Summary of 2016 Animas River Water Quality Monitoring at Rotary Park in Durango, CO

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SAN JUAN MOUNTAINS, CO

Monitoring Program Overview

Mountain Studies Institute (MSI), an independent research and education center based in the San Juan Mountains, monitored water quality of the Animas River before, during, and after the 2015 Gold King Mine release. MSI continued to monitor the Animas River at Rotary Park in 2016, collecting water quality samples during spring runoff, base flows, and storm events from February through November.

The 2016 monitoring program was part of a partnership between MSI and the City of Durango to communicate Animas River water quality information to the public. Following the 2015 Gold King Mine release, there was increased concern in local communities about the water quality of the Animas River and whether metal concentrations in the river pose any threat to human health, agriculture, or aquatic life.

MSI collected grab samples from the Animas River at Rotary Park at weekly intervals during peak river recreation season, and every other week in February, March, August, September, October, and November (Figure 1). Samples were analyzed by Green Analytical laboratory in Durango, CO, for total and dissolved concentrations of aluminum, arsenic, copper, iron, manganese, lead, selenium, and zinc.

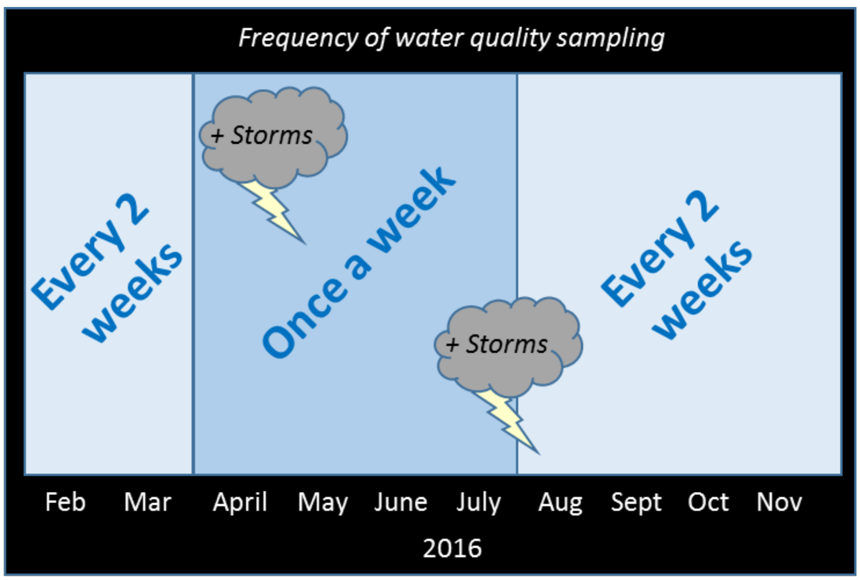


Figure 1: Water quality sampling frequency

MSI's analysis of the 2016 Animas River water quality data centered on four questions:

- How did metal concentrations in 2016 compare to water quality benchmarks?
- Was Animas River water quality in 2016 any different than previous years?
- Do metal concentrations in the Animas River increase during storm events?
- Do metal concentrations in the Animas River correlate with other water quality parameters such as flow, pH, conductivity, or turbidity?

Water Quality Benchmarks

The Colorado Department of Public Health and the Environment (CDPHE) and the Environmental Protection Agency (EPA) have developed water quality standards and benchmarks that can be used to evaluate whether water quality is sufficient to support uses such as recreation, agriculture, domestic water supply, and aquatic life (CDPHE 2017; EPA 2015). Graphs of each metal in relation to water quality benchmarks can be found in Appendix A at www.mountainstudies.org/animasriver.

Recreation

- All metals analyzed in 2016 were below EPA's recreational screening levels, which are protective of users who accidently swallow river water (swimmers, rafters, tubers) or users who intentionally ingest river water (backpackers, overnight river users).

Agriculture

- All metals analyzed in 2016 were at safe levels for agricultural uses such as irrigation and livestock watering (based on CDPHE water quality standards, CDPHE 2017).

Domestic Water Supply

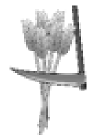
- Most metals analyzed in 2016 were at safe levels for domestic water supply use (based on CDPHE water quality standards, CDPHE 2017).
  - On at least two occasions in 2016, concentrations of lead surpassed CDPHE water quality standards set to protect the Animas River for use as a domestic drinking water source. However, City of Durango water is thoroughly treated and meets all drinking water quality standards prior to public consumption.
  - Levels of manganese surpassed CDPHE water supply standards, but manganese at this level is not of concern for human health. The concern is associated with aesthetic effects such as staining of appliances.

Aquatic Life

- Metals thought to be most harmful to aquatic life (copper, zinc, and selenium) were found to be at levels considered safe (based on CDPHE water quality standards, CDPHE 2017). However, MSI did detect high levels of iron and aluminum.
  - Iron surpassed the CDPHE chronic water quality standard. Chronic water quality standards are set by CDPHE to be protective of aquatic life from persistent, long-term exposure to a contaminant.

- Aluminum was close to surpassing the CDPHE chronic water quality standard for aquatic life (aluminum surpassed the chronic water quality standard based on average hardness, but did not surpass the chronic water quality standard based on paired metal-hardness values).

Table 1: Water quality benchmarks.

					
Metal	CDPHE Domestic Water Supply Standard	CDPHE Agriculture Chronic	CDPHE Aquatic Life Acute Standard	CDPHE Aquatic Life Chronic Standard	EPA Recreational Screening Level
Aluminum	-	-	n	n	n
Arsenic	n	n	n	n	n
Copper	n	n	n	n	n
Iron	n	-	-	Y	n
Lead	Y*	n	n	n	n
Manganese	Y**	n	n	n	n
Selenium	n	n	n	n	n
Zinc	n	n	n	n	n

n = metal did not surpass water quality benchmark
Y = metal surpassed water quality benchmark
- = no water quality benchmark available

*This standard is based on pre-treated river water. City of Durango water is thoroughly treated and meets all drinking water quality standards prior to public consumption.
** Manganese at this level is not of concern for human health. The concern is associated with aesthetic effects such as staining of appliances.

2016 Water Quality Data in Context of Historical Data

Following the 2015 Gold King Mine release, there was concern that the water quality of the Animas River could be worse, in 2016, than during years prior to the Gold King Mine release. Using historical data from the Colorado River Watch program, MSI compared 2016 Animas River water quality data to data from 2002-2014.

- Statistical analysis indicated that metal concentrations in the Durango stretch of the Animas River were *not* significantly higher in 2016 than in 2002-2014.

- In other words, metal concentrations at Rotary Park in 2016 were consistent with observations from 2002-2014.

Spring Runoff and Storm Events

The Animas River naturally turns various shades of brown during spring runoff as a result of snowmelt and suspended sediment. Changes in river color also occur after storm events when rain water flows over the adjacent landscape and delivers sediment to the river. MSI assessed whether metal concentrations were higher during changing river conditions (storm events or when spring runoff caused a rapid rise in river level) as compared to during stable conditions.

- Statistical analysis indicated that several metals in 2016 were significantly higher during periods of quickly changing conditions (storm events or rapidly rising river levels).
    - Total aluminum
    - Total arsenic
    - Total iron
    - Total manganese
    - Dissolved manganese
    - Dissolved zinc

- The elevated levels of metals observed in the Durango stretch of the Animas River during storm events were not high enough to pose a threat to human health.

Metals and Other Water Quality Parameters

In 2016, USGS began to provide continuous measurement of pH, turbidity, and conductivity at several gauges on the Animas and San Juan Rivers including the Animas River gauge in Durango, CO. MSI examined the relationship between metal concentrations and these additional water quality parameters.

- In 2016, concentrations of several metals correlated at a statistically significant level with discharge, turbidity, pH, and conductivity (Table 2).

So What?

The 2016 water quality data from Rotary Park was encouraging – we have no indication of any threat to human health from Animas River water in Durango and it does not appear that metal concentrations in 2016 were any higher than previous years (2002-2014). We did detect elevated metal concentrations during storm events when turbidity and discharge rose, and conductivity and pH dropped. However, the elevated levels of metals observed in the Durango stretch of the Animas River during storm events were not high enough to pose a threat to human health.

The data did raise concerns for aquatic life in the Durango stretch of the Animas River. These concerns can only be evaluated by continued monitoring of water quality and aquatic life.

For more information regarding MSI's 2016 water quality monitoring analysis, including technical details, tables, graphs, and statistics, please see Appendix B at www.mountainstudies.org/animasriver.

Table 2: Relationship between metal concentrations and discharge, turbidity, pH, and conductivity.

					Aluminum		**Arsenic**		**Copper**		**Iron**		**Lead**		**Manganese**		**Zinc**	
					T	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**
When…	*…discharge…*	*…increased…*	*…the following metals…*	*…increased*	X				X	X	X		X		X		X	
	…turbidity…	*…increased…*		*…increased*	X		X		X	X	X		X		X		X	
	…turbidity…	*…increased…*		*…decreased*												X		X
	…pH…	*…decreased…*		*…increased*	X				X	X	X		X		X		X	
	…conductivity…	*…decreased…*		*…increased*	X				X	X	X		X		X		X	
	…conductivity…	*…decreased…*		*…decreased*												X		

Note: X with blue highlight indicates a metal that correlated with a water quality parameter at a statistically significant level.

References:

