REBUTTAL REPORT

Joseph A. Pakootas et al. v. Teck Cominco Metals, Ltd.

Case No. CV-04-0256-LRF
U.S. District Court for the Eastern District Of Washington

Prepared for
The State of Washington and
The Confederated Tribes of the Colville Reservation

Prepared by
Dimitrios Vlassopoulos, Ph.D.
Anchor QEA, LLC

May 13, 2011

REBUTTAL REPORT OF DIMITRIOS VLASSOPOULOS, Ph.D.

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
CCT	Confederated Tribes of the Colville Reservation
cm	centimeter
FA	Factor Analysis
mg/L	milligrams per liter
mm/sec	millimeters per second
MRL	method reporting limit
PCA	Principal Component Analysis
SEM	scanning electron microscope
SCE	sequential chemical extraction
Teck	Teck Cominco Metals, Ltd.
UCR	Upper Columbia River

1 INTRODUCTION

1.1 Retention and Assignment

I, Dimitrios Vlassopoulos of Anchor QEA, LLC, have been retained jointly by the State of Washington and the Confederated Tribes of the Colville Reservation (CCT) in the ongoing matter of *Joseph A. Pakootas et al. v. Teck Cominco Metals, Ltd.* (Case No. CV-04-0256-LRS, U.S. District Court for the Eastern District of Washington).

I have been asked to review the expert report of Arthur "Sandy" Riese dated January 11, 2011 (Riese 2011), regarding the release of metals from slag and liquid effluents originating from Teck Cominco Metals, Ltd.'s (Teck's) smelter located in Trail, British Columbia, to the Upper Columbia River (UCR) in Washington. Specifically, I was asked to evaluate the technical analyses presented by Dr. Riese and the validity of his conclusions and opinions based upon those analyses and to respond to his comments on my expert report dated September 17, 2010 (Vlassopoulos 2010).

In developing this rebuttal report, I also reviewed numerous reports, data, and documents, including information presented by Dr. Riese as supporting information and provided to me on a hard drive.

1.2 Qualifications

I am a principal scientist with Anchor QEA, a privately owned environmental science and engineering consulting firm with corporate headquarters in Seattle, Washington. I am located in the firm's Portland, Oregon, office and my primary area of expertise is in geochemistry. In this capacity, I conduct scientific investigations for various clients and provide expert consultant services. My credentials, professional experience, publication record, and previous depositions and testimony are summarized in my resume, which is provided as Appendix A to this rebuttal report.

1.3 Compensation

Anchor QEA is being compensated at my standard billing rate of $210 per hour for office work and $315 for deposition and trial testimony.

1.4 Organization of Report

In Section 2, I respond to Dr. Riese's comments on my expert opinions (Vlassopoulos 2010). Section 3 is a critical review of some of the technical analyses and interpretations presented in Dr. Riese's report (2011) and a summary of significant shortcomings and inconsistencies of some of Dr. Riese's conclusions that render their validity highly questionable.

2 RESPONSE TO DR. RIESE'S COMMENTS ON MY OPINIONS

In Section 4.1 of his report (2011), Dr. Riese provides lengthy comments on the opinions expressed in my expert report (Vlassopoulos 2010). After a careful review of his arguments and criticisms, I conclude that none of Dr. Riese's remarks lead me to reconsider or change any of the opinions as stated in my expert report.

My main opinions can be summarized as follows: (1) slag and liquid effluent metals discharged from Teck's Trail facility to the Columbia River have been transported in the river and come to be located within the UCR site, and (2) these Trail-derived contaminants are released at the site.

The fact that Trail smelter slag has come to be located at the UCR site is not even disputed by Dr. Riese, in particular north of Northport. He only claims that Trail slag cannot be distinguished from other sources of contamination in UCR sediments south of Northport. However, factor analysis (FA) and lead isotope data reveal that the dominant metals signal across the UCR is from Trail slag, and other signals that may represent other potential sources are localized. Laboratory leaching studies and porewater sampling at the UCR site show that Trail slag leaches toxic metals. Dr. Riese does not provide any direct evidence to rebut this conclusion; instead he relies on what he calls "alteration rims" or "rinds" covering slag particles as his only evidence that slag does not leach. These "rims" are actually just the outer weathered layer of slag particles, which are themselves tangible evidence that slag breaks down in the river environment. This weathered layer is not contiguous and does not prevent leaching of metals from slag.

Teck's effluent-derived metals have been deposited with the sediments that have accumulated at the UCR site. Dr. Riese seems to assert that all of these metals have instead flowed past the Grand Coulee Dam, which is not possible from either a scientific or factual standpoint. Dissolved metals will continuously partition to settling particles within the river system. Sediment samples show that Teck's effluent metals signal is present throughout the UCR site. After settling, metals are released by natural processes occurring within the sediments, which Dr. Riese confirms. He even attempts to quantify this release by estimating the zinc mass flux out of UCR sediments. His simple approach is flawed, underestimates the actual rate of zinc release, and ignores the fact that other toxic metals are also being released. Furthermore, he only considers the upper five centimeters of sediment, which ignores the fact that releases to porewater occur below this depth where benthic organisms that can be exposed are also present. Given the size of the UCR site and its complexity, quantifying these releases with any degree of certainty would be a monumental undertaking that would require substantial additional studies.

In the following sections, I address Dr. Riese's specific comments directed at my main opinions.

2.1 Dr. Riese's Comments on Opinion 1

My first opinion, reproduced below, relates to the fact that Trail slag and hazardous substances from Trail effluent are located at the UCR site:

> *Slag and liquid wastes generated at Teck Cominco's Trail Operations have been historically discharged into the Columbia River at Trail, British Columbia. These materials have been transported by the river into the United States, where they have accumulated within and contaminated the sediments of the Upper Columbia River and Lake Roosevelt, between the U.S.-Canada border and the Grand Coulee Dam.*

2.1.1 Release of Trail Slag to the Upper Columbia River

On page 48 of his report, Dr. Riese states, "Dr. Vlassopoulos incorrectly suggests that the Trail metals are located in the United States and none of the Trail metals have been removed from the Upper Columbia/Lake Roosevelt system."

This statement misrepresents my opinion and is illogical. My expert report never claims that all of the slag and effluent metals discharged from Trail are now located at the UCR site. Dr. Riese's choice of words could suggest that none of the Trail metals have been transported across the United States-Canada border into the UCR site, which would be an equally illogical assertion, and clearly in contradiction with the widespread occurrence of Trail slag in the UCR (for example, Black Sand Beach and elsewhere), to which Dr. Riese himself refers to several times in his report.

2.1.2 Release of Trail Effluent Metals to the Upper Columbia River

In addition to direct discharges of slag, both dissolved and particulate metals have been discharged to the Columbia River from Trail sewer effluents and accidental spills. Adsorption of metal cations, including cadmium, copper, lead, zinc, and mercury, onto sediment particle surfaces is favored by the neutral to slightly alkaline pH of the river water; therefore, a significant portion of the metals load is expected to be in particulate form. Evidence for this is provided by comparing metals concentrations in filtered (dissolved) and unfiltered (total) water samples. The difference between total and dissolved concentrations can be attributed to metals associated with particles that are removed by filtering, and therefore provides an estimate of the particulate metals concentration in a sample. Water samples collected from the Columbia River at Waneta, B.C., near the international border (data from "Waneta Surface Water Quality_Graph Data.xlsx," produced by Dr. Riese) indicate that more than 50 percent of the cadmium and up to 90 percent or more of the copper, lead, and zinc in the river water can be present in particulate form (see Figures 1 to 4).

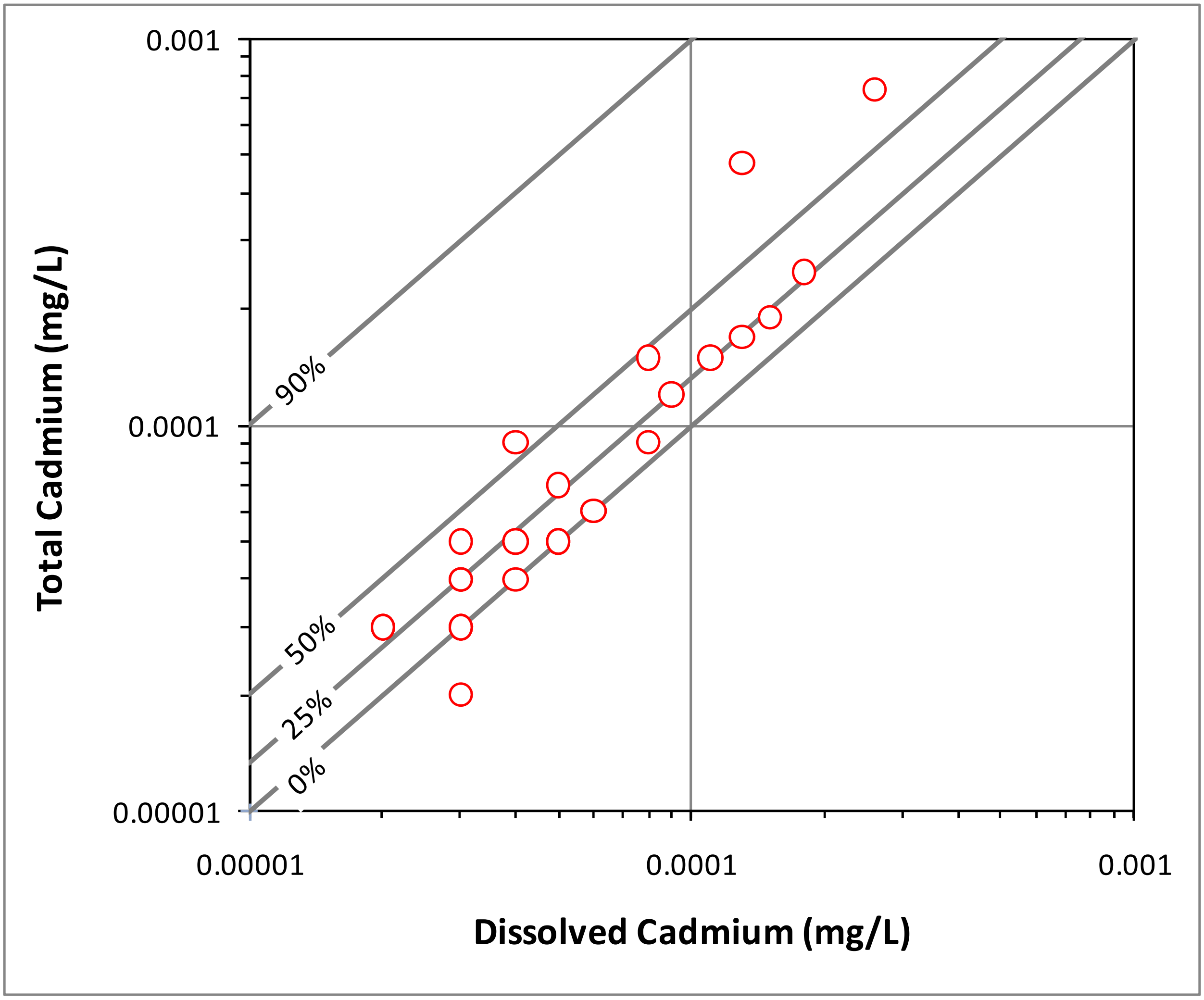


Figure 1

Cadmium: Total and Dissolved Concentrations in the Columbia River at Waneta and Estimated Percentage Particulate Fraction

