek was excluded from this analysis since nearly 90% of the results were below reporting limits; all other data were included except those that failed to meet MQOs.

Table 2 shows results of the Seasonal Kendall Test and seasonal slope estimate at each site. Estimates of slopes were generally upward for river sites during the spring, whereas downward slopes were found for fall results at all sites except Longfellow Creek. Thornton Creek, showing relatively large downward slopes for both spring and fall, was the only location demonstrating a significant overall trend ($p<0.05$).

The following sections describe general trends in lead concentrations observed at the monitoring sites. Spring and fall data are separated and fitted with simple (least squares) regressions lines as a visual tool to display general patterns in the data.

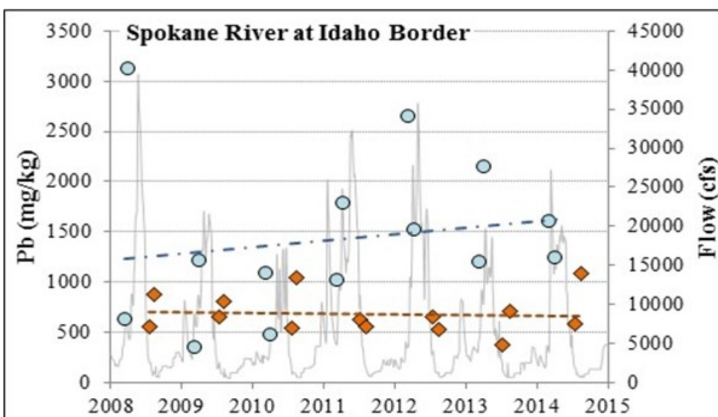
Table 2. Temporal Trend Statistics for All SPM Lead Data, 2008-2014.

Waterbody	n	Seasonal Kendall Slope Estimate (mg/kg/yr)		Seasonal Kendall
		Spring	Fall	Pooled Season p-value
Spokane River				
Spokane River at Idaho Border	28	53	-27	1.000
Spokane River at Nine Mile	28	28	-3.6	0.75
Columbia River				
Columbia River, Upper	28	-1.9	-1.5	0.915
Columbia River at Rock Island Dam	26	6.7	-3.1	0.339
Columbia River at McNary Dam	25	2.4	-0.8	0.750
Columbia River, Lower	26	0.6	-1.5	0.595
Mid-sized Rivers				
Duwamish River	28	0.7	-0.9	0.915
Queets River	28	0.1	-1.2	0.167
Yakima River	24	-0.1	-1.4	0.111
Wenatchee River	25	1.8	-2.6	0.595
Small Streams				
Thornton Creek	16	-9.9	-25	**0.031**
Longfellow Creek	16	-3.4	0.9	0.471
Leach Creek	16	6.3	-19	0.810
Hylebos Creek	26	-1.3	-1.6	0.339

Bold values indicate significance at $p<0.05$.

Spokane River

Figure 5 shows lead concentrations and streamflow at the Spokane River sites from 2008 to 2014. No consistently increasing or decreasing patterns emerged at either of the Spokane River sites. Maximum lead concentrations for both sites occurred in the spring of 2008 and 2012 during the highest flows, and minimum spring concentrations occurred during low-flow years (2009, 2010). Fall samples had less variability than spring samples. Hallock (2010) found that total lead significantly ($p<0.10$) decreased in Spokane River water samples between 1994 and 2009, although these decreases were not significant when data were flow-adjusted or when only data from 2001-2009 were evaluated.



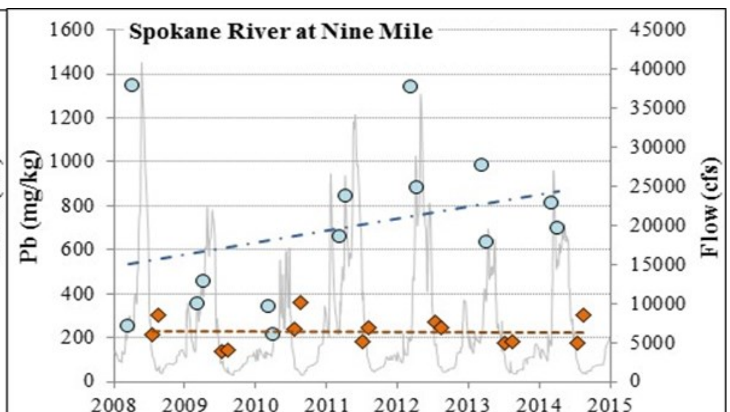


Figure 5. Lead Concentrations in SPM and Streamflow at Spokane River Sites, 2008 to 2014.