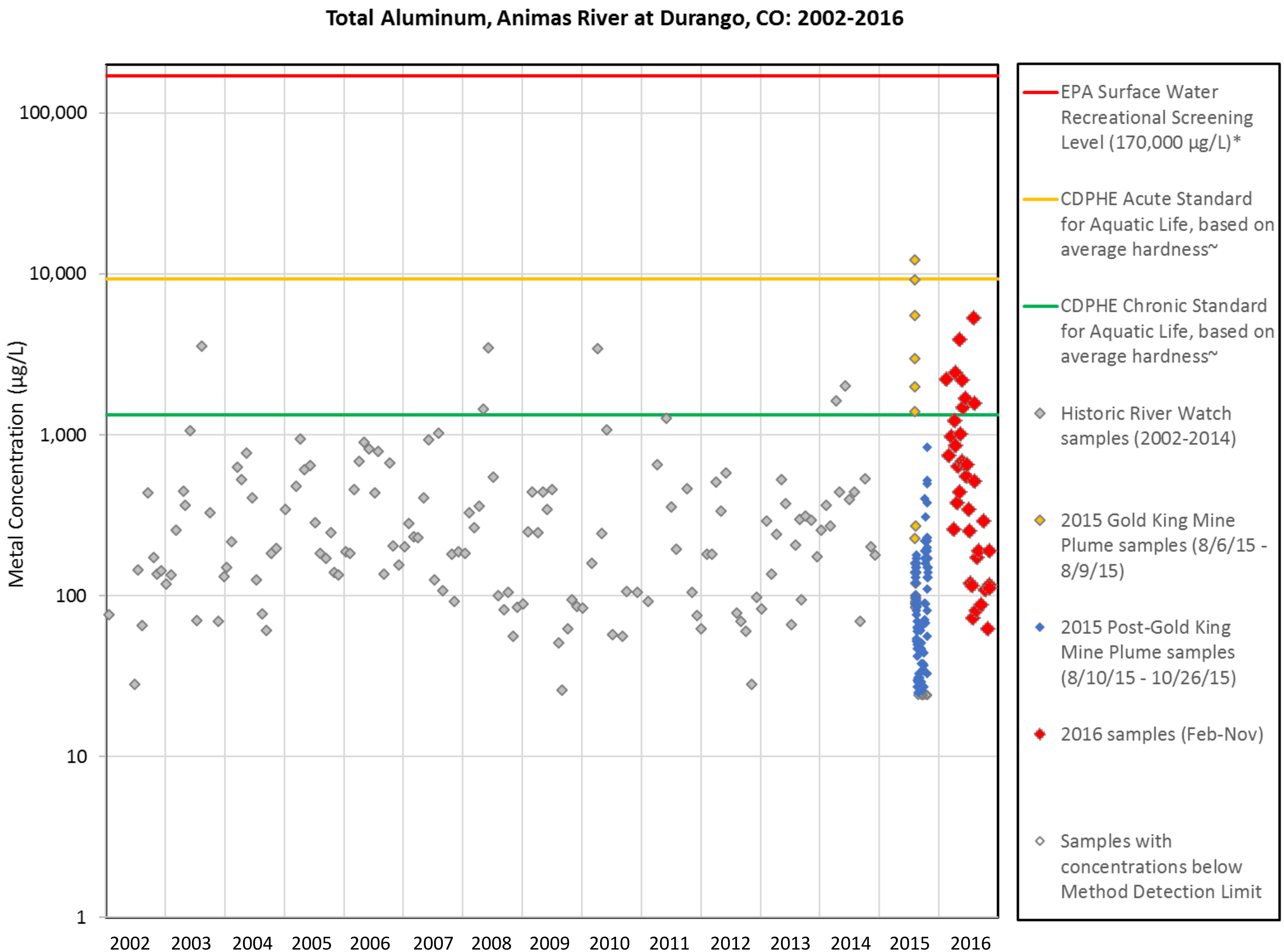
Colorado Department of Public Health and Environment (CDPHE). 2017. Regulation No. 31 - The Basic Standards and Methodologies for Surface Water (5 CCR 1002-31), effective 3/1/17. Available: https://www.colorado.gov/pacific/cdphe/water-quality-control-commission-regulations.

EPA. 2015. Memorandum: Screening Levels for Recreational Receptors at the Gold King Mine Site. September 2015.

<u>Appendix A:</u>

Graphs of Animas River metal concentrations at

Rotary Park in relation to water quality benchmarks



* The recreational screening level represents the level at which no adverse health effects are expected to occur in humans consuming 2L of water per day, from the Animas, orally, for 64 days each year for a total of 30 years.

~Colorado Department of Public Health and the Environment (CDPHE) standards based on Colorado surface water quality classifications and Reg. 31 and 34. Standards vary with water hardnesss and are plotted here using an average water hardness of the Animas River at this location, 208 mg/L.

Note: 2002 - 2014 data is River Watch data from the Animas River at the fish hatchery in Durango, CO. 2015 and 2016 data is Mountain Studies Institute data from the Animas River at Rotary Park in Durango, CO

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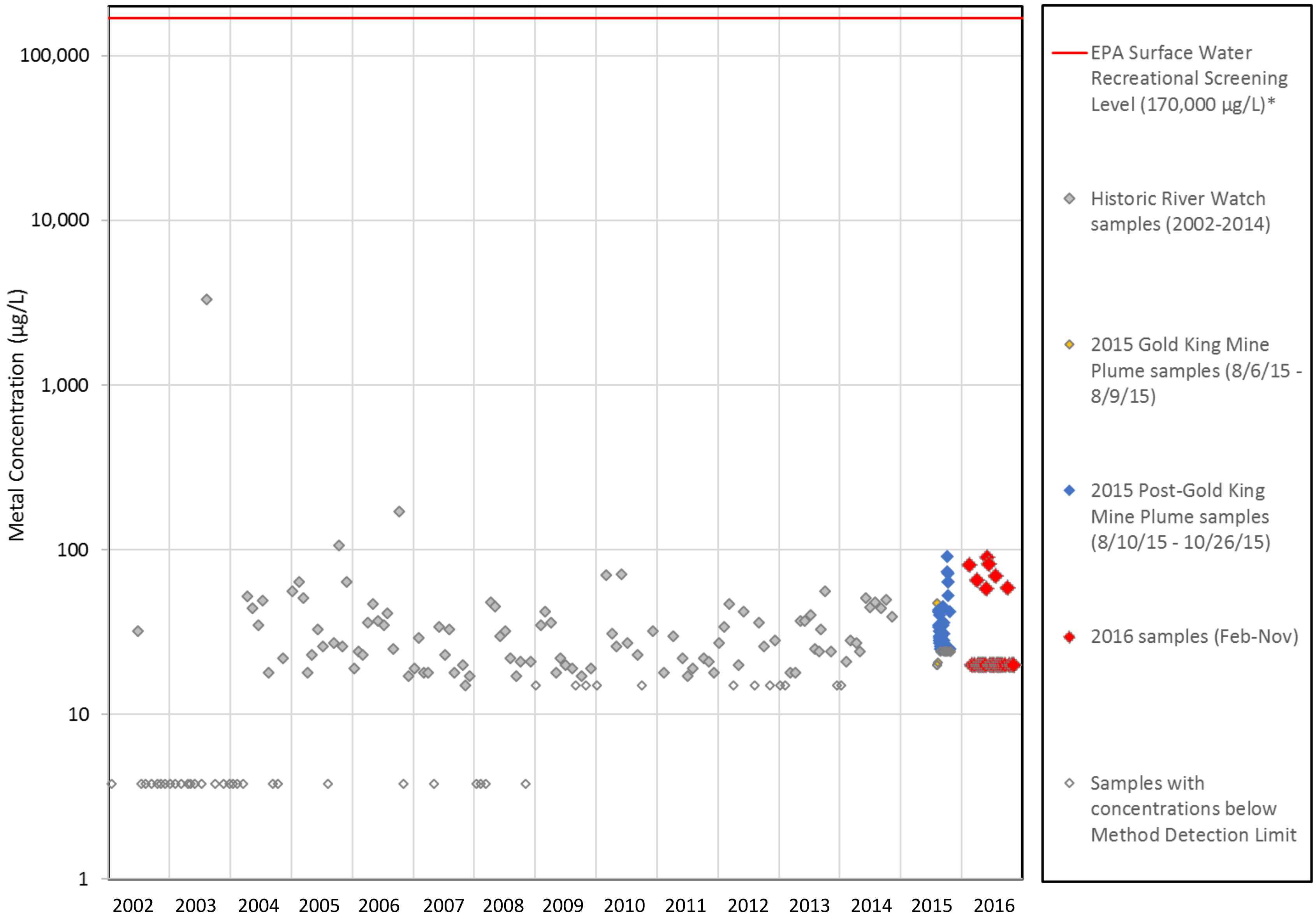
Dissolved Aluminum, Animas River at Durango, CO: 2002-2016



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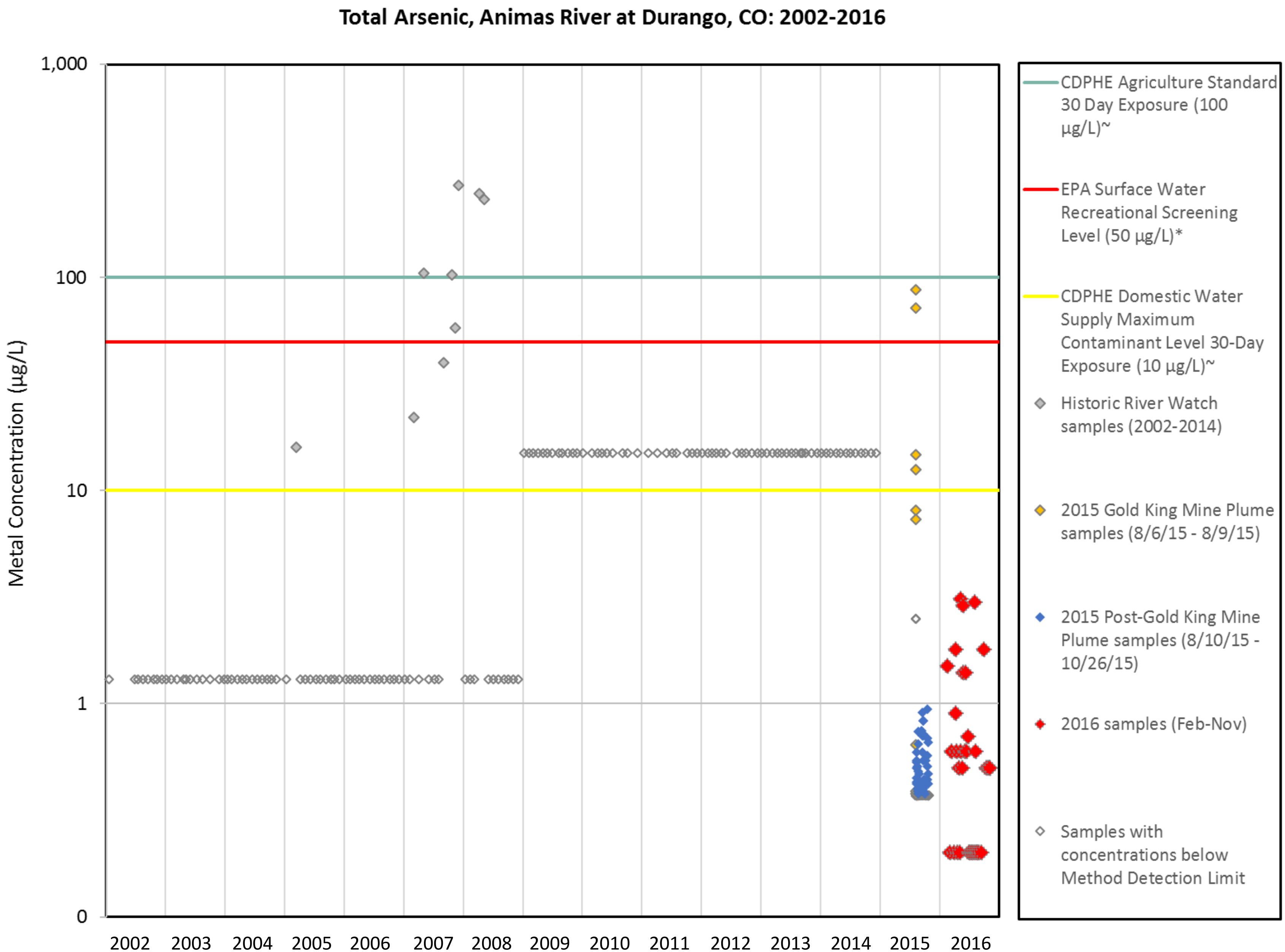