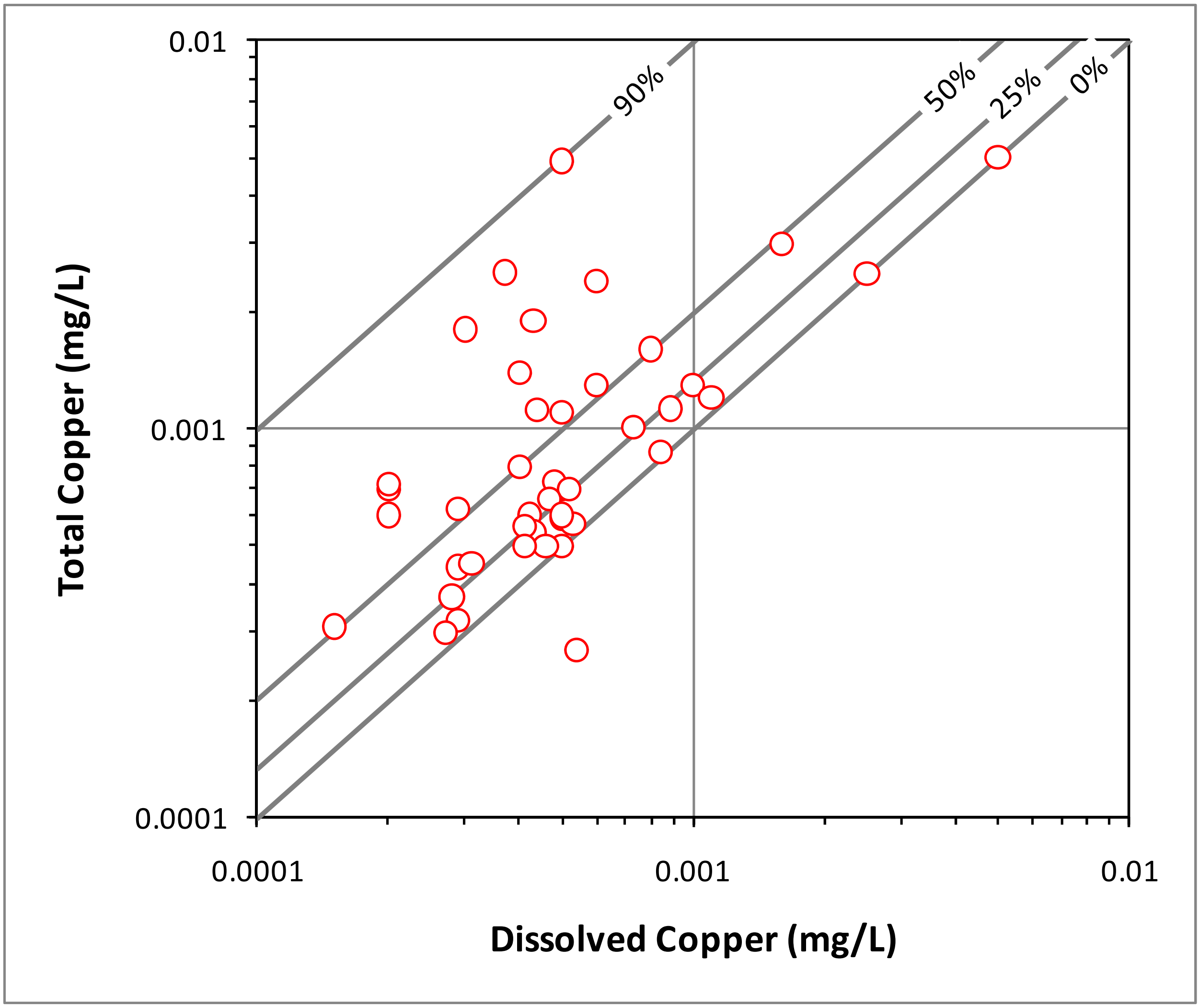


Figure 2

Copper: Total and Dissolved Concentrations in the Columbia River at Waneta and Estimated Percentage Particulate Fraction

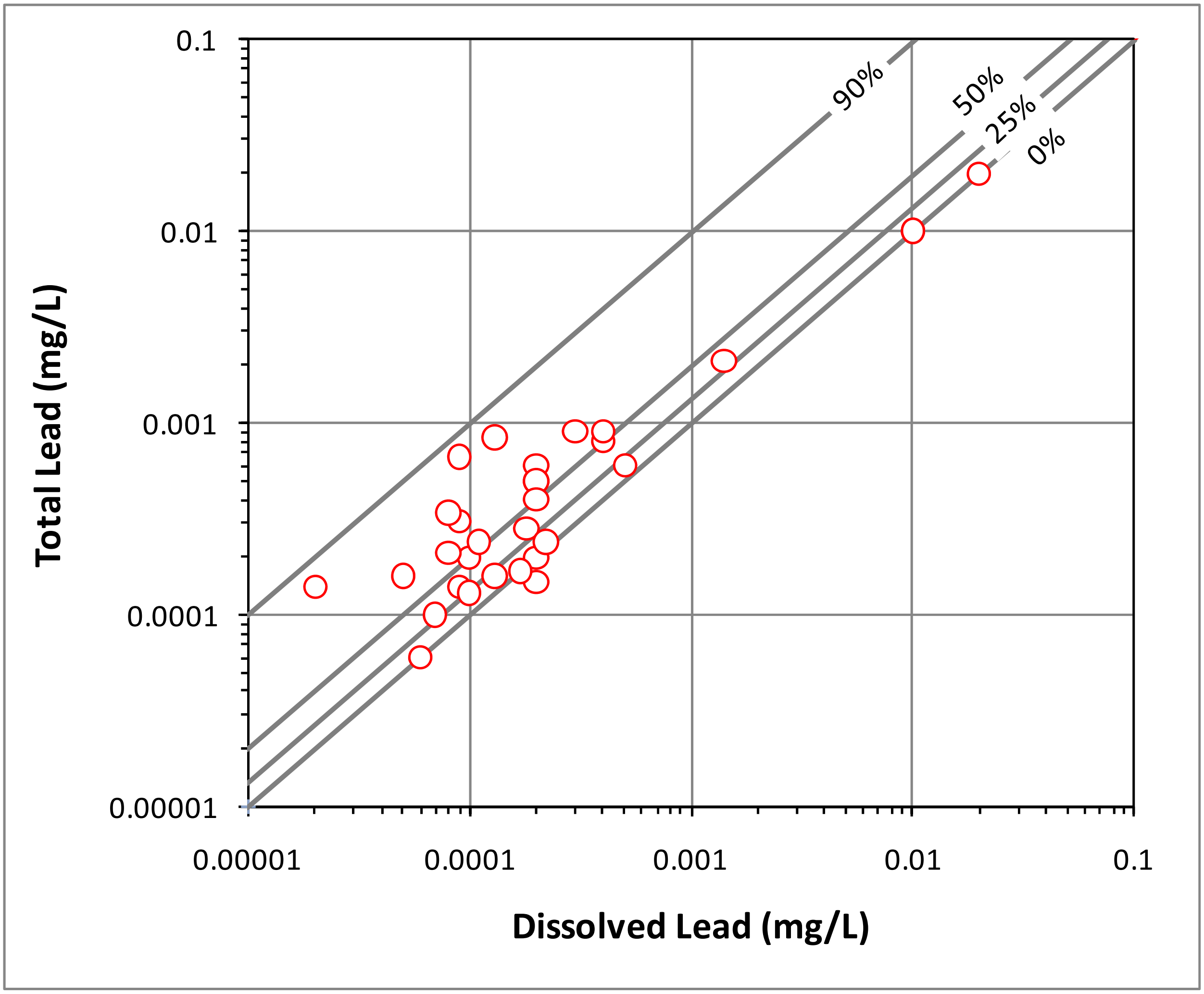


Figure 3

Lead: Total and Dissolved Concentrations in the Columbia River at Waneta and Estimated Percentage Particulate Fraction