Note the different y-axes units and scales. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Spokane River flow data provided by the U.S. Geological Survey.

Columbia River

Pooled 2008-2014 data for each of the Columbia River locations are plotted as box-and-whiskers in Figure 6. Decreasing lead concentrations occur with each successive downstream reach sampled. The site just downstream of the Canada border contains lead in SPM an order of magnitude higher than the site near the mouth. This pattern suggests that attenuation and dilution are the major factors altering lead concentrations in downstream reaches. Signs of major lead sources — including the Spokane River — are dampened at the large scale of Columbia River reaches.

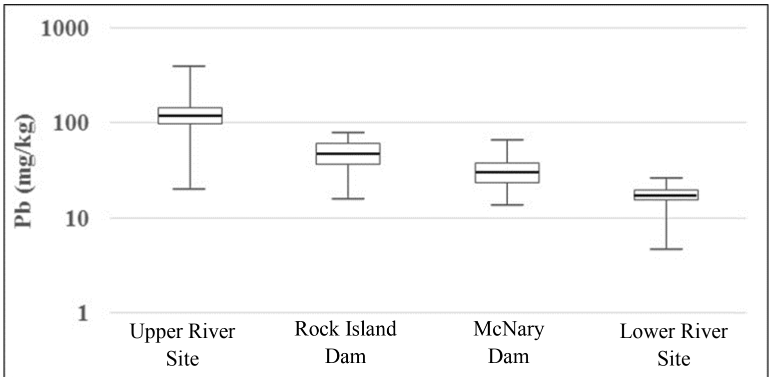


Figure 6. Lead Concentrations in SPM at Columbia River Sites, 2008-2014.

Figure 7 displays the Columbia River SPM lead concentrations and streamflow from 2008 to 2014. As noted previously (Table 2), fall lead concentrations showed nearly flat or slightly decreasing trends over the study period, while lead concentrations in spring generally increased. At Rock Island Dam, lead in SPM continues to increase beyond the significant increase reported for the years 2008-2013 (Clinton and Mathieu, 2015).

No other patterns were apparent for the other three Columbia River sites from 2008 to 2014. The Upper Columbia River site continued to have the highest values of the four sites. Like the Spokane River, the highest lead concentrations at the Upper Columbia River site were measured in the spring of 2008 and 2012.