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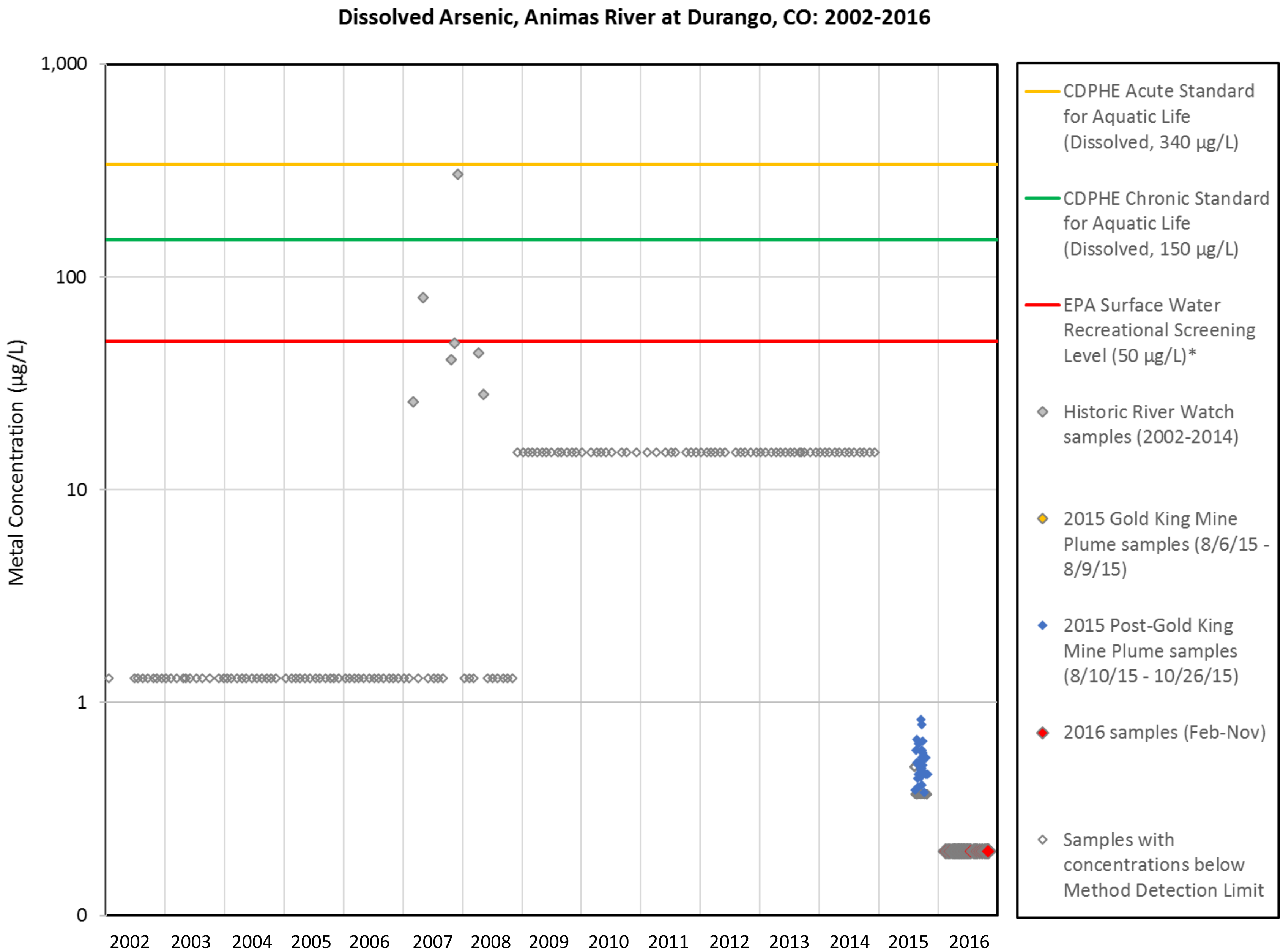

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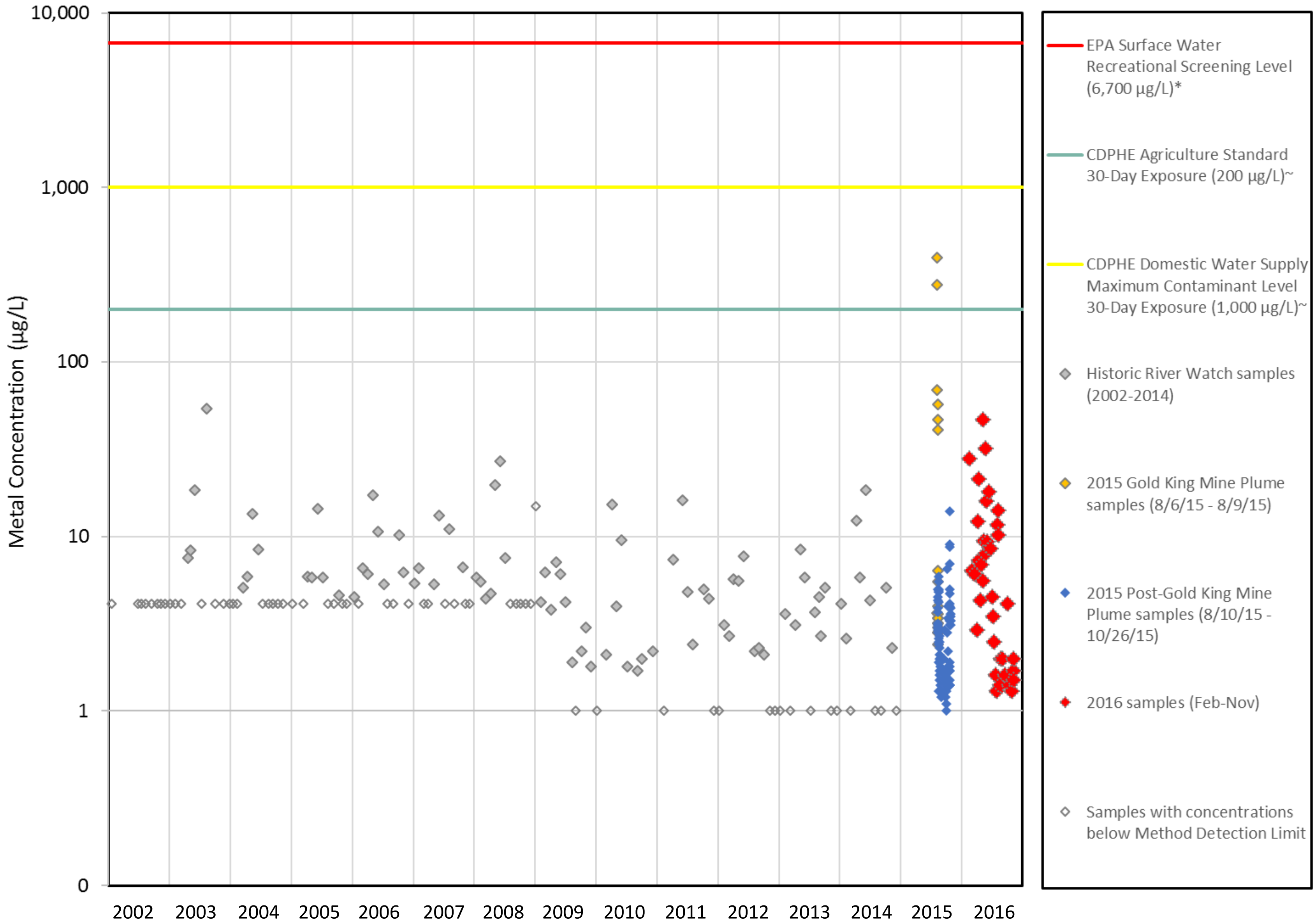
Total Copper, Animas River at Durango, CO: 2002-2016



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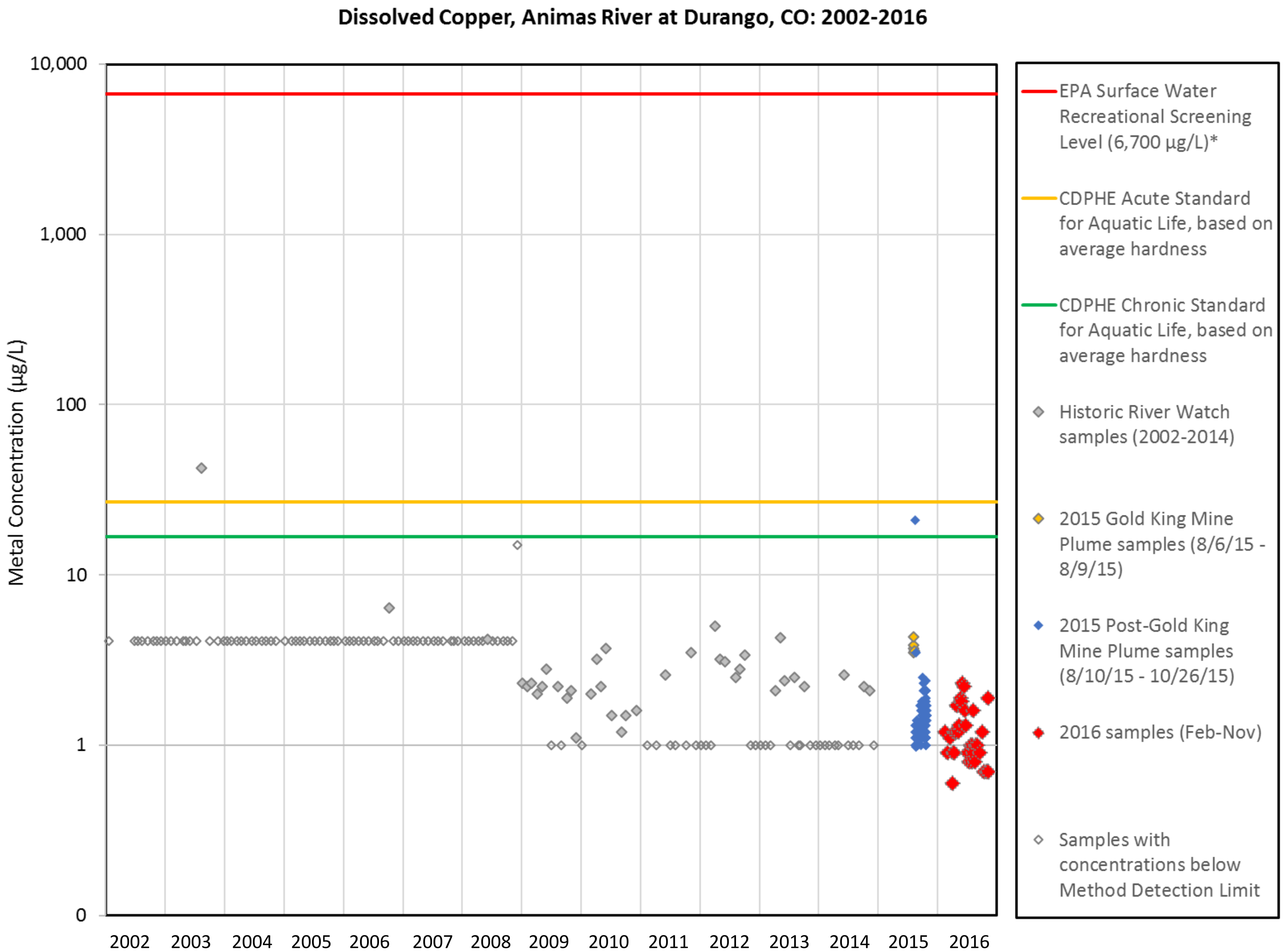