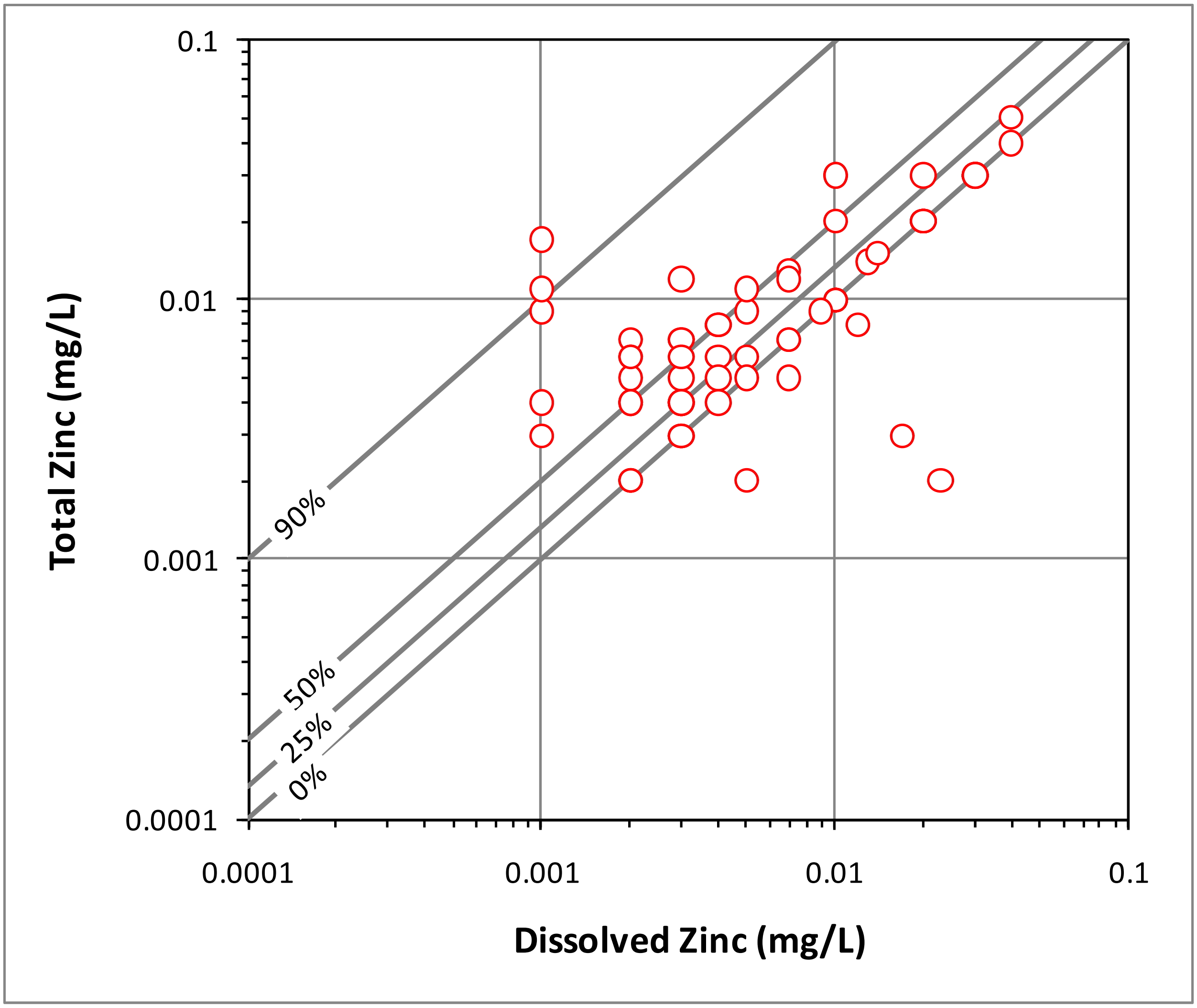


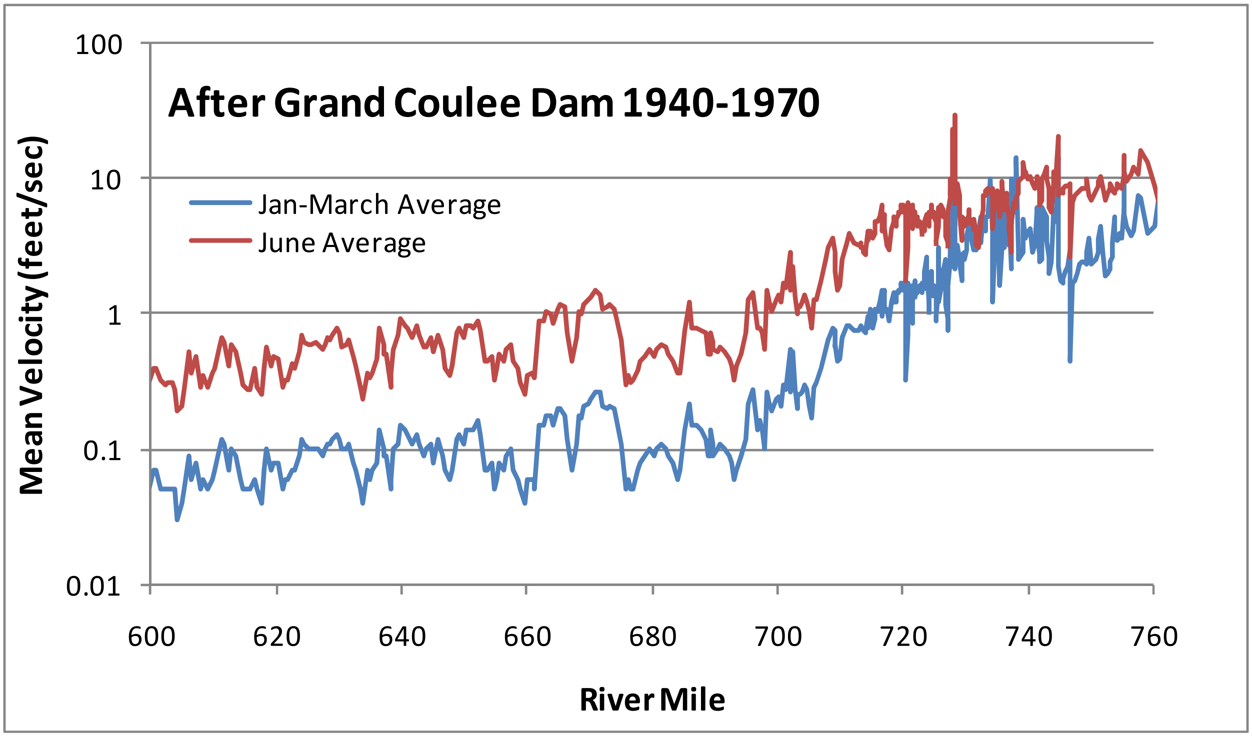
Figure 4

Zinc: Total and Dissolved Concentrations in the Columbia River at Waneta and Estimated Percentage Particulate Fraction

Dr. Riese claims in his Opinion 7 (Riese 2011, p. 38) that Trail effluent metals (dissolved, colloidal, and suspended) would have moved out of the UCR prior to installation of the Grand Coulee Dam in the 1940s due to the high flow velocities, and thereafter would have continued to flow past the dam. Flow velocities were greatly reduced in the reservoir reach after the dam was operational.

Dr. Riese estimates the average flow velocity in the middle and lower reach as being between 370 and 740 millimeters per second (mm/sec), and concludes that all particles smaller than sand size would be transported downstream, including effluent metals from Trail. However, Dr. Riese also admits that local conditions within the lake and river can exist where velocities are much lower than the average and may have resulted in the deposition of some silt and clay sized sediments.

The minimum flow velocity—rather than the average—is a more relevant indicator of the potential for sediment deposition in the river. McLean (2011) used a one-dimensional HEC-RAS model of the UCR developed by Hydro-Qual to investigate hydraulic conditions in the UCR between Birchbank and Grand Coulee Dam. The model accounts for spatial variability in flow velocity along the river. Between 1940 and 1970, the average flow velocity in the reservoir reach (from Marcus to the dam) during the annual low-flow period (January to March) was 0.09 feet per second (27 mm/sec). Minimum computed velocities in this reach were 0.03 feet per second (9 mm/sec). It is important to note that time-averaged seasonal flows were used in computing the velocity profiles. In any given year, flow rates—and, therefore, velocities—may be higher or, more importantly for sediment deposition, lower than the average.

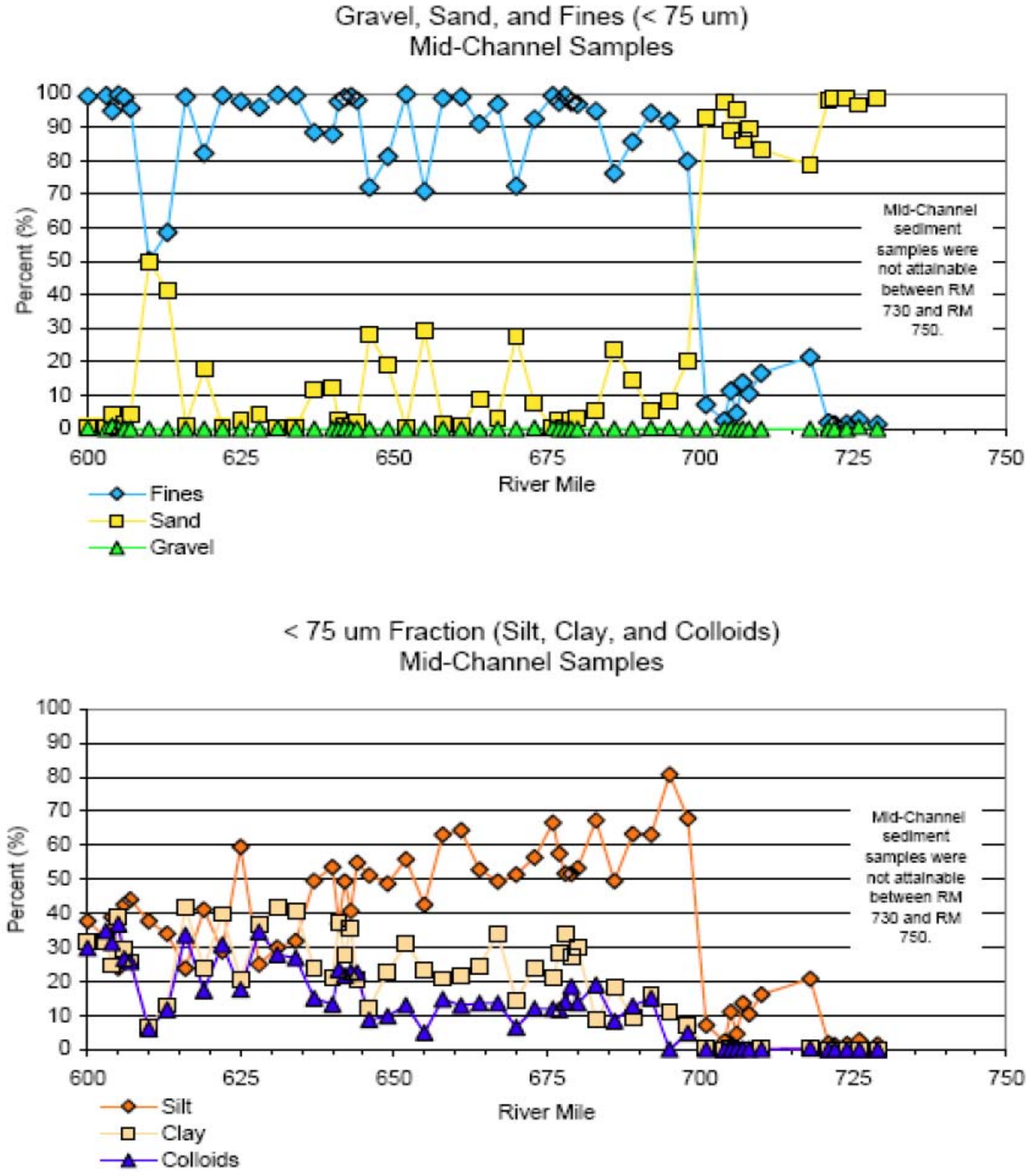


Source: McLean 2011

Figure 5

Modeled Seasonal High- And Low-Flow Average Velocity Profiles in the Upper Columbia River After the Grand Coulee Dam Was Built

These lower velocities are indicative of lacustrine conditions that, according to Figure 19 in Dr. Riese's report, would be expected to lead to net deposition of silty sediments. This expectation is confirmed by the extensive documented accumulations of fine sediment (less than 75 micron particle size, including silt, clay, and colloids) in the mid-channel of Lake Roosevelt (Figure 6).



Source: CH2MHill 2006

Figure 6

Grain-size Distribution of Sediments in the Mid-channel of the Upper Columbia River

Teck's effluent metals associated with settled particles would therefore also accumulate in the lake sediments. This would include both particulate metals transported from Trail as well as a portion of the dissolved metals which become adsorbed onto particles during transport within the UCR.

2.1.3 Other Sources

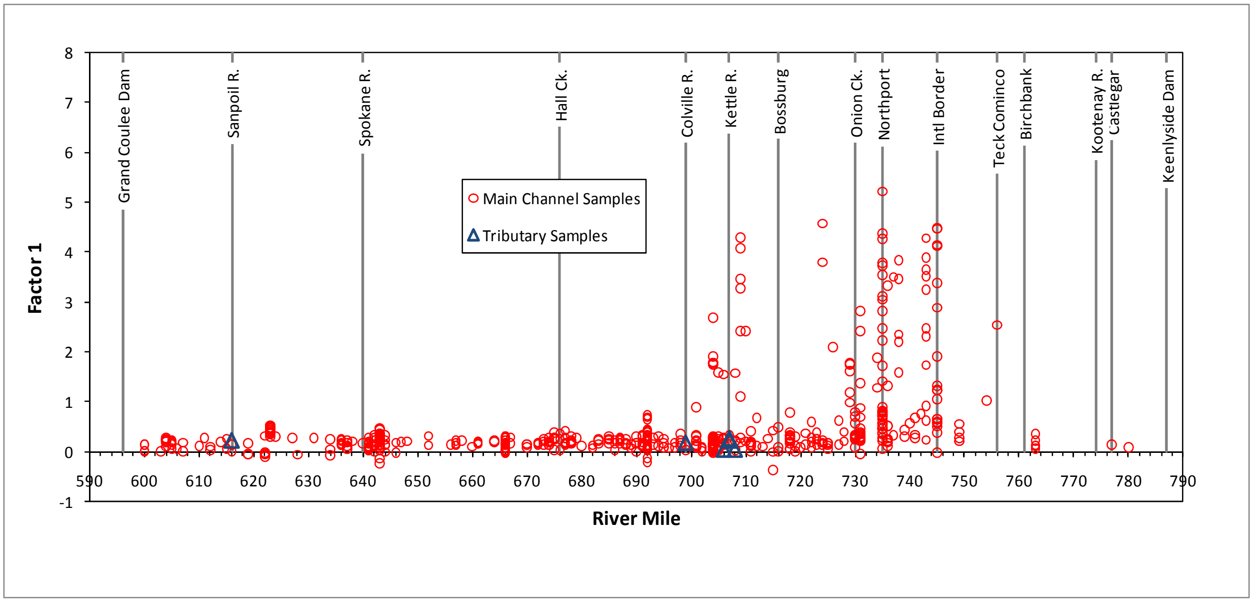
Dr. Riese incorrectly suggests that my analyses ignore other sources that may contribute metals to the UCR. While I clearly acknowledge the existence of potential secondary sources of metals (Vlassopoulos 2010, p. 18), my objective was to demonstrate that at least some of the metals detected in UCR sediments are clearly derived from Trail. Other plaintiffs' experts are addressing Teck's claims regarding other potential sources. Nevertheless, there are several factors that would limit the potential importance of other sources:

- Mines, mills, and other smelters within the UCR site generally did not operate continuously or for as long a period as the Trail smelter (1896 to present).
- Although the documentation is incomplete, none of these alleged potential sources appears to have discharged the amount of metals (in slag and effluent) that was cumulatively discharged directly into the UCR from Trail. For example, estimates by Teck's expert of total granulated lead slag production at the Northport smelter (1916 to 1921) are approximately 398,000 tons (McNulty 2011), while estimates by both plaintiffs' and Teck's experts show the total amount of granulated lead slag discharged from the Trail smelter are on the order of 10,000,000 tons (Higginson 2010; Queneau 2010, 2011). Even according to the estimates made by Teck's expert, the total mass of Northport granulated slag represents less than 4 percent of the amount discharged to the UCR at Trail. As such, it could only be a minor contribution to the metals in sediments impacted by Trail slag, except in the immediate vicinity of the Northport smelter site. Furthermore, the entire operating period of the Northport/Leroi smelter predates the Grand Coulee Dam by approximately 20 years, so some portion of the slag is likely to have been transported out of the site.
- Most of these alleged mine and mill sources are located upland or on tributaries to the UCR. Their documented impacts on sediment chemistry are generally localized (EPA 2002). With only a few exceptions, sediment metals concentrations in tributaries are generally less than or similar to the UCR main channel upstream of their confluence,

> as documented by sediment samples from the mouths of a number of tributaries including Big Sheep Creek, Onion Creek, Kettle River, Colville River, Spokane River, and the Sanpoil River (CH2MHill 2006, p. 5-34).