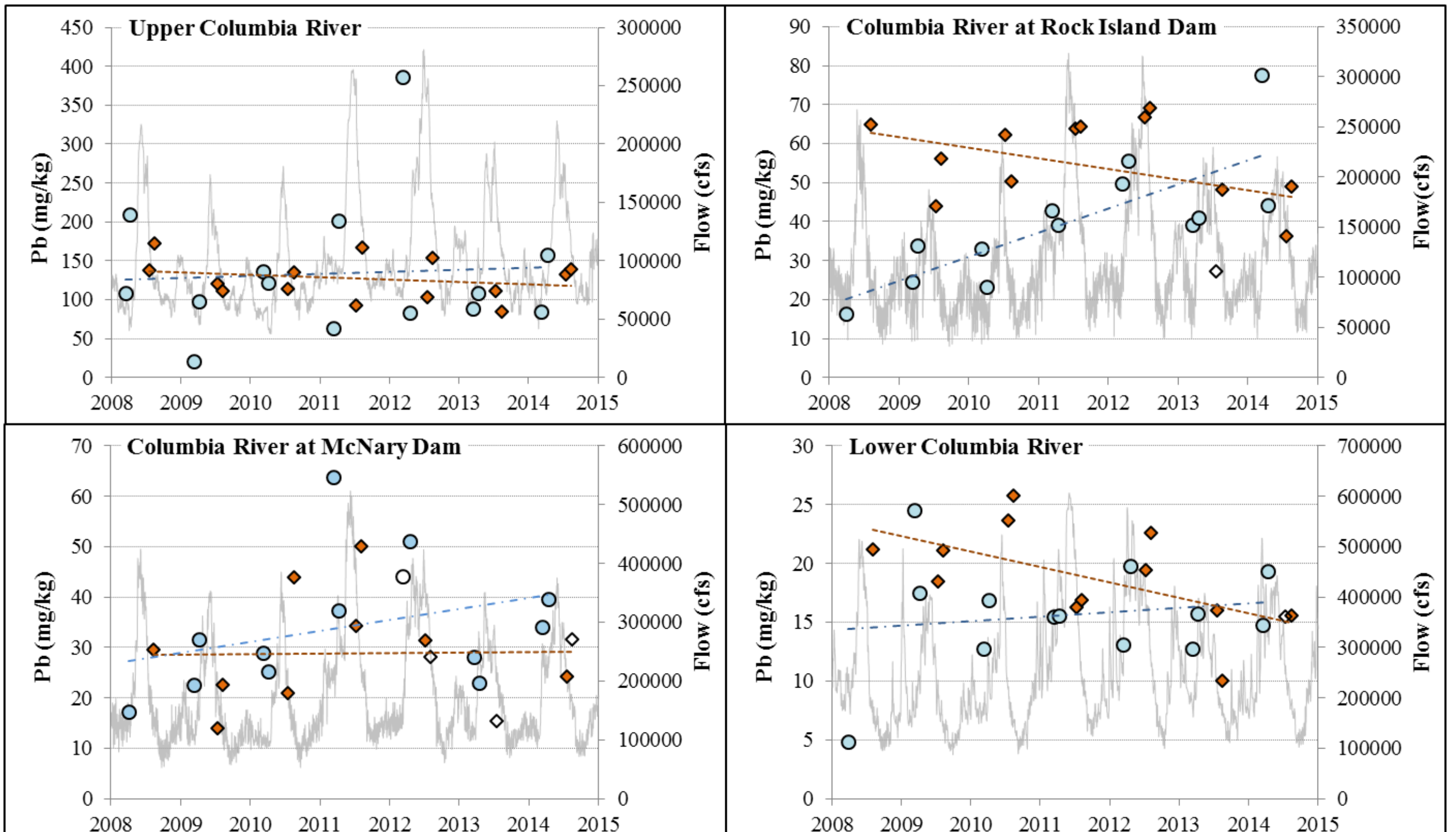


Figure 7. Lead Concentrations in SPM and Streamflow at Columbia River Sites, 2008 to 2014.
Note the different y-axes units and scales. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Hollow Symbols=Values Above Detection Limit and Below Reporting Limit. Columbia River flow data provided by the U.S. Geological Survey and U.S. Army Corps of Engineers.

Mid-sized Rivers

For the 2008-2014 period, mid-sized rivers (Duwamish, Queets, Wenatchee, and Yakima) showed decreasing trends in SPM lead during the fall sampling (Figure 8). At the Queets River location, lead in SPM continued to decrease below the significant declines reported for the years 2008-2013 (Clinton and Mathieu, 2015). The Queets River serves as a river reference site for this study because the watershed lies primarily on national park land and has few roads and little development. Nevertheless, median concentrations of SPM lead in the Queets River during the 2008-2014 study period were higher than in the Yakima, Wenatchee, and Duwamish Rivers, as well as the Columbia River at the lower river site.

Concentrations of lead in SPM sampled during the spring showed little discernible upward or downward trend in the Duwamish and Queets Rivers. The Wenatchee River also demonstrated no trend in spring concentrations over time when the 2014 outlier (358 mg/kg) was removed.

Lead in SPM from mid-sized rivers 2008-2014 had a pooled median of 17 mg/kg and concentrations rarely exceeded 40 mg/kg. Spring samples at all of the mid-sized rivers have remarkably small variability within and among years, which makes the Wenatchee 2014 outlier all the more striking.