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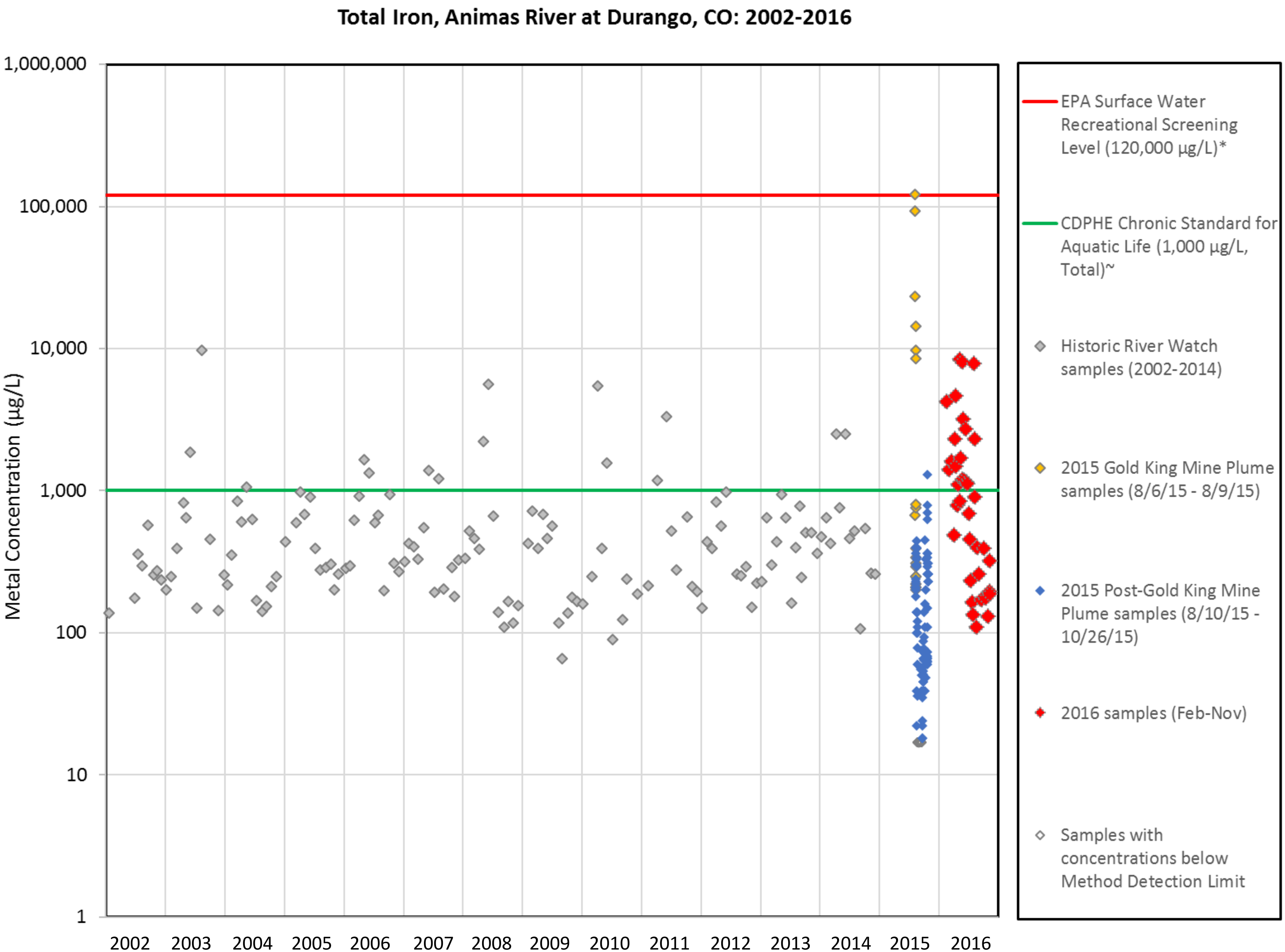

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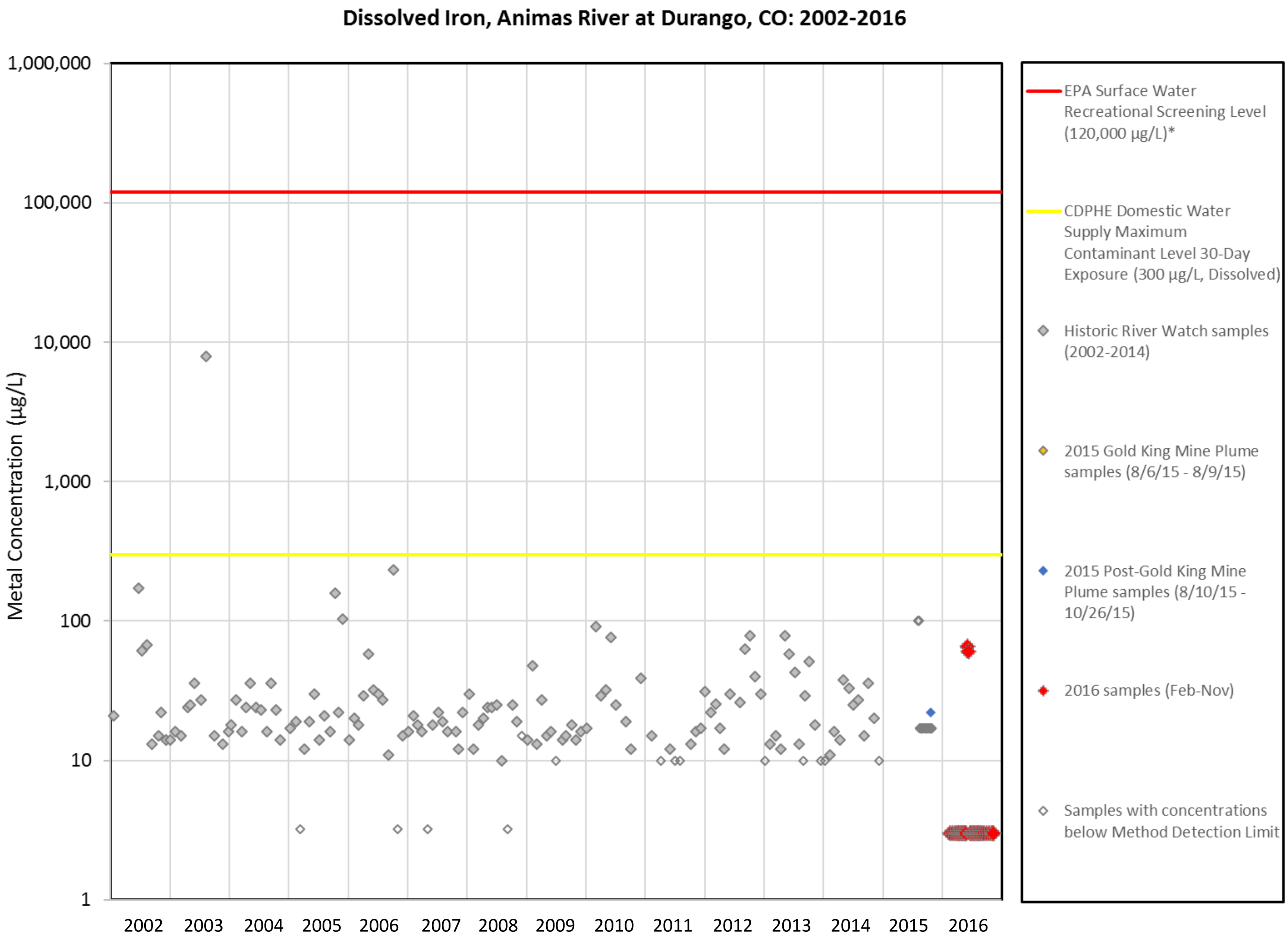

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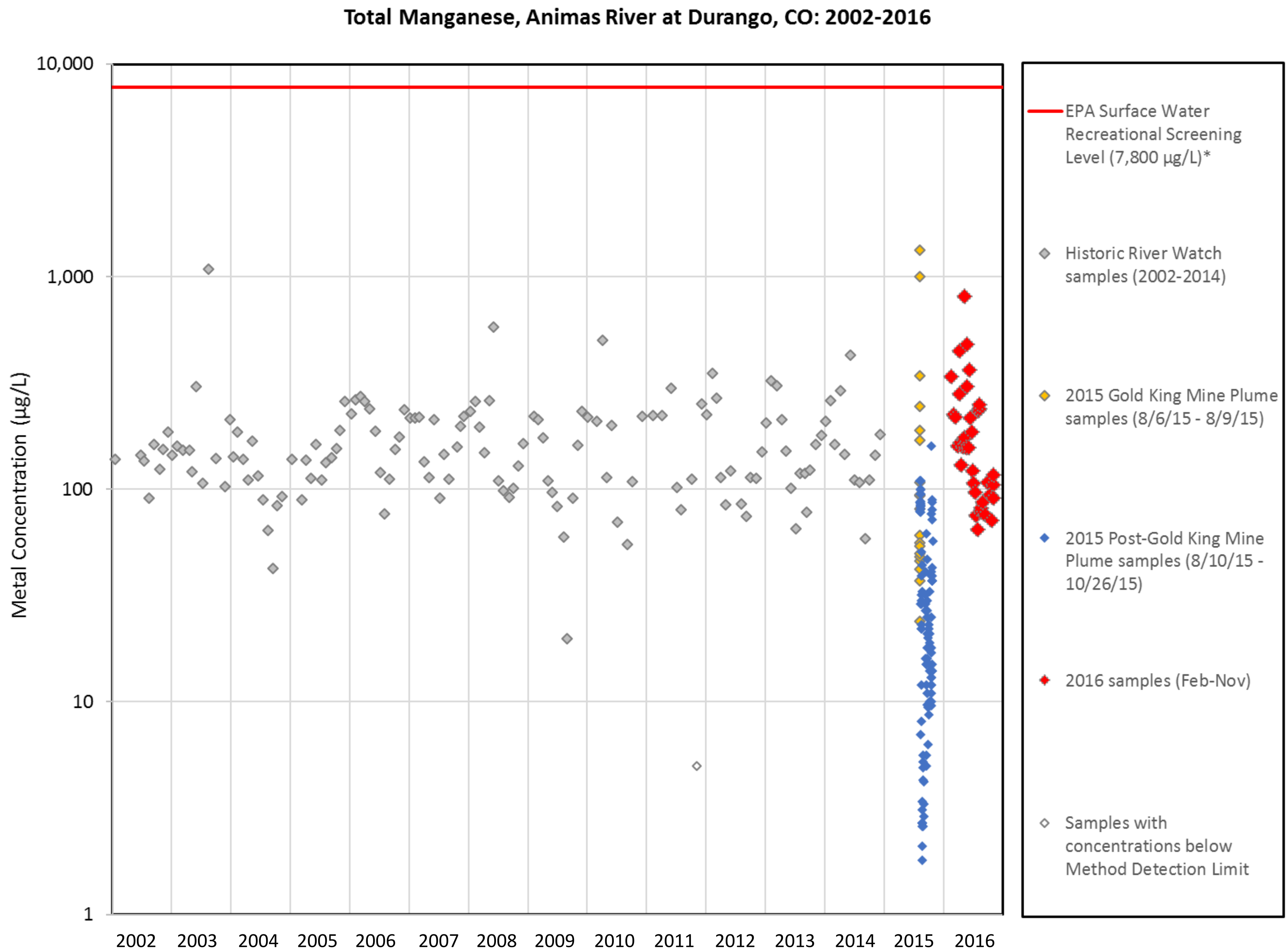