The results of a factor analysis (FA) performed on an extensive UCR sediment dataset indicates that most of the variability in the UCR sediment metals concentrations can be explained by two components chemically similar to Trail slag and liquid effluents. If other (such as mine and mill) sources had widespread impact on UCR sediment chemistry, greater variability would be expected.

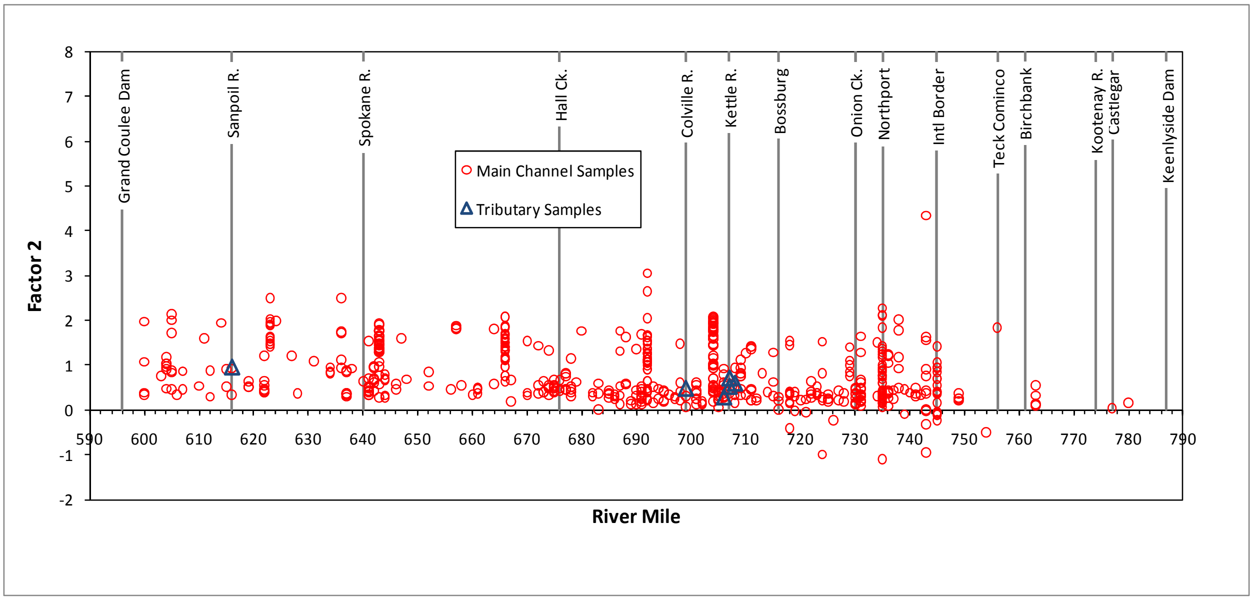
Even if other sources of metals are contributing, the fact that they were not resolved by FA indicates that they do not affect a large enough proportion of samples in a detectable way; that is, the magnitude and spatial extent of their impact on UCR sediment chemistry are limited compared to the Trail smelter source, which is more pervasive. Mapping of the sample scores showed that both the slag and effluent signals originate at Trail (Vlassopoulos 2010, Figures 3 and 4). If other sources had been significant, then the factor mapping would have revealed a signal originating from other locations. The sample scores for Factors 1 through 3 are also plotted by river mile in Figures 7 to 9, respectively. Different symbols are used to distinguish sediment samples in the main stem UCR from tributary samples. As discussed in my expert report (Vlassopoulos 2010), Factor 1 corresponds to the chemical signature of slag, Factor 2 was interpreted as background, and Factor 3 was identified with Trail liquid effluents. Although the tributary sample population is small, it can be seen that tributary sediment samples score low for either Factor 1 (slag) or Factor 3 (liquid effluent), indicating those signatures are absent in tributary samples. In contrast, sediment samples with higher scores for these factors occur in the mainstem of the UCR both upstream and downstream of the tributary confluences, confirming that the tributaries are not the source of the slag-like and liquid effluent-like metal enrichments in the Columbia River sediments.



Source: Vlassopoulos 2010

Figure 7

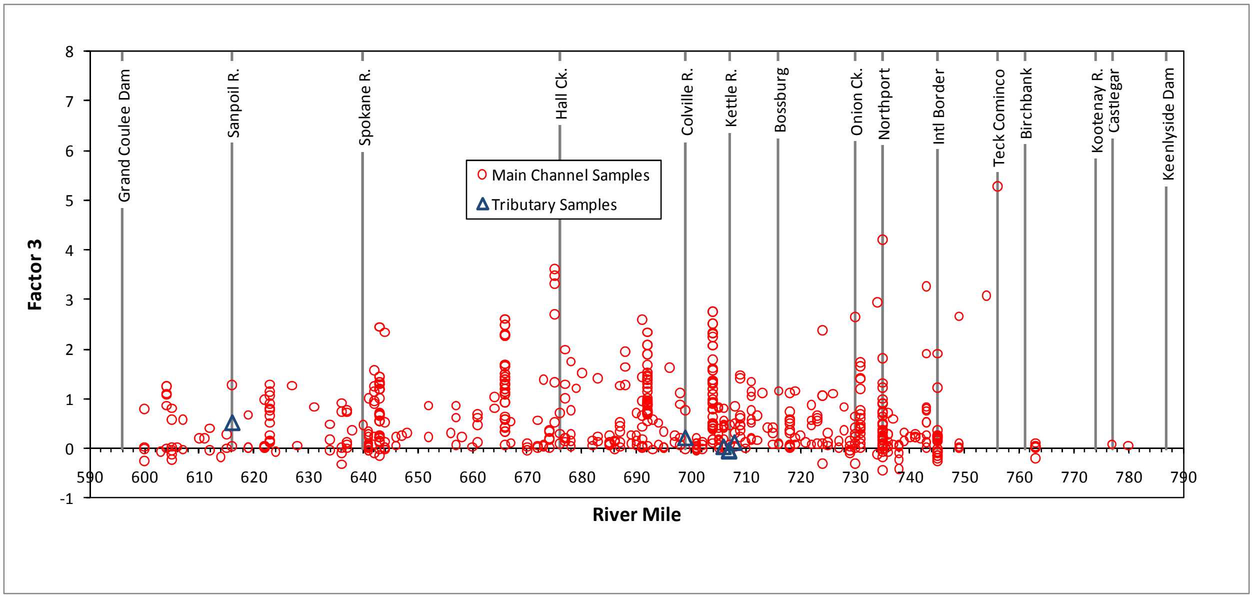
Factor 1 (Slag) Sample Scores Plotted Against River Mile



Source: Vlassopoulos 2010

Figure 8

Factor 2 Sample Scores Plotted Against River Mile



Source: Vlassopoulos 2010

Figure 9

Factor 3 (Liquid Effluent) Sample Scores Plotted Against River Mile

2.1.4 Dr. Riese's Comments on Data Selection and Methodology for Factor Analysis

This section responds to some of Dr. Riese's specific comments on my FA (Riese 2011, Section 4.1.1).

Dr. Riese claims that the "approach to treatment of non-detected data in the statistical analyses is inconsistent with standard statistical and professional practices." Dr. Riese does not state, however, specifically how the treatments are inconsistent and what he considers standard statistical practices. There is no one "standard" method for treating non-detected data. There are several commonly used methods and the choice is based on minimizing potential bias in the analysis results. The typical method of assigning a value between the detection limit and zero often works well with some univariate analyses, but is particularly problematic with multivariate analyses such as FA. Because FA results are affected by the proportional makeup of a suite of analytes in each sample, they can be particularly susceptible to bias from high non-detect values. This is often a concern when using data from multiple data sources, as is the case with the UCR sediment chemistry dataset. While an ideal approach would be to exclude all samples with non-detect values for any analyte, this can result in a greatly reduced dataset and loss of spatial coverage. Because of this, the choice was made to exclude only samples with non-detect values for which the detection limit was greater than 1 percent of the analyte concentration range; this allowed most samples with non-detects to be retained while minimizing potential bias. Non-detects in retained samples were replaced with zero.

Dr. Riese also presents results of a Principal Components Analysis (PCA) but does not state the method used for non-detect treatment or why he chose that method.

Dr. Riese's statement (2011, p. 50) that my analysis does not consider multiple sources of contamination is incorrect and indicates misunderstanding of the analysis technique. FA neither explicitly includes nor excludes Northport-adjacent, tributary and tributary-adjacent samples: it is a data exploration technique that objectively identifies the strongest chemical signals in the dataset. It is, therefore, incorrect to state that sources other than Trail have been excluded or not considered. Dr. Riese's statement appears to indicate a lack of understanding of the analysis.

Dr. Riese further states of my FA results: "Notably, his results could not be reproduced using his data input file and SYSTAT software package." The FA presented in my report was performed using the Multivariate platform of the statistical software program JMP (Version 9). It is not entirely surprising that Dr. Riese did not produce identical results given that he used a different software package, and there are many options for preparing the data and performing the factor rotations. Perhaps what is more interesting is that Dr. Riese's independent PCA produced similar results to mine (see section 3.2 below), despite his use of additional data, a different rotation method, and unspecified data transformations.

Dr. Riese also suggests that data were excluded inconsistently, specifically that "93 iron values were excluded from the dataset for no discernable reason. In addition, two more samples were excluded, although the detection limits were well below 1/100th of the maximum value. This is inconsistent with Dr. Vlassopoulos' statement that only a 'small number of additional samples were removed due to inconsistencies in their records.'"
Dr Riese appears to have overlooked the fact that samples that do not have results for all

variables being considered in the FA were by default excluded. This is a specific methodological constraint of any multivariate analysis; this comment therefore suggests a lack of understanding. Dr. Riese refers to a table 1 as containing over 160 samples that were apparently excluded from analysis (p. 50). This table was not found in his report so this claim could not be verified.

Dr. Riese states that "the 604 samples chosen for PCA analysis include numerous samples that are from the same cores and from nearby locations and are thus statistically unrepresentative." This comment is illogical, as it is typical to include all available samples in PCA or FA in order to capture the full range of variability. Furthermore, although Dr. Riese does not explain how he handled multiple samples from the same cores and clustered samples in his PCA, it appears that they were treated in the same way as I did.