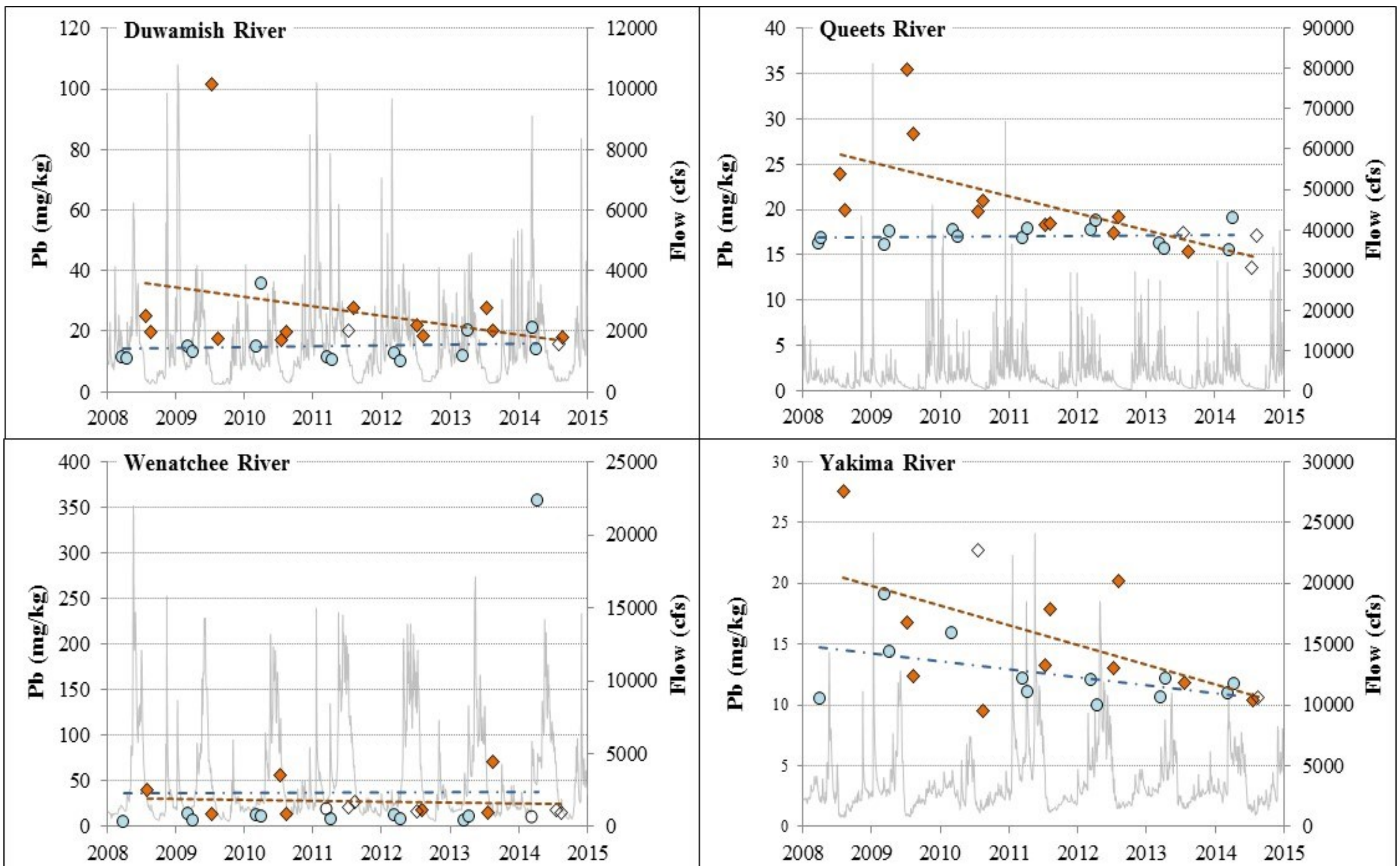


Figure 8. Lead Concentration in SPM and Streamflow at Mid-sized River Sites, 2008 to 2014.

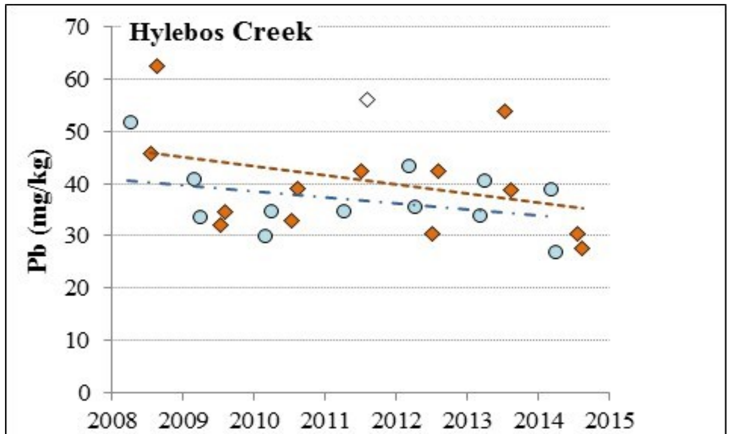
Note the different y-axes units and scales. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Hollow Symbols=Values Above Detection Limit and Below Reporting Limit. Flow data for the mid-sized rivers provided by the U.S. Geological Survey.