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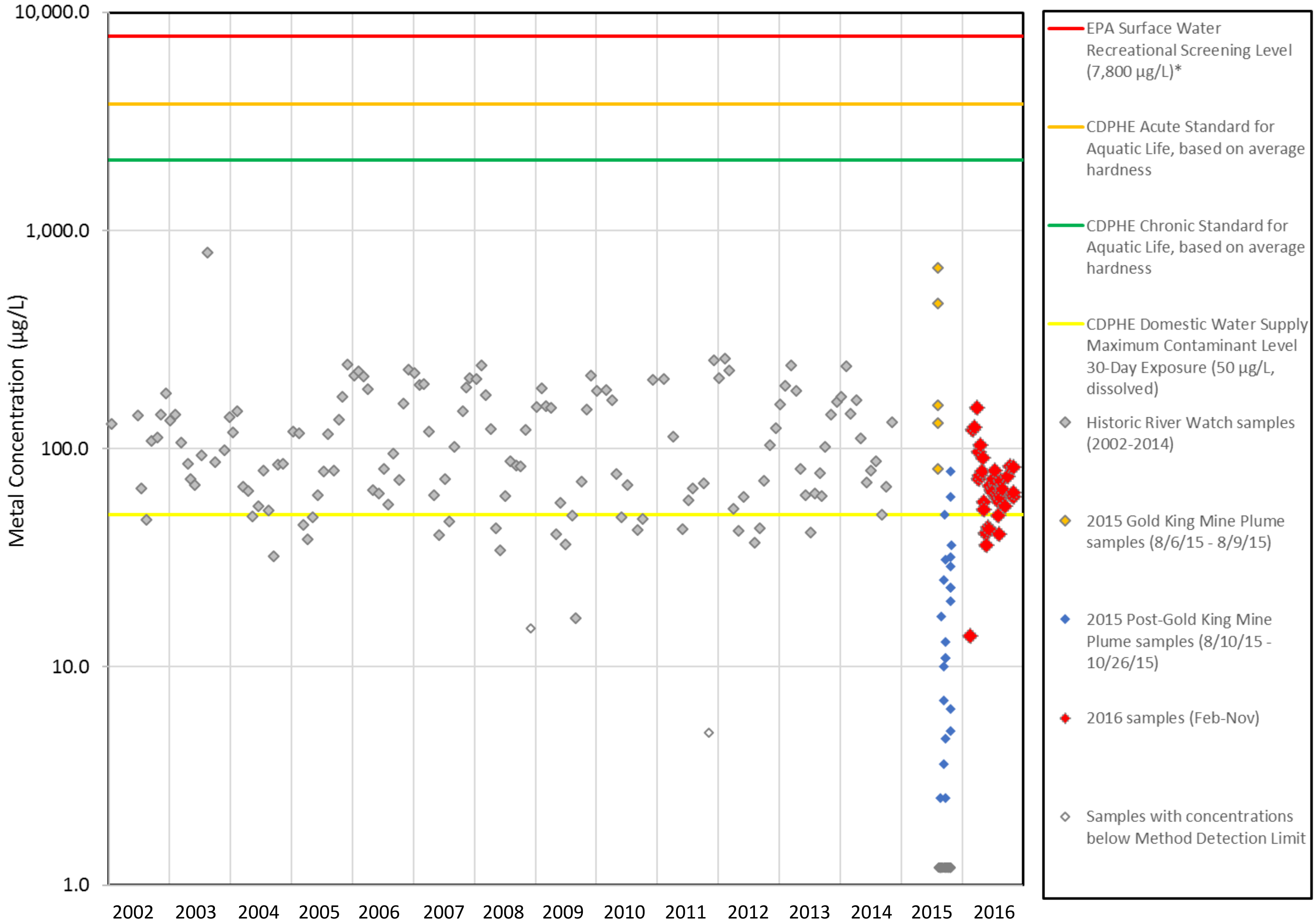
Dissolved Manganese, Animas River at Durango, CO: 2002-2016



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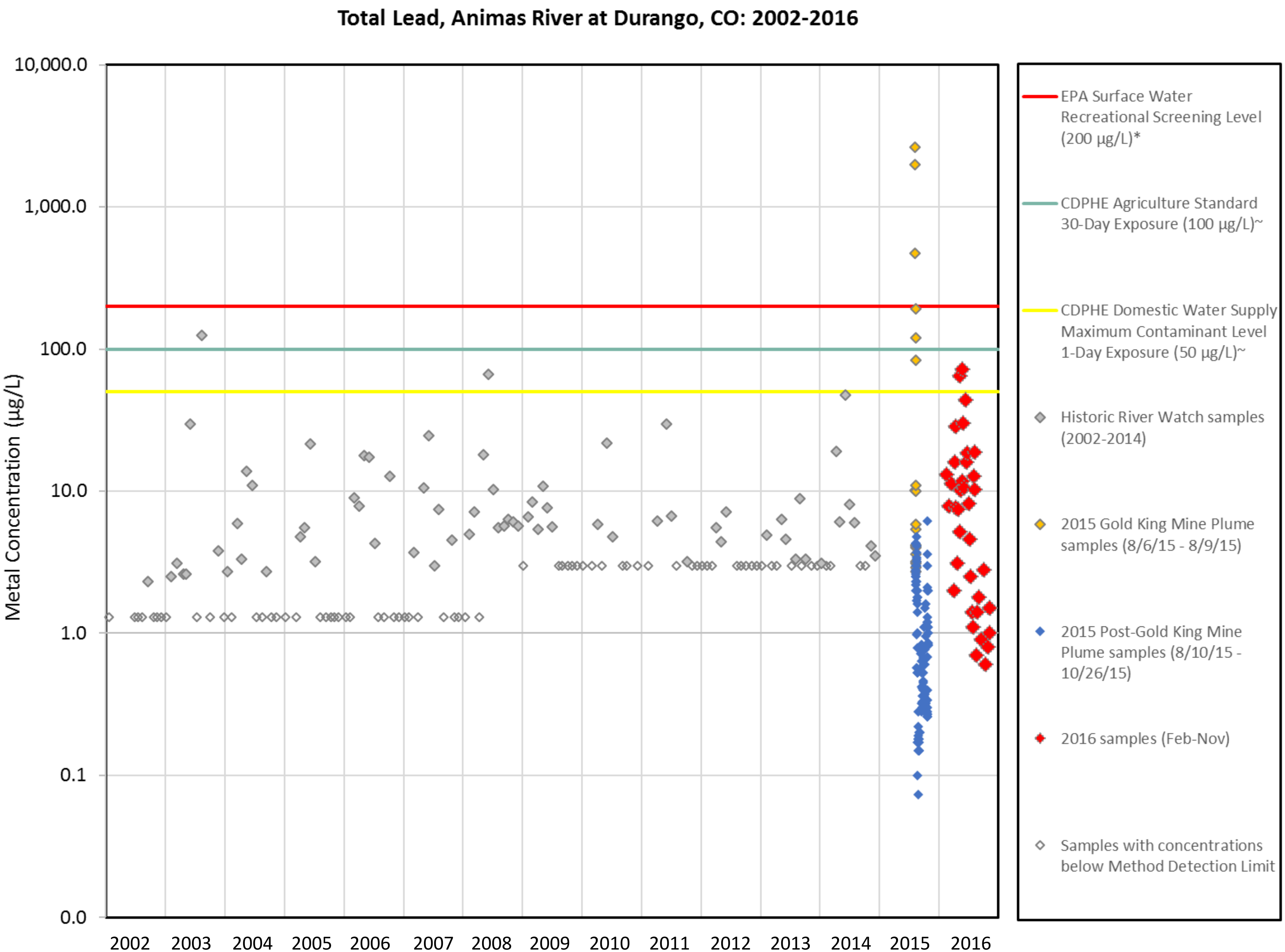

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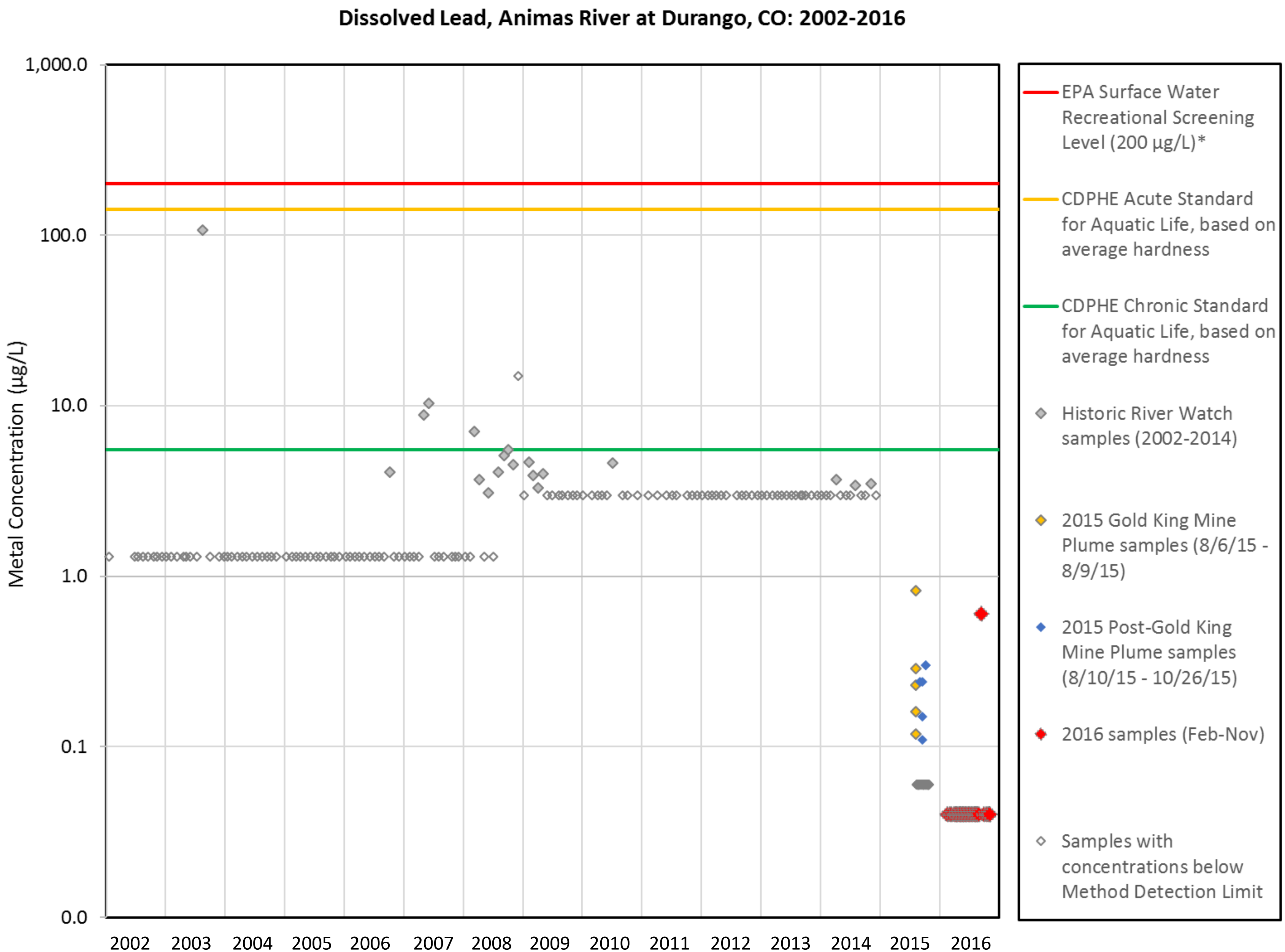