Dr. Riese comments that "Scrutiny of the factor maps shows that the graphic approach taken emphasizes the higher loadings, while hiding the lower loadings or negative loadings of many adjacent analyses". The intended purpose of the factor score maps (Vlassopoulos 2010, Figures 3 and 4) was to visualize the spatial distribution of high scoring samples for each factor, e.g. samples with a strong slag signature (Factor 1). The geographic origin of Factor 1 at Trail is very apparent. For convenience, the FA results are also reproduced in this rebuttal report in Figures 7 to 9 as scatter plots versus river mile similar to the depictions used by Dr. Riese.

Dr. Riese states that "A PCA analysis of the same river and lake sediments was performed by CH2MHill in 2005 ... differences and their significance are not discussed by Dr. Vlassopoulos."[1] First, the CH2MHill analysis would not be expected to be identical to my analysis because they are not based on the same data set. Specifically, I included data from more recent sampling. Second, differences are also to be expected depending on differences in non-detect and outlier treatments, exclusions, and transformations, which Dr. Riese does not mention. Dr. Riese focuses on minor differences, but fails to recognize the overall similarity in findings between my FA and the CH2MHill PCA results, namely that two out of the three components identified by both studies are defined by enrichment in:

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[1] See USEPA 2006 for CH2MHill's 2005 analysis.

1. The slag metals copper, iron, manganese, and zinc
2. The effluent metals mercury and cadmium

Dr. Riese also attempts to claim that the PCA and FA results are problematic because they show some systematic variation with study or data source. While some variation is to be expected given the different sampling studies may have targeted different sample types (for example, mid-channel versus bank) and depths (grab versus core), this claim is not supported by the results. In evaluating results, it is important to draw robust conclusions that are consistent over multiple studies. For example, Dr. Riese's Factor 1 (Riese 2011, Figure 33) and my Factor 1 (Figure 10) plots are very consistent across many studies: showing a strong slag signal extending downstream from Trail. Factor 2 (background) does appear to show some differences between studies (Figure 11), but this does not affect my conclusions regarding Factors 1 and 3, given the identifiability of these signals with Teck's slag and effluents. The Factor 3 (liquid effluent) plot, like Factor 1, does not show significant variation by study (Figure 12).

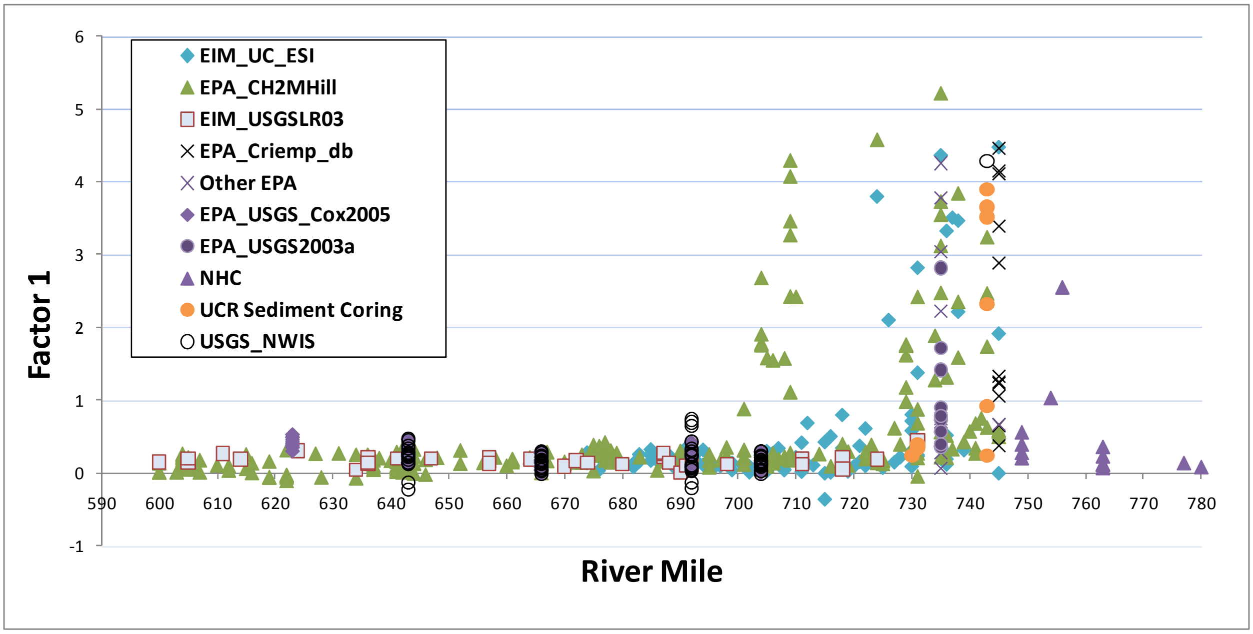


Figure 10

Factor 1 Scores versus River Mile, Coded by Study

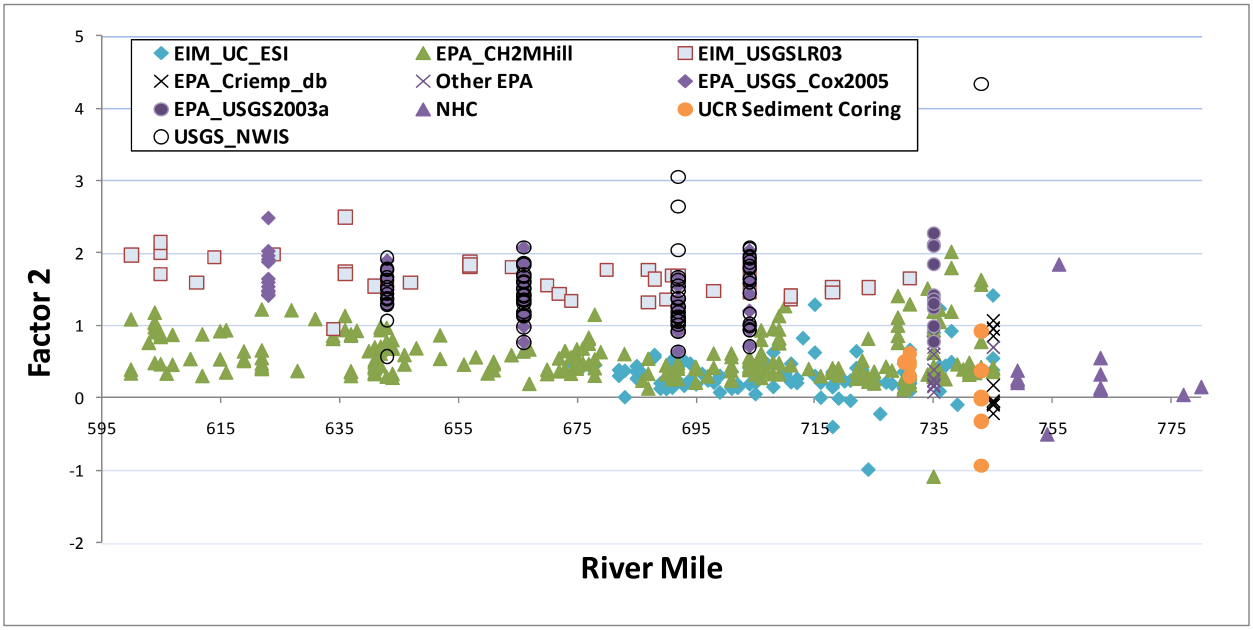


Figure 11

Factor 2 Scores versus River Mile, Coded by Study

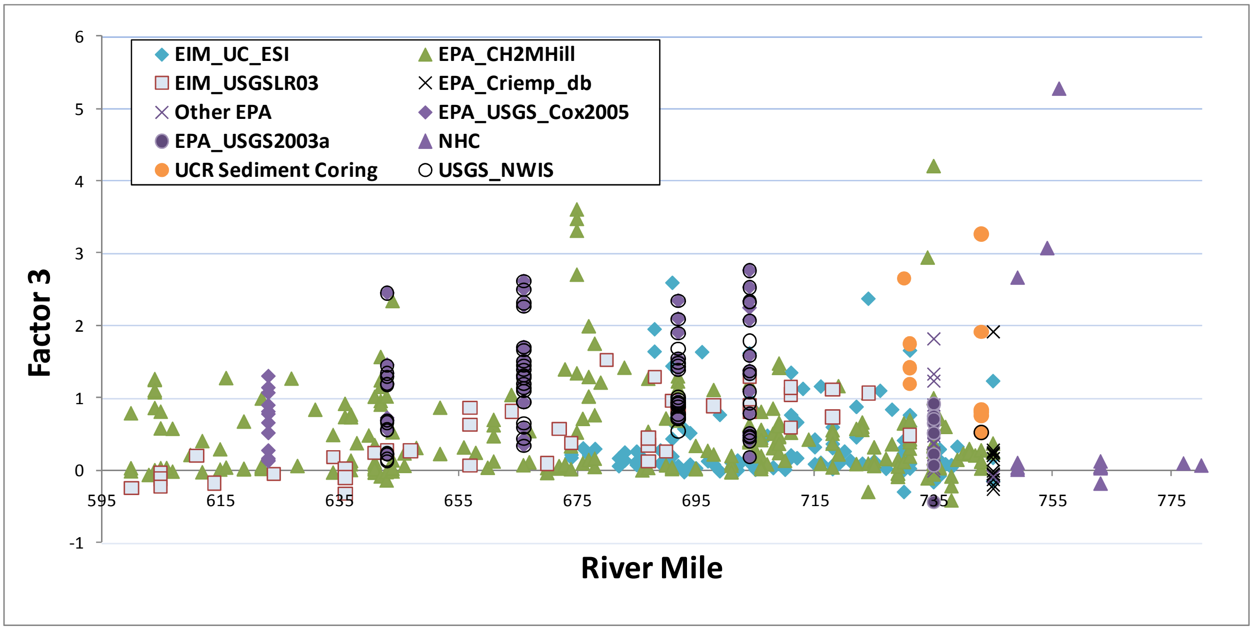


Figure 12

Factor 3 Scores versus River Mile, Coded by Study.

The main difference between the distribution of Factor 1 and Factor 3 scores is that the high scores for Factor 1 (slag) are generally found upstream of river mile 700, while high scores for Factor 3 (effluent metals) occur throughout the UCR site. Factor 3 scores show that effluent metals are heterogeneously distributed throughout the UCR site.

The variability in Factor 3 scores appears to be partly related to sediment characteristics such as grain size. Sample scores for Factor 3 show a weak but statistically significant positive correlation (r = 0.49) with clay content (Figure 13). This observation also supports my conclusion that Factor 3 is related to particulate metals discharged in Teck's liquid effluents which have accumulated as fine sediment in depositional areas in the UCR downstream of Trail.