Small Streams

Lead concentrations in SPM from Leach and Longfellow Creeks were consistently higher than at other sites, with the exception of the Spokane River. Concentrations in Thornton Creek were also higher compared to mid-sized rivers and all Columbia River locations except the Upper Columbia site. These three urban streams continue to have SPM lead an order of magnitude higher than Huge Creek, the small stream reference site.

Fall SPM lead was generally lower than during previous years, continuing the downward trends measured previously (Figure 9). One notable exception is Longfellow Creek, where average SPM lead was more than double the concentrations seen the previous year and was substantially higher than any of the fall samples collected during previous years. There is no apparent explanation for this jump in lead concentrations at Longfellow Creek; it may signal an additional lead input, or might be normal variability that has yet to be revealed with only four years of sample data.

Aside from Leach Creek, spring SPM appears to show a slight decreasing trend since 2011. Spring sampling at Leach Creek demonstrated high intra-year variability.



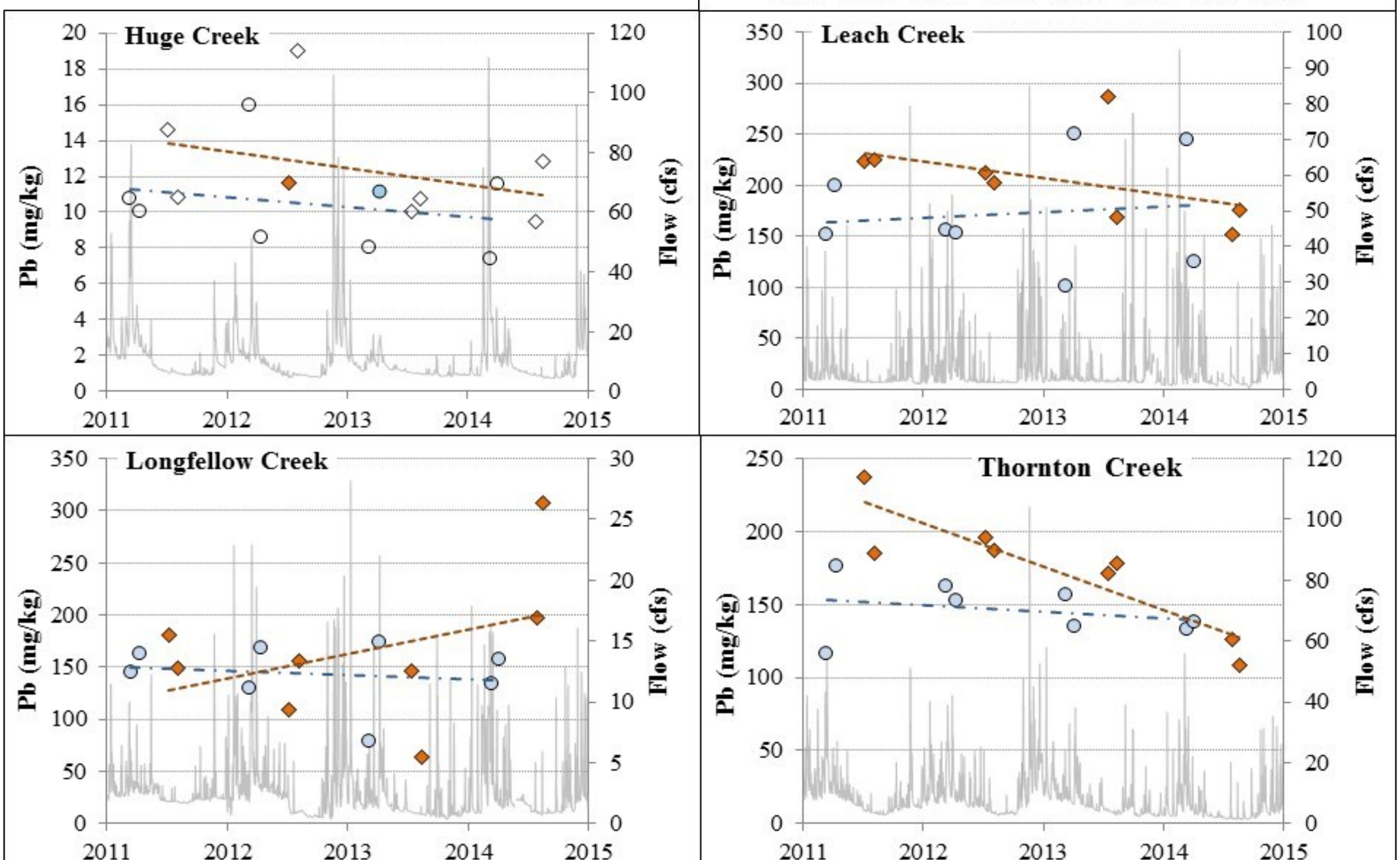


Figure 9. Lead Concentration in SPM and Streamflow at Small Streams, 2008 to 2014.

Note the different y-axes units and scales. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Hollow Symbols=Values Above Detection Limit and Below Reporting Limit. Flow data for Huge and Leach Creeks provided by the U.S. Geological Survey. Flow data for Longfellow and Thornton Creeks provided by Seattle Public Utilities. No flow data are available for Hylebos Creek.

Conclusions

This report summarizes results from the seventh year of a long-term study to evaluate temporal trends in environmental lead concentrations in selected Washington State rivers and streams. A total of 60 suspended particulate matter (SPM) samples from 15 sites were analyzed for lead in 2014. Results include the following:

- Lead concentrations in SPM ranged from below reporting limits (7-31 mg/kg) to 1,600 mg/kg.
- Samples collected from the Spokane River at the Idaho border contained the highest concentrations, followed by the Spokane River at Nine Mile.
- Lead concentrations were also elevated in the Upper Columbia River and the three urban streams compared to concentrations at other sampling sites.
- Six out of 60 samples (10%) contained lead concentrations above Ecology's freshwater Sediment Cleanup Objective of 360 mg/kg. All samples collected from the Spokane River at the Idaho border and both spring samples from the Spokane River at Nine Mile were above this threshold.