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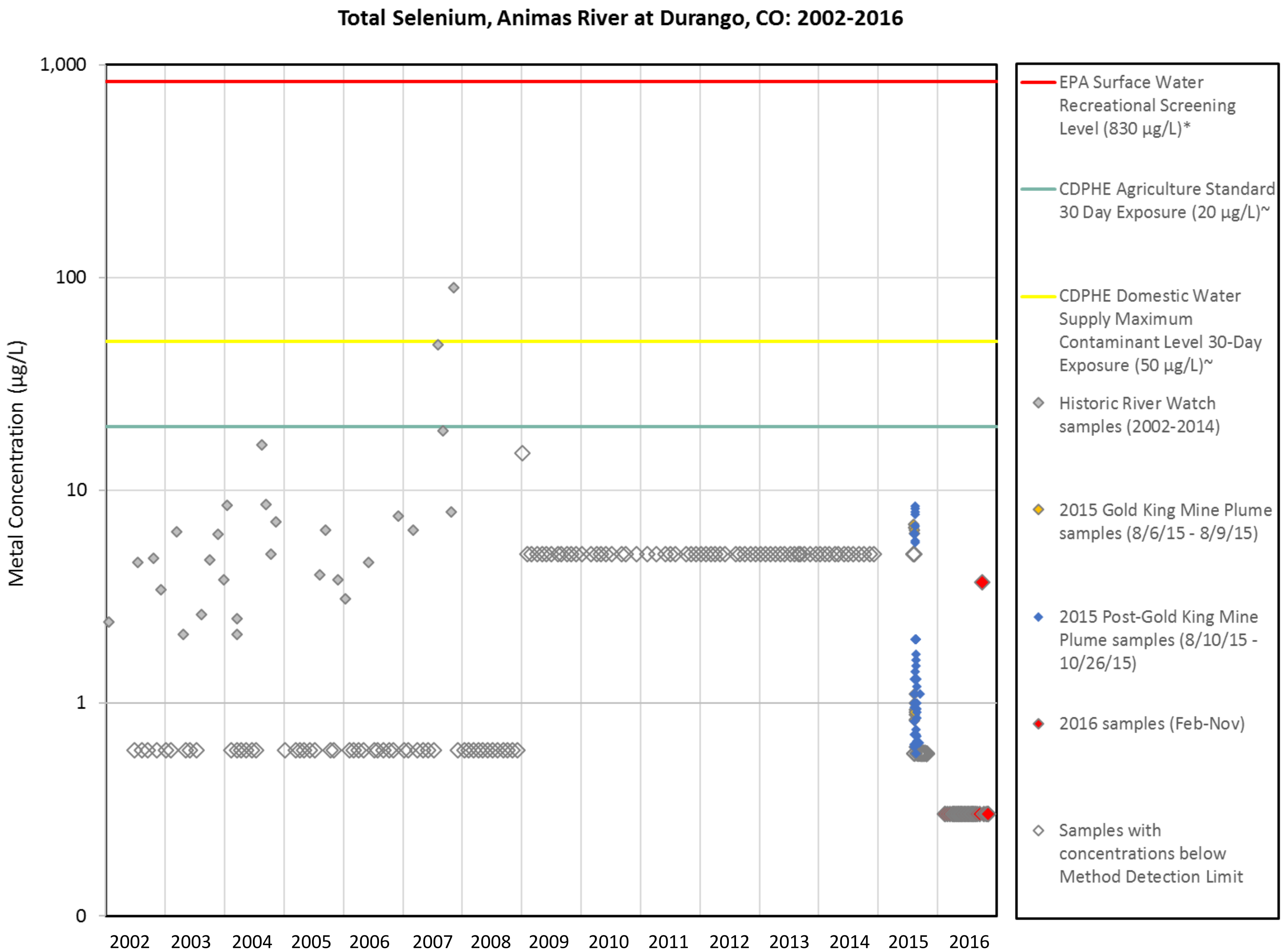

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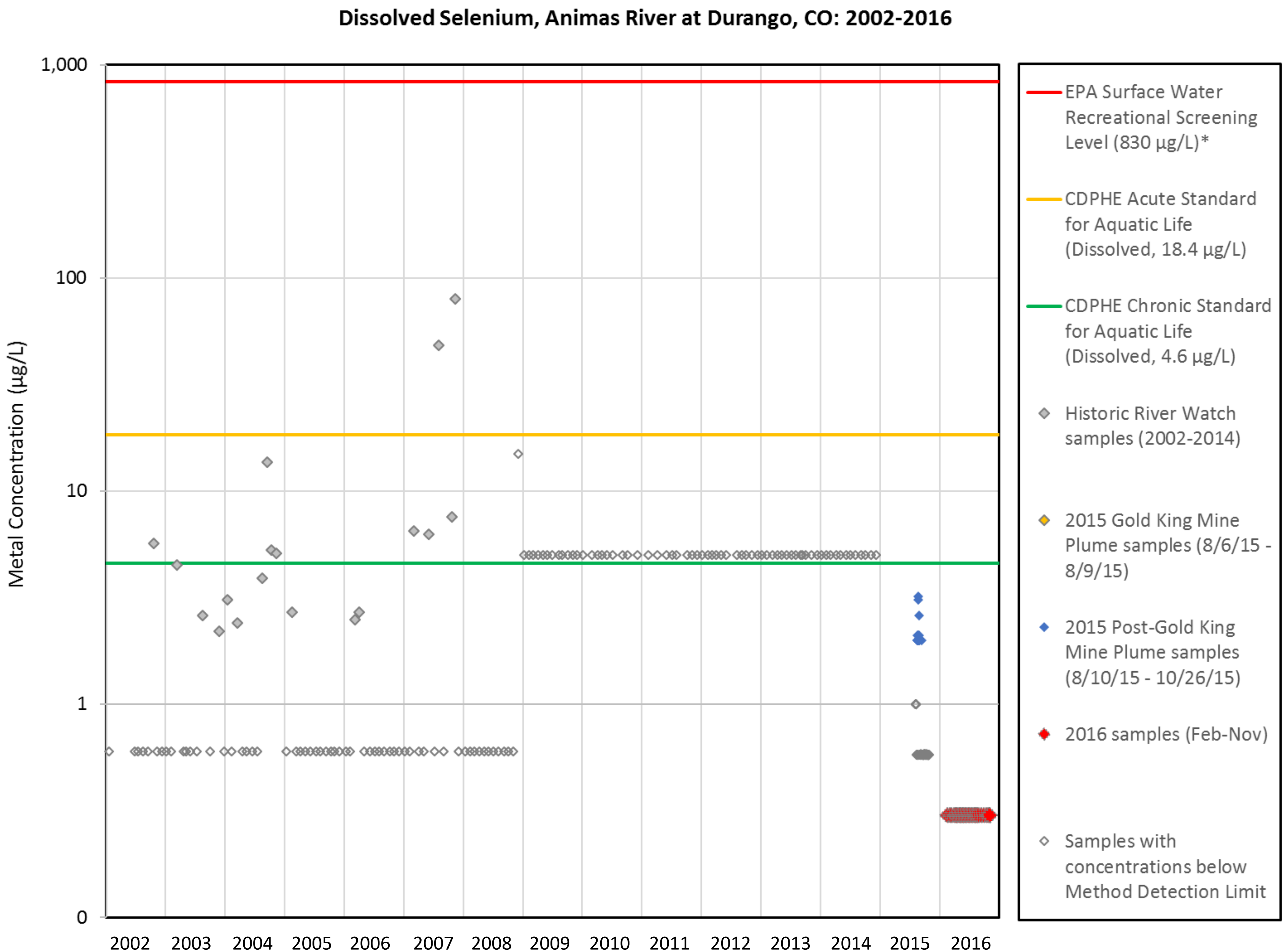