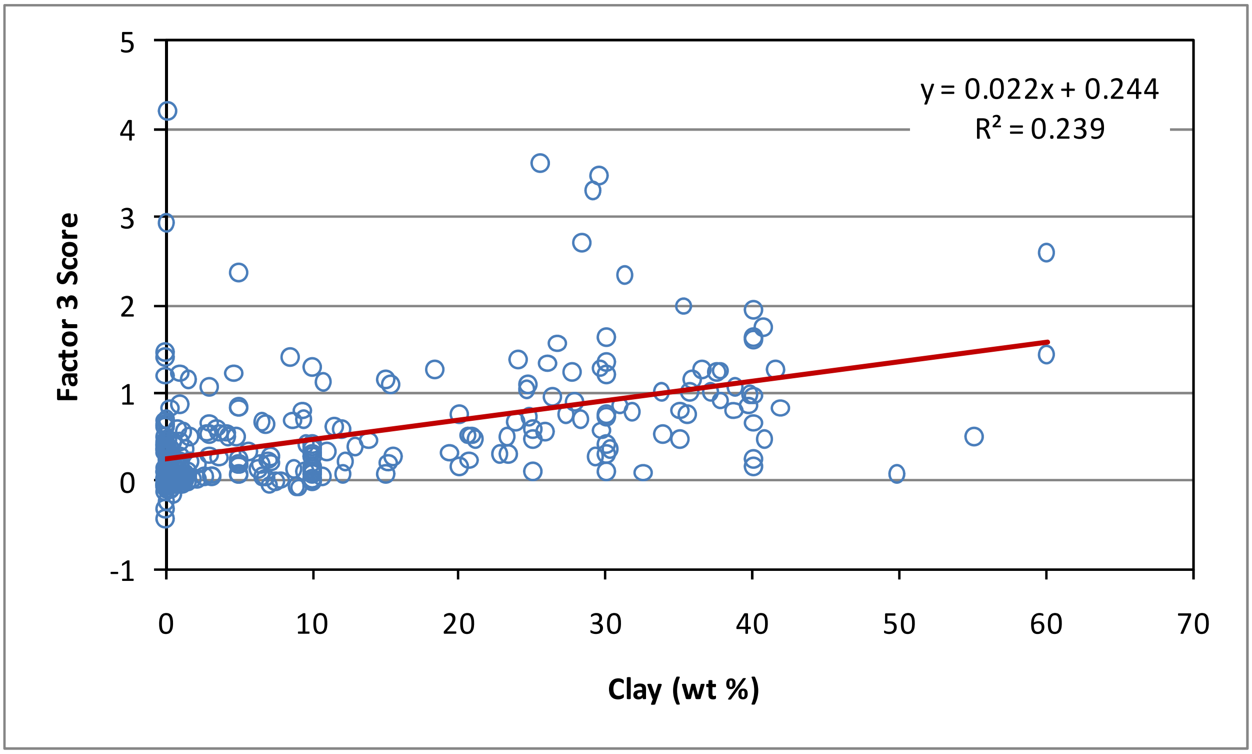


Figure 13

Variation of Factor 3 Sample Scores with Clay Content of Samples

2.1.5 *Lead Isotope Signatures*

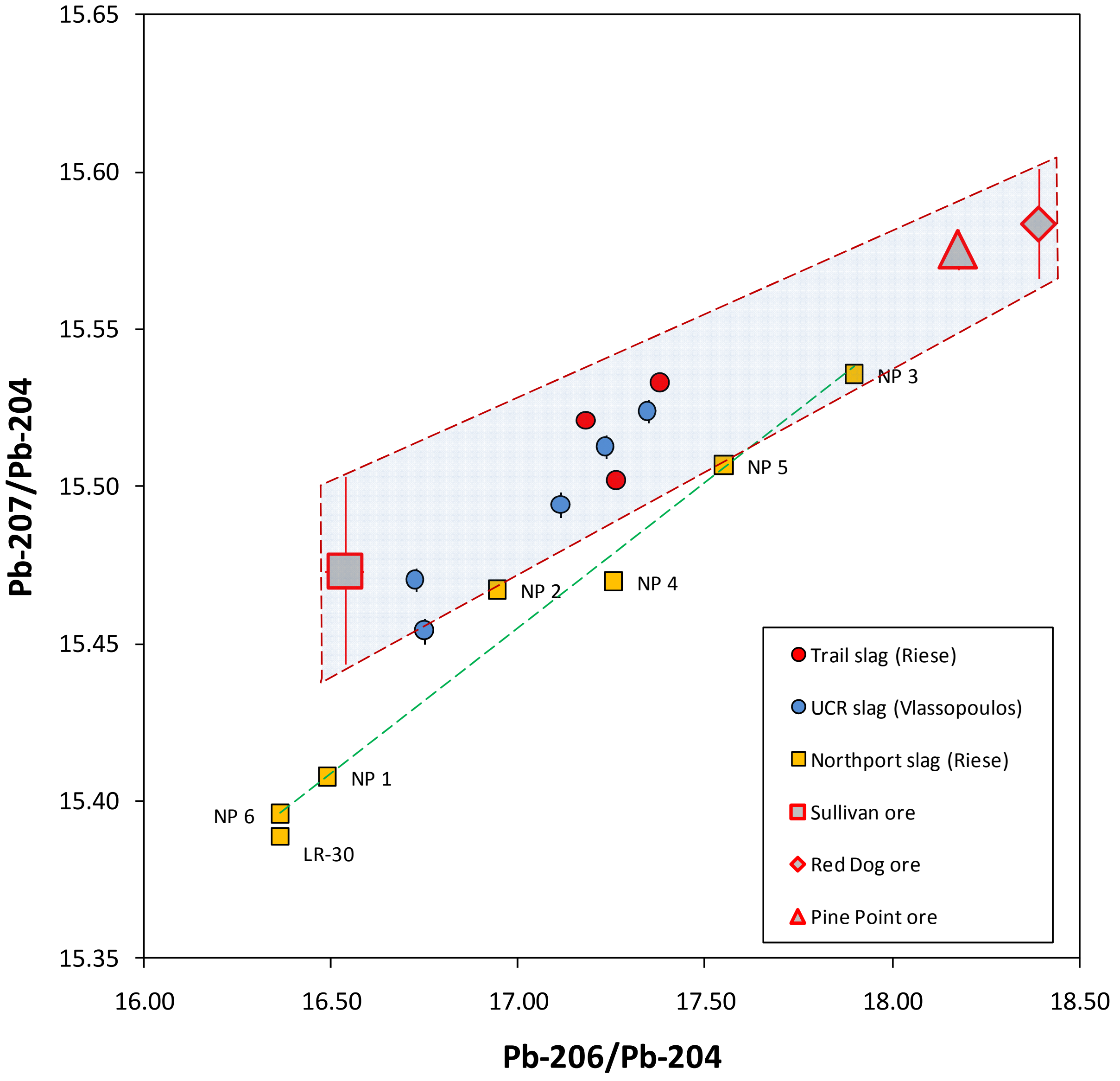
Dr. Riese suggests that lead isotope signatures cannot be used to distinguish Trail slag from other sources at the UCR site. He presents lead isotope data for samples that he claims represent Northport/Leroi smelter slag and Bossburg tailings that have lead isotope ratios that are indistinguishable from those of Trail slag. In this section, I demonstrate that this conclusion is unfounded and that his interpretations are contradicted by the supporting information. Regardless, it is important to note that none of Dr. Riese's analyses address or disprove my conclusion that the only plausible source of the elevated lead (and other associated metals) concentrations in UCR sediments upstream of Northport is the Trail smelter. Furthermore, all of the UCR sediment lead isotope data, including Dr. Riese's own samples, are explained by mixing of isotopically distinct Trail lead with locally derived lead, as presented in my expert report.

Dr. Riese claims he analyzed samples of "identified" Northport/Leroi slag (designated Bulk Northport slag type 1 to 6 and LR-30). Coordinates for the sample locations provided in his supporting information indicates these samples were collected from a location approximately 1 mile downstream from the former smelter site, on a sandy stretch along the east bank of the river (Figure 14). However, due to the location of these sampling sites at some distance from the former smelter site, it is not possible to rule out with any reasonable degree of certainty that Trail slag may also be present in these samples, and therefore their identification as Northport/Leroi slag is uncertain.

Figure 14

Sampling Locations of Dr. Riese's "Identified Northport/Leroi Slag" Samples Relative to the Former Smelter Site

Nevertheless, as noted by Nelson (2011), and contrary to Dr. Riese's claim, these purported Northport slag samples are in fact isotopically distinguishable from Trail slag and slag recovered from UCR sediments based on their Pb-207/Pb-204 ratios, as seen in Figures 15 and 16.

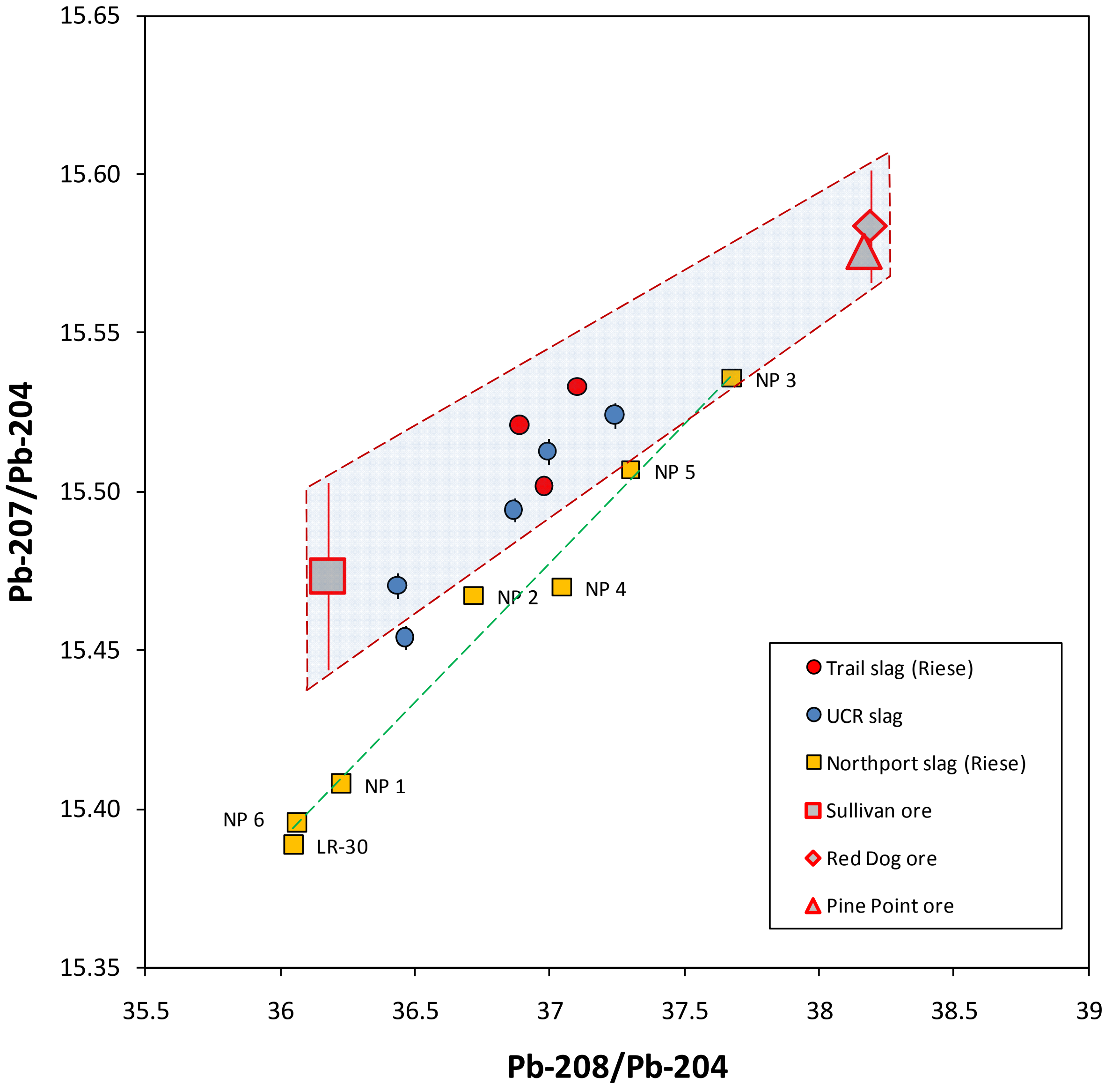


Note: Shaded area defines envelope for Trail slag

Figure 15

Pb-207/Pb-204 versus Pb-206/Pb-204 of Slag Samples

Dr. Riese's Trail slag samples and slag separated from UCR sediments fall squarely within the envelope defined by the Sullivan, Pine Point, and Red Dog ores (the main historical feeds to the Trail smelter). Three of Dr. Riese's samples from the Northport area (LR-30, type 1, and type 6 slag [labeled NP1 and NP6, respectively]) plot outside the Trail envelope. These three samples may well represent Northport blast furnace slag produced from smelting Coeur d'Alene ores, which were processed at Northport between 1916 and 1921. These samples, along with the rest of Dr. Riese's "Northport slag" samples define a linear array that falls below and partially overlaps onto the Trail envelope. While Dr. Riese proposes that this trend indicates that Trail and Northport slags are isotopically identical, he did not rule out an alternative and equally valid explanation that the Northport samples define a mixing trend between Northport and Trail slag end members, as indicated by the green dashed line in Figures 15 and 16.