- The Upper Columbia River site had the highest particulate lead loading, ranging from 20 to 230 kg/day, followed by the Lower Columbia, Spokane River locations, and Mid-Columbia River sites. Mid-sized rivers (Duwamish, Queets, Wenatchee, and Yakima) had SPM lead loads an order-of-magnitude lower than the Columbia or Spokane Rivers. Loads in urban streams were comparatively small, commensurate with smaller flows.
- The Seasonal Kendall test revealed a significant decreasing trend for lead in SPM at Thornton Creek from 2011 through 2014. None of the other locations had significant trends over the four or seven years of monitoring. However, slope estimates generally showed decreasing lead in SPM, particularly in fall samples.

Recommendations

The authors of this report should consider changes to the sampling design of the lead monitoring program. The following changes may be considered:

- Add more urban streams to the SPM monitoring site list. The lead concentrations in small, urban streams are most likely to respond to implementation of chemical action plan (CAP) reduction strategies. Increasing the frequency of small-stream sampling should also be considered.

Several recommendations made in the 2013 report (Clinton and Mathieu, 2015) were implemented in the monitoring effort for 2015. These included:

- *Discontinue sampling at most river monitoring sites, as no significant trends have been detected after six years of monitoring. Lead concentrations measured from the mid-sized river sites were low and reflective of baseline conditions; therefore, trends are not likely to be seen.* This recommendation was implemented in 2015 by dropping the sampling efforts in the Columbia River at the Lower River, McNary Dam, and Rock Island Dam sites, and at the Duwamish, Queets, Wenatchee, and Yakima River sites.
- *Continue monitoring the Upper Columbia River and Spokane River sites because lead levels continue to be elevated, despite the lack of apparent trend.* Monitoring was continued at these locations in 2015.
- *Research other methods, such as sediment traps, for collecting SPM that would integrate time and allow for collecting larger sample material size.* Sediment traps were used at two locations—Longfellow and Thornton Creeks—in 2015.

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This report is available on the Department of Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1603015.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search Study ID, PbTrends14.

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