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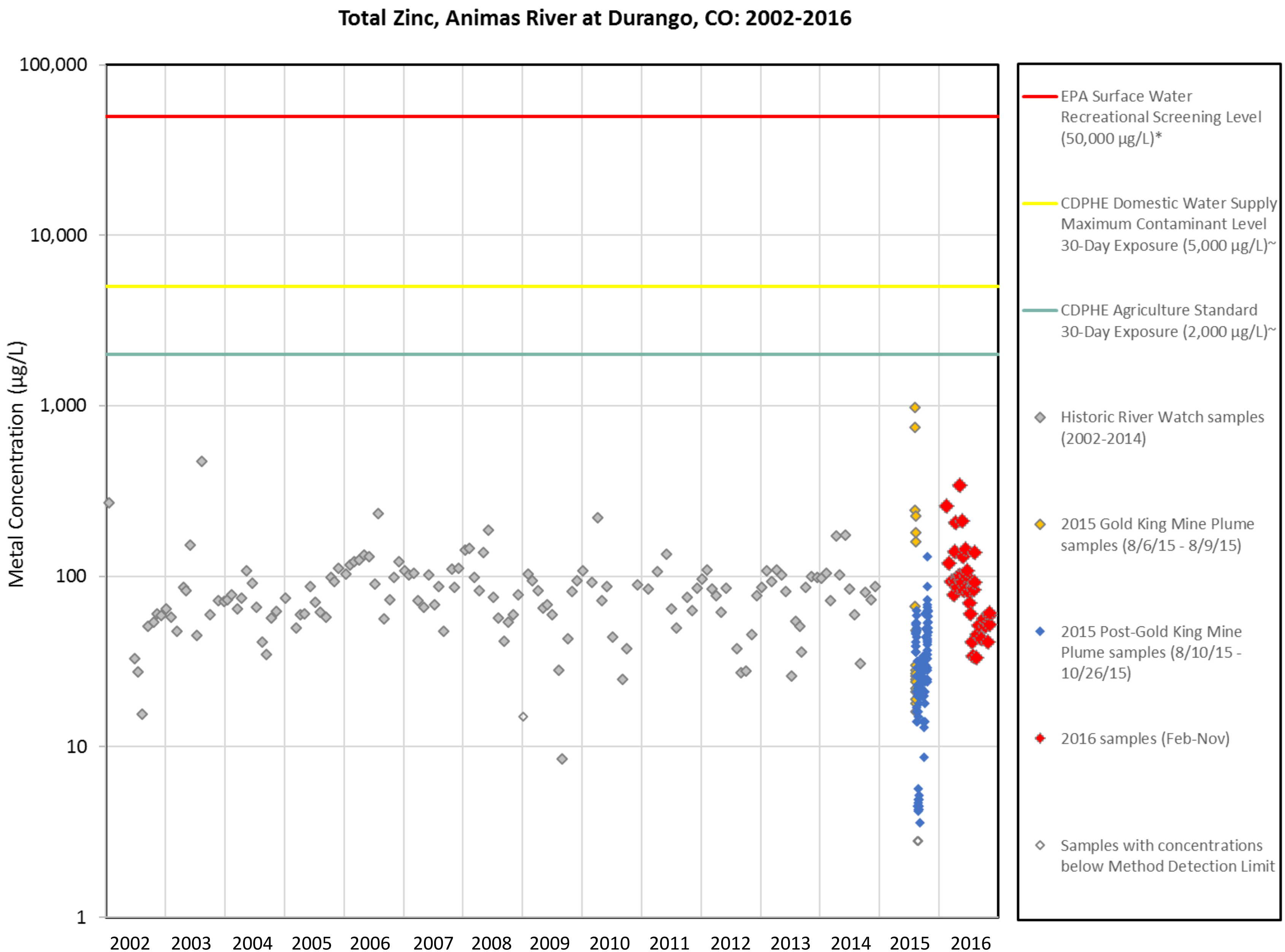

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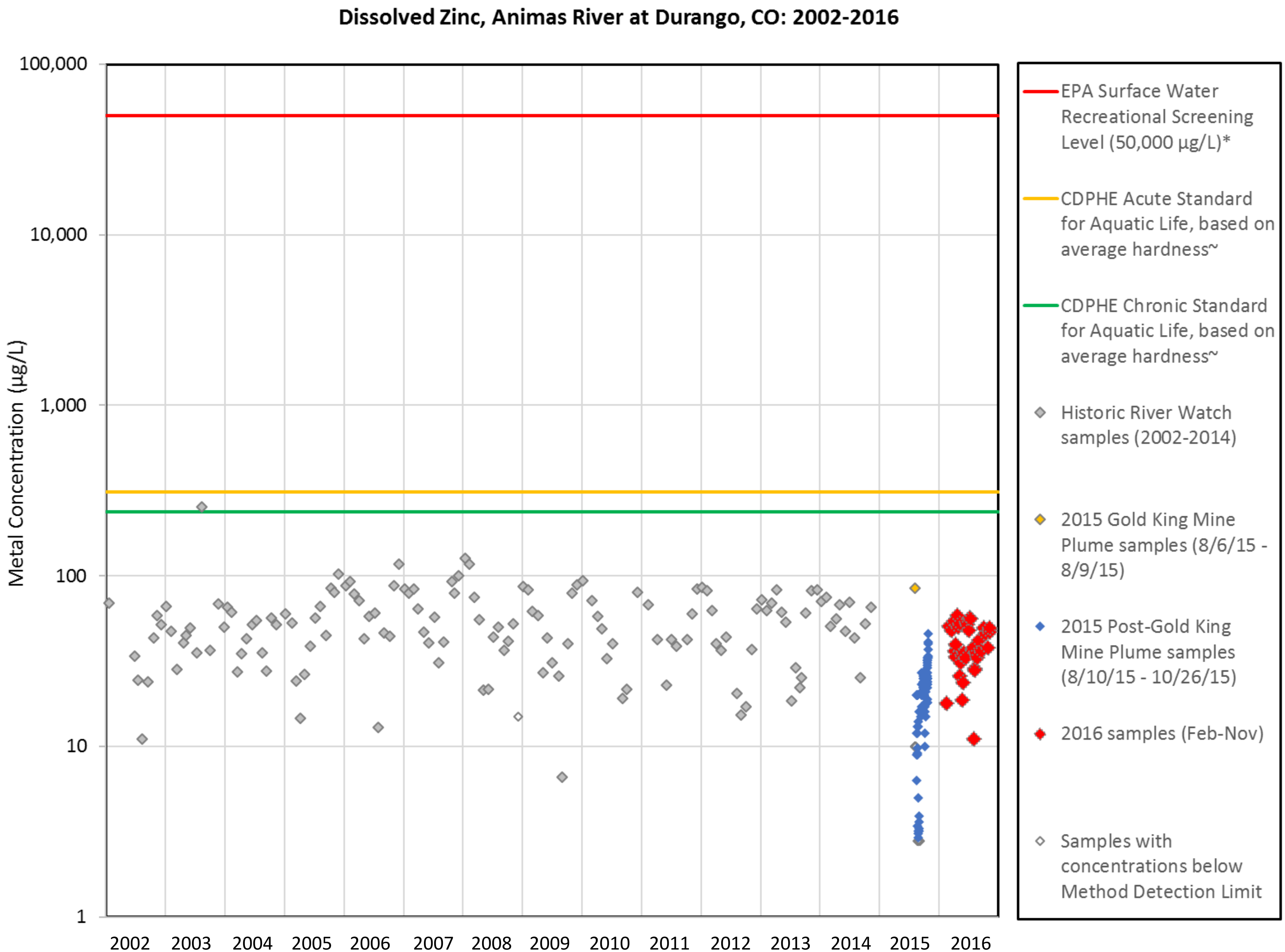

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<u>Appendix B:</u>

Additional technical details regarding
Mountain Studies Institute's
2016 water quality monitoring analysis

Appendix B: Additional technical details – Mountain Studies Institute's 2016 water quality monitoring analysis

Water Quality Benchmarks: Iron and aluminum chronic water quality standards

In 2016, concentrations of iron and aluminum reached levels of concern for long term exposure to aquatic life. CDPHE provides chronic water quality standards that are set to be protective of aquatic life from persistent, long-term exposure to metals. The chronic aquatic life water quality standard for iron is evaluated based on the median observed value. The median value for total iron over the 2016 monitoring period was 1,115 ug/L, which is higher than the CDPHE chronic aquatic life standard of 1,000 ug/L (CDPHE 2017). CDPHE evaluates chronic aluminum impairment by two methods (CDPHE 2015). The first method compares the 85th percentile of total aluminum concentration values to a chronic standard based on an average hardness value. For the 2016 Rotary Park data, the 85th percentile was 1,636 ug/L, which surpasses the average hardness based standard of 1,029 ug/L. The second method assigns a chronic standard for each sample based on the hardness value observed at the time the sample was collected. Impairment is designated if 50% of the samples exceed their paired chronic standard. For the 2016 Rotary Park data, 15 of 37 samples (41%) surpassed their paired chronic standard for aluminum, which is less than the 50% threshold that would designate impairment. CDPHE considers the second method (paired hardness-concentrations) more representative than the first method (based on average hardness) so although total aluminum concentrations were relatively high, they are not high enough to technically surpass the CDPHE chronic aquatic life standard for aluminum.

2016 Water Quality Data in Context of Historical Data: Summary statistics and statistical analysis

MSI compared Animas River metal concentrations in 2016 to those observed by River Watch from 2002 to 2014 (CDSN 2015) using a statistical test called Wilcoxon rank sum test. The results of the test indicate that there is no significant difference in metal concentration of the Durango stretch of the Animas River in 2016 compared to the 2002-2014 time period (Table 1).

Spring Runoff and Storm Events: Summary statistics and statistical analysis

MSI compared 2016 Rotary Park metal concentrations from opportunistic samples collected during changing river conditions (storm events or rapid river level rise) to samples collected at regular weekly and bi-weekly intervals during stable river conditions. Results from Wilcoxon rank sum tests indicate that there was a significant difference in metal concentrations measured during changing conditions compared to those measured during stable conditions (Table 2).

Metals and Other Water Quality Parameters: Correlation statistics and an example graph of the four USGS water quality parameters: discharge, turbidity, pH, and conductivity

In 2016, USGS began to provide continuous measurement of pH, turbidity, and conductivity at their Animas River gauge in Durango, CO (data available at https://waterdata.usgs.gov/nwis/uv?09361500). MSI examined the relationship between metal concentrations and these additional water quality parameters (Figures 1-3). Spearman correlation coefficients indicate that several metals correlated at a statistically significant level with discharge, turbidity, pH, and conductivity (Table 3).

Table 1: Summary statistics for metal concentrations observed in 2016 and for the River Watch data set (2002-2014). P values are test results of Wilcoxon rank sum test.

	ug/L	Al		Cu		Fe		Mn		Pb		Zn	
		2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014
Total	n	27	120	15	126	27	236	27	236	16	105	27	239
	Min	62	26	4.3	4.2	109	66	65	20	3.1	3.1	33	8.5
	Mean	522	433	9	11	941	783	154	158	13	15	81	97
	Median	377	253	8.0	7.7	791	428	157	122	10	8.4	82	84
	95th	1412	1276	17	29	2607	2899	298	356	33	43	137	191
	Max	1680	3555	18	71	3190	9770	363	1084	44	124	145	472
	p value	0.120		0.686		0.180		0.539		0.561		0.290	
Dissolved	n	*		*		*		27	141	*		27	142
	Min							36	17			24	6.6
	Mean							74	99			44	54
	Median							68	72			46	53
	95th							124	226			56	85
	Max							154	791			59	253
	p value							0.383				0.030	

*Dissolved aluminum, copper, iron and lead could not be included in statistical analysis due to the limited number of samples where concentrations were detected.

Table 2: Summary statistics for metal concentrations observed in 2016 during changing river conditions and during stable river conditions. P values are test results of Wilcoxon rank sum test. Yellow-highlight indicates statistical significance at the 0.05 alpha level.

	ug/L	Al		As		Cu		Fe		Mn		Pb		Zn	
		Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms
Total	n	27	10	27	10	27	10	27	10	27	10	27	10	27	10
	Min	62	111	0.20	0.20	1.30	0.60	109	188	65	81	0.60	1.00	33	46
	Mean	522	1868	0.52	1.43	5.79	14.23	941	3738	154	309	8.43	22.40	81	149
	Median	522	1885	0.50	1.05	4.50	10.95	791	3265	157	246	5.20	12.90	82	115
	95th	1412	4706	1.40	3.06	14.79	40.16	2607	8264	298	661	26.62	68.64	137	304
	Max	1680	5340	1.80	3.10	18.10	47.00	3190	8390	363	808	43.50	71.70	145	342
	p value	0.033		0.037		0.194		0.027		0.024		0.101		0.094	
Dissolved	n	*		27	10	27	10	*		27	10	*		27	10
	Min			0.20	0.20	0.60	0.70			36	14			33	11
	Mean			0.21	0.26	4.21	1.23			74	54			81	29
	Median			0.21	0.20	1.00	1.10			68	57			82	18
	95th			0.20	0.50	2.27	1.90			124	78			137	48
	Max			0.50	0.50	83.50	1.90			154	83			145	50
	p value			0.112		0.63				0.025				0.001	

*Dissolved aluminum, iron, and lead could not be included in statistical analysis due to the limited number of samples where concentrations were detected.