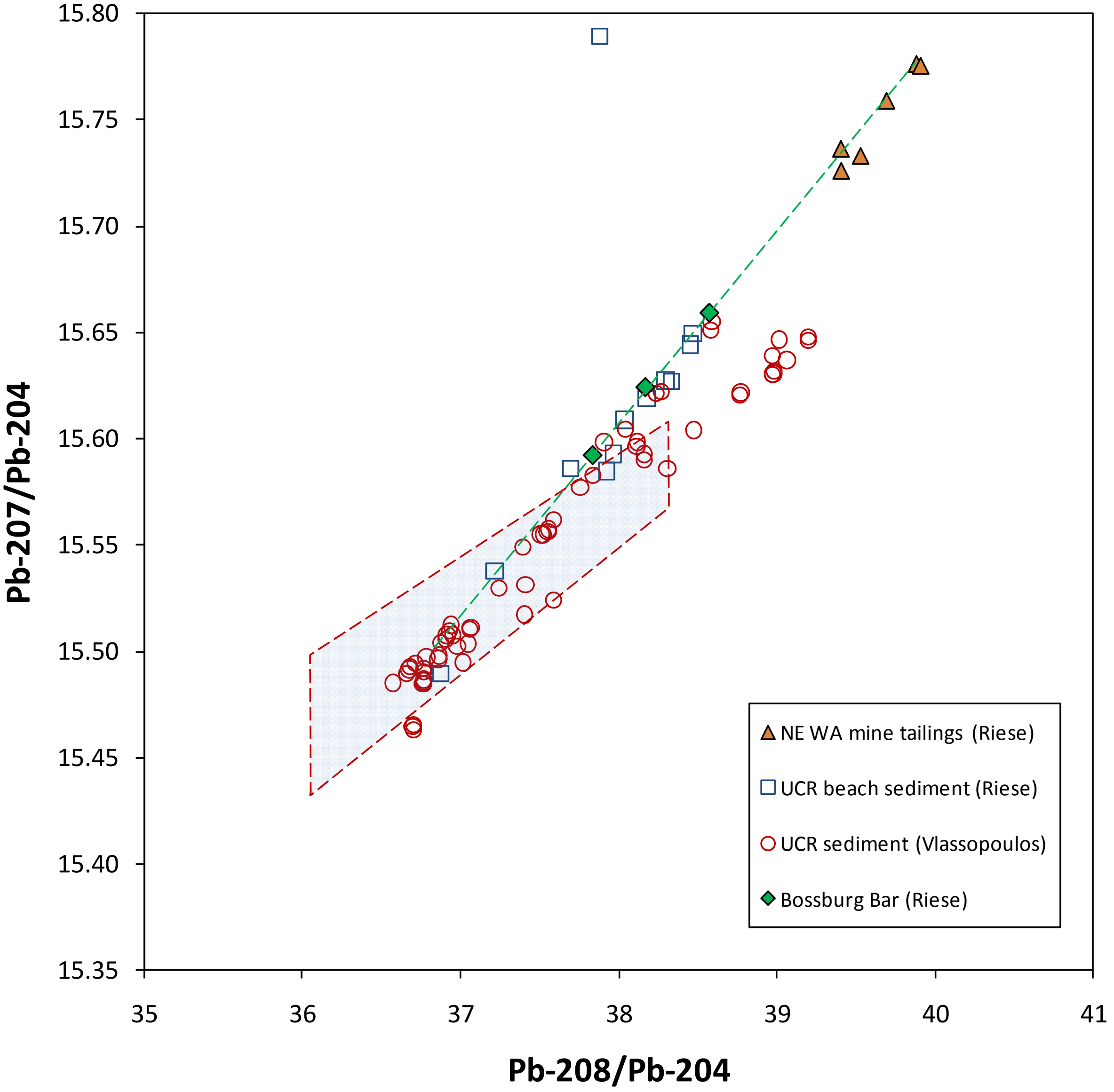


Note: Shaded area defines envelope for Trail slag

Figure 16

Pb-207/Pb-204 versus Pb-208/Pb-204 of Slag Samples

Dr. Riese also sampled UCR sediment below Northport adjacent to Bossburg for lead isotope analysis and found values that overlap the upper range of ratios for the Trail source. Tailings from the Gregor Mill at Bossburg originating from processing of ores from the Young America and other local mines should have lead isotope ratios similar to the regional background which is more radiogenic (that is, higher ratios) than the older Trail ore lead. However, descriptions of sample locations from the Bossburg bar noted up to several percent slag (in "1615A_~1.XLS" from the supporting materials of Adrian Brown). Consistent with these descriptions, the Bossburg bar samples fall on a well defined mixing trend between Trail slag and tailings from several mines and mills in the area for which Dr. Riese provides data (Figure 17). Interestingly, samples of tailings from upland locations at Bossburg were apparently available to Dr. Riese (Hazen 2010b, Appendix C, p. 17), but he did not analyze them. Therefore, the unlikely theory that Bossburg tailings have similar lead isotope ratios as Trail slag and effluents cannot be supported. The lead isotope data for the Bossburg bar samples simply reflect the presence of Trail slag in these samples.



Note: Shaded area defines envelope for Trail slag

Figure 17

Pb-207/Pb-204 versus Pb-208/Pb-204 of Sediment Samples

2.2 Dr. Riese's Comments on Opinion 2

My second opinion states that:

> *Slag discharged from the Teck Cominco smelter is a predominantly glassy material. Once released into the aquatic environment, it slowly but irreversibly breaks down to more stable weathering products by physical and*

> *chemical processes. Through the action of these processes, heavy metals and other potentially toxic constituents present in the slag including arsenic, antimony, barium, cadmium, copper, lead, and zinc are released over time from the slag to the sediment porewater and the aquatic environment.*

In support of this opinion, I used multiple lines of evidence to demonstrate that Trail slag releases toxic metals to water, including:

- Review of slag leaching studies previously conducted or commissioned by Teck and its predecessors
- Laboratory leaching studies of slag separated from UCR sediment
- Sampling porewater from slag-containing sediments

None of the arguments and claims that Dr. Riese presents can detract from this inevitable conclusion. To the contrary, some of the data presented by Dr. Riese provides additional insight and support for my opinion.

In his opening statement to Section 4.1.2 (p. 58), Dr. Riese appears to deny the fact that Trail slag is predominantly composed of glassy material. This directly contradicts his earlier statement that "Trail barren slag has a homogeneous, glassy, amorphous texture" (Riese 2011, p. 31) and the detailed chemical and mineralogical analyses of slag presented in Hazen (2010a, b). This is a key defining characteristic of slags that determines their capacity to leach chemical constituents into the aquatic environment, because all glassy materials are inherently unstable and irreversibly break down over time. The rate of leaching of individual metals from slag deposited in the UCR will vary as a function of the metal, its concentration in slag, and the local environmental conditions which vary across the site.

Dr. Riese goes on to explain that Trail slag contains "magnetite and zinc spinels that are extremely insoluble and inert in oxidized waters" (Riese 2011, p. 58), a conclusion apparently based on solubility calculations at pH 7. This statement, as well as the calculations, are too simplistic, as they neglect the fact that the solubilities of magnetite and zinc spinel are strongly dependent on both pH and redox conditions. In Figure 18, the calculated solubilities in water at pH 7 of magnetite and zinc ferrite (spinel) are shown as a function of redox potential (Eh). The solubility curves were calculated using the React module of the

Geochemist's Workbench (www.rockware.com), a state-of-the-science computer program for geochemical modeling. As shown on Figure 18, the solubility of iron and zinc increases exponentially with increasingly reducing conditions (lower Eh). The calculations suggest that dissolved zinc concentrations in the milligram per liter (mg/L) range are possible when the potential becomes negative. Such conditions would be expected to occur within the UCR, for example, where thick piles of slag-bearing sediment have accumulated and the decomposition of organic matter depletes oxygen leading to anaerobic conditions. Similarly, the solubilities of magnetite and spinel also increase as pH decreases.