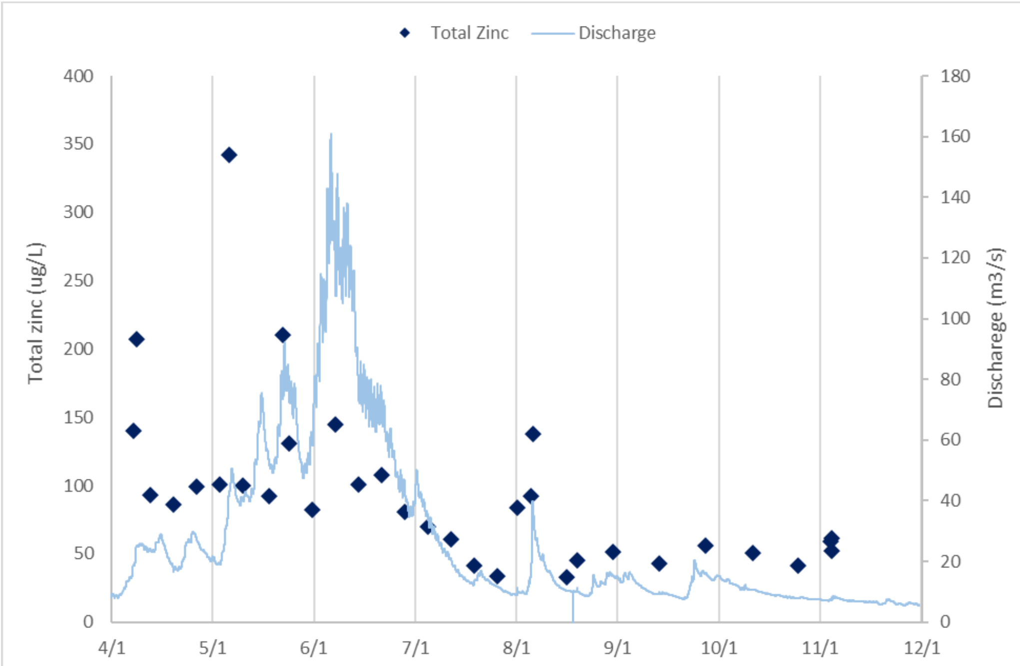

Figure 1: Discharge and total zinc.

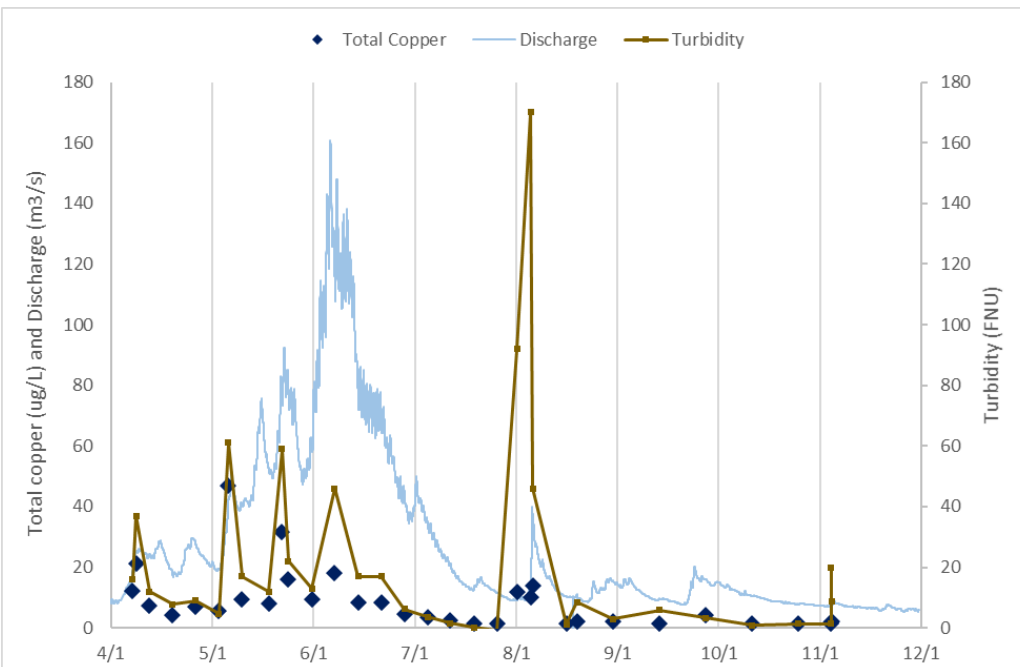

Figure 2: Turbidity and total copper.

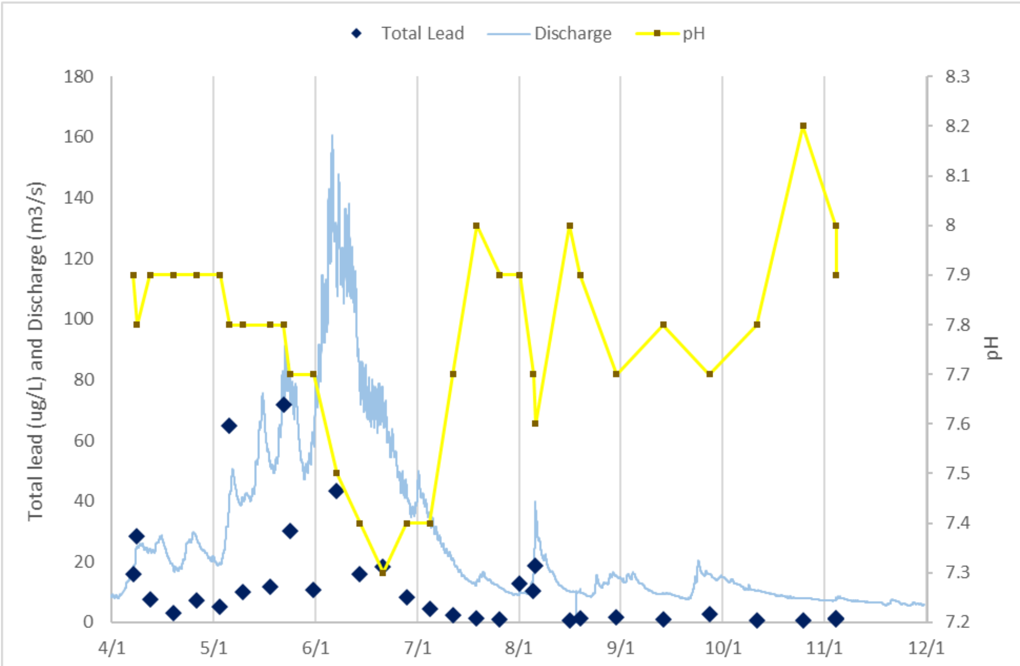

Figure 3: pH and total lead.

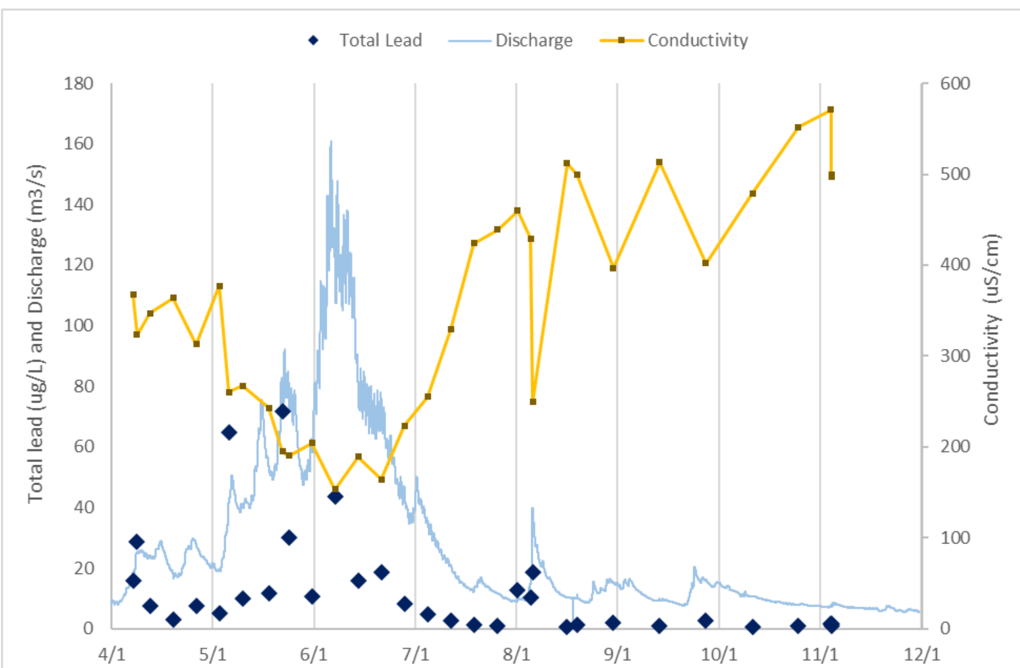

Figure 4: Conductivity and total lead.

Table 3: Spearman correlation coefficients. Yellow highlight indicates a statistically significant correlation at the 0.05 alpha level.

					Aluminum		Arsenic		Copper		Iron		Lead		Manganese		Zinc	
					T	D	T	D	T	D	T	D	T	D	T	D	T	D
When…	*…discharge…*	*…increased…*	*…the following metals…*	*…increased*	0.542	*	0.011	*	0.756	0.63	0.555	*	0.721	*	0.502		0.565	
	…discharge…	*…increased…*		*…decreased*		*		*				*		*		-0.28		-0.13
	…turbidity…	*…increased…*		*…increased*	0.826	*	0.581	*	0.861	0.397	0.852	*	0.815	*	0.857		0.787	
	…turbidity…	*…increased…*		*…decreased*		*		*				*		*		-0.46		-0.56
	…pH…	*…decreased…*		*…increased*	-0.39	*	-0.29	*	-0.75	-0.39	-0.42	*	-0.55	*	-0.48		-0.52	-0.1
	…pH…	*…increased…*		*…increased*		*		*				*		*		0.167		
	…conductivity…	*…decreased…*		*…increased*	-0.74	*	-0.02	*	-0.79	-0.6	-0.75	*	-0.86	*	-0.73		-0.73	
	…conductivity…	*…increased…*		*…increased*		*		*				*		*		0.401		0.224

*Dissolved aluminum, arsenic, iron, and lead could not be included in statistical analysis due to the limited number of samples where concentrations were detected.

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