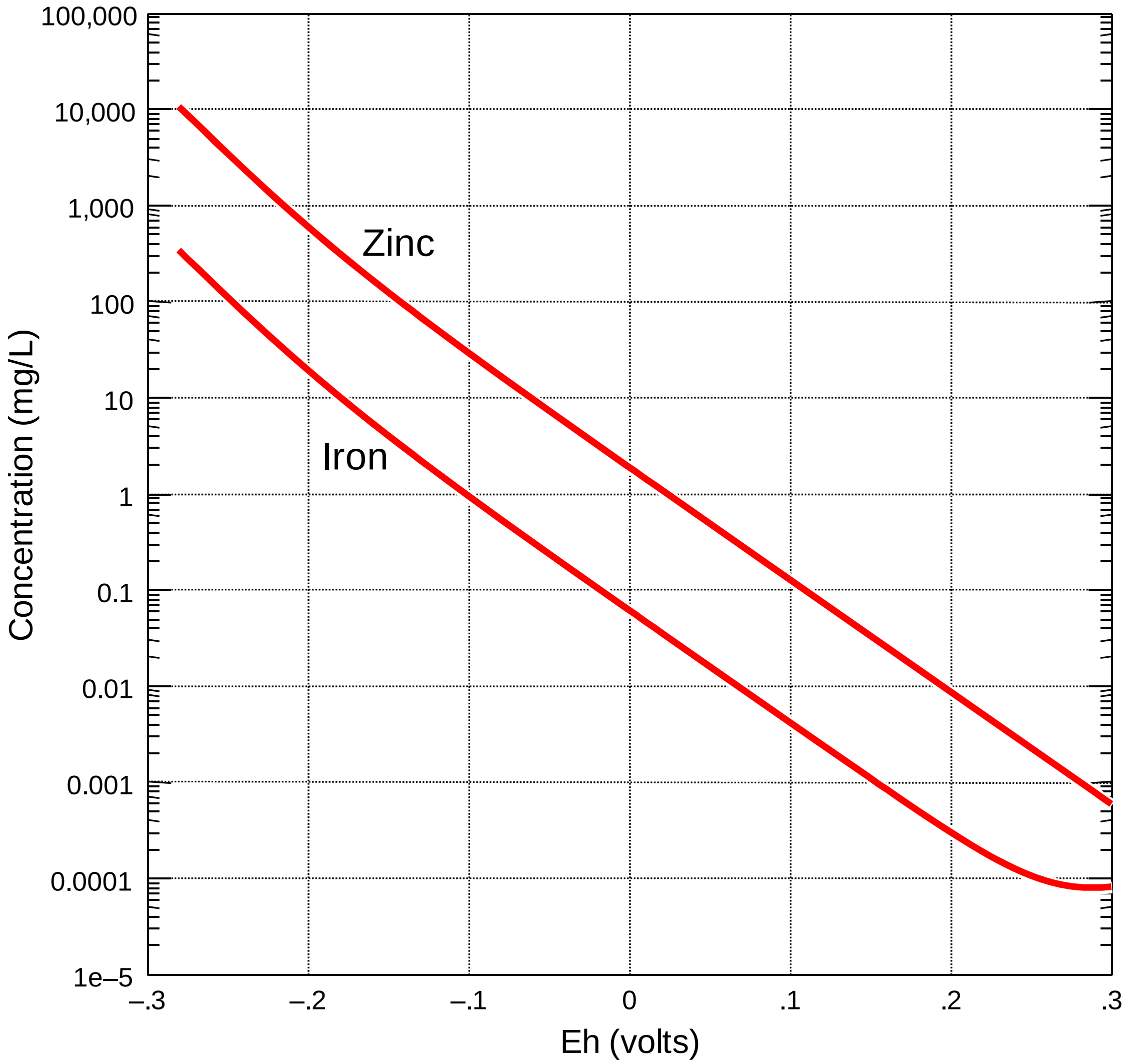


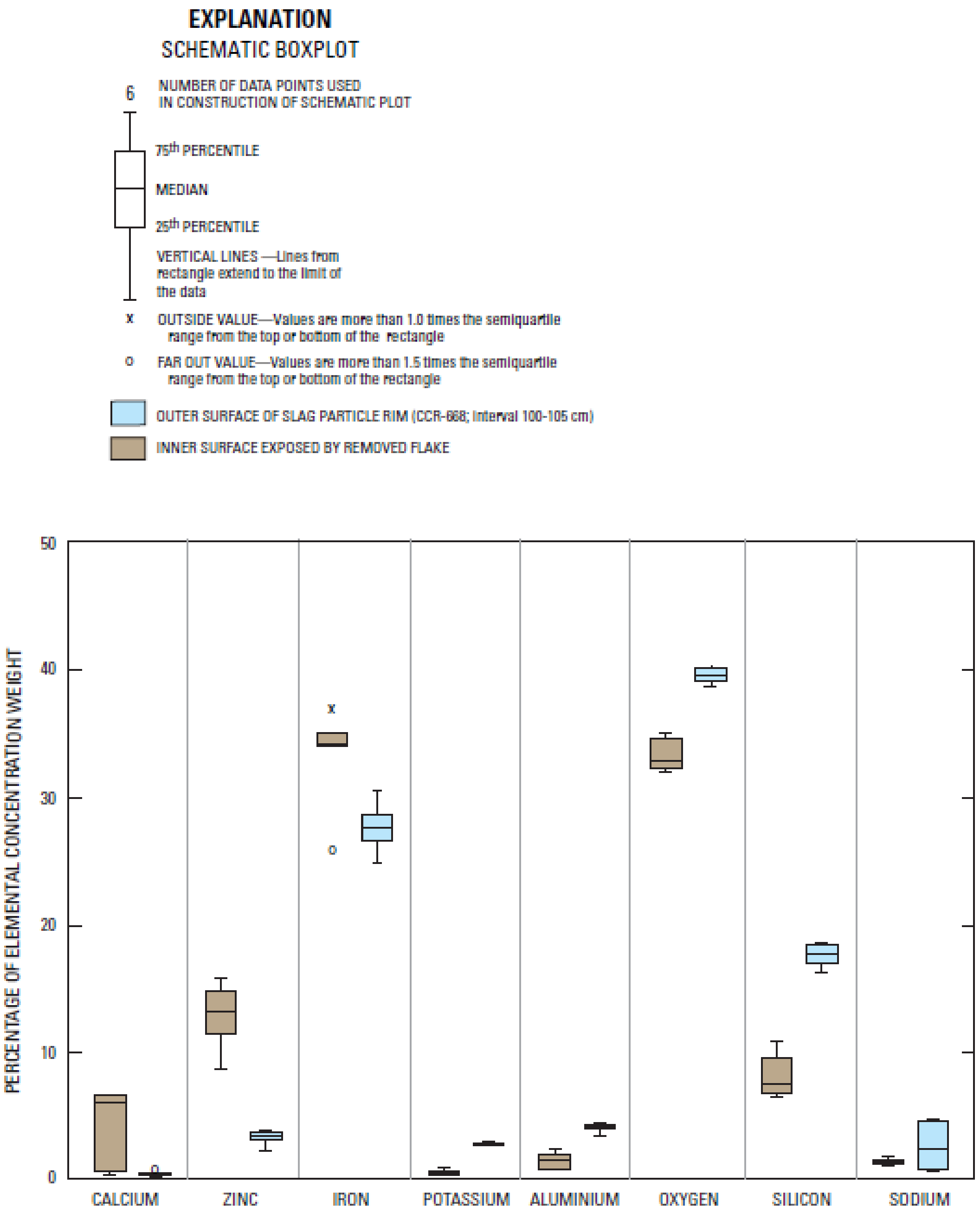
Figure 18

Calculated Solubilities of Magnetite and Zinc Spinel in Water at pH 7 as a Function of Redox Potential (Eh)

To support his claim that potentially toxic metals are not leached from slag in the UCR, Dr. Riese refers to Figure 14 in the report by Cox and others (2005), which shows the concentrations of selected elements in the interiors and surfaces of slag particles as determined with an electron microscope. However, this line of evidence is of limited value because the detection limits of the instrument are such that zinc and iron are the only metals of interest which are present at detectable concentrations. Dr. Riese goes on to argue that because zinc, unlike calcium, is not depleted in the rims of slag particles, then it must be conserved in the slag rims. Interestingly, Figure 16 in the report by Cox and others (2005), reproduced here as Figure 19, shows that zinc, iron, and calcium are depleted in the rims of some slag particles, suggesting that leaching has occurred.

Similar variability is observed in elemental concentration profiles of Trail slag particles analyzed by Hazen Research (see Figures 10, 27, and 29 in Hazen 2010b for examples of concentration profiles of slag particles that show depletion of zinc in the rim). Due to this lack of consistency, slag particle chemical profiles cannot provide conclusive evidence regarding leaching of toxic metals from slag.

Furthermore, Riese's assertion that enrichment of metals in the "rim" or outer weathered layer of a slag particle indicates that the metal is not leaching is flawed. The fact that a weathered layer is developed at all is proof that slag leaches. The metals concentrations in the outer layer represent the mass remaining in the outer layer of the slag particle at any given time but not what has been removed. Concentration differences between the particle interior and the outer weathered layer reflect the relative rates at which different elements are leached. Slower leaching elements will tend to become concentrated in the weathered layer relative to faster leaching elements, but the concentration profiles do not provide any information about the absolute amounts of these elements leached. This type of analysis therefore cannot be used to conclude that elements do not leach from slag.



Source: Cox et al. 2005

Figure 19

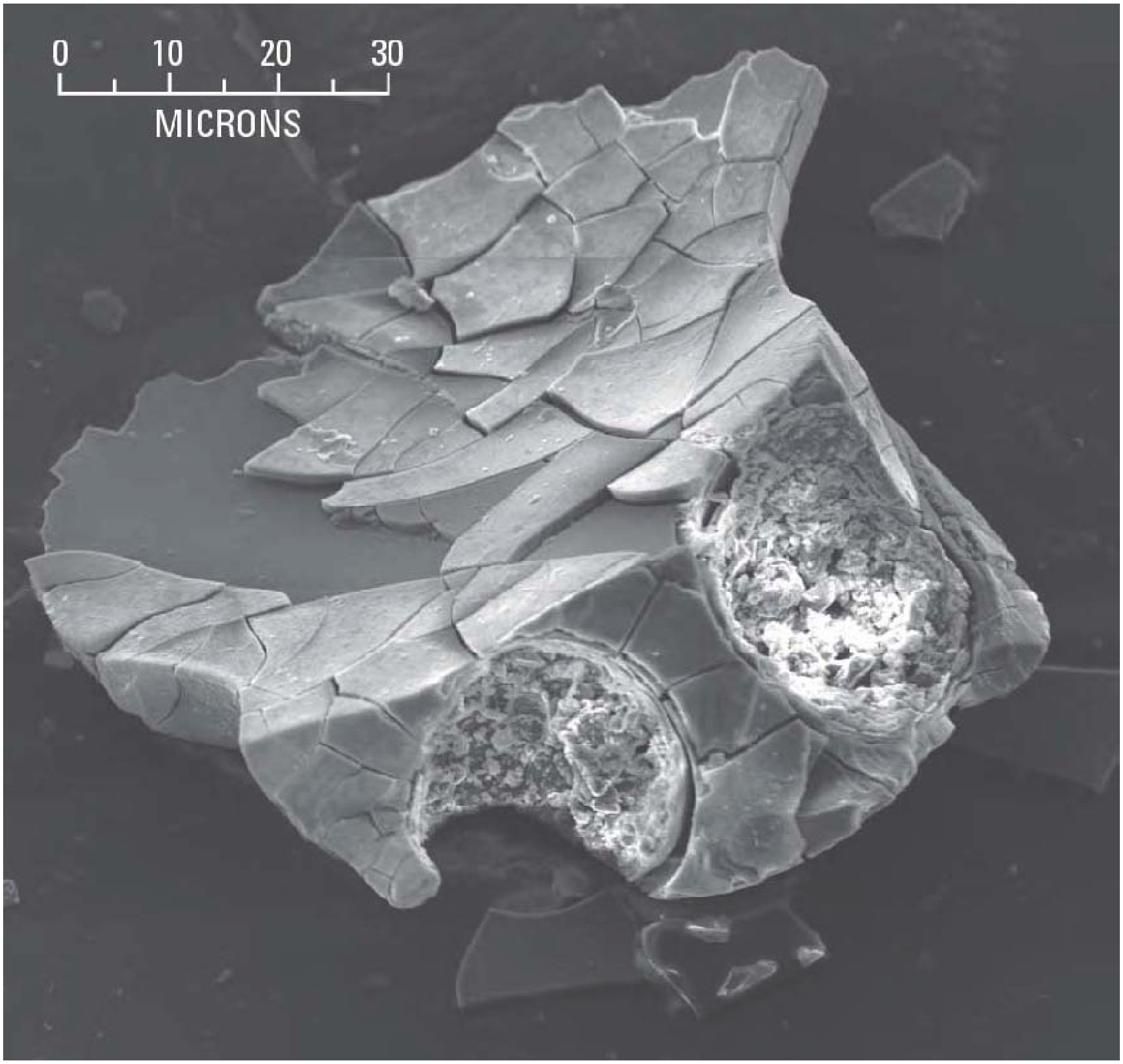
Element Concentrations on Surfaces of Slag Particle Rims and Inner Surfaces Exposed by Removing Rim

Teck's electron microprobe studies (Riese 2011, Hazen 2010a,b) show variable chemical concentration profiles in slag particles, with metals concentrations in the rims sometimes depleted, sometimes enriched, and sometimes unchanged relative to the particle interior. This appears to reflect the different relative leaching rates of elements under specific conditions; some are leached slower than others and appear to become concentrated in the rims.

A more direct assessment of slag leaching (such as leach testing) was not attempted by Dr. Riese. Instead, he relies on what he calls "alteration rims" or "rinds" covering slag particles as evidence that slag does not leach metals. These "rims" are actually just the outer weathered layer of slag particles, which as mentioned earlier, are themselves physical evidence that slag breaks down in the river environment. Contrary to Dr. Riese's assertions, this weathered layer is not contiguous and does not provide a barrier to leaching of slag.

As is evident in practically every microphotograph of slag particles presented in Dr. Riese's report (2011) and Hazen (2010a, b), and additional scanning electron microscope (SEM) images obtained by Nelson (2011) for slag particles collected from the UCR site upstream of Northport, these weathered layers are either discontinuous, cracked or partially detached from the slag particles, and thus the underlying slag surface can come into contact with water (Figures 20 through 26). Figure 24, in particular, shows a Trail slag particle with an extensively pitted slag surface underneath the outer weathered layer, indicating dissolution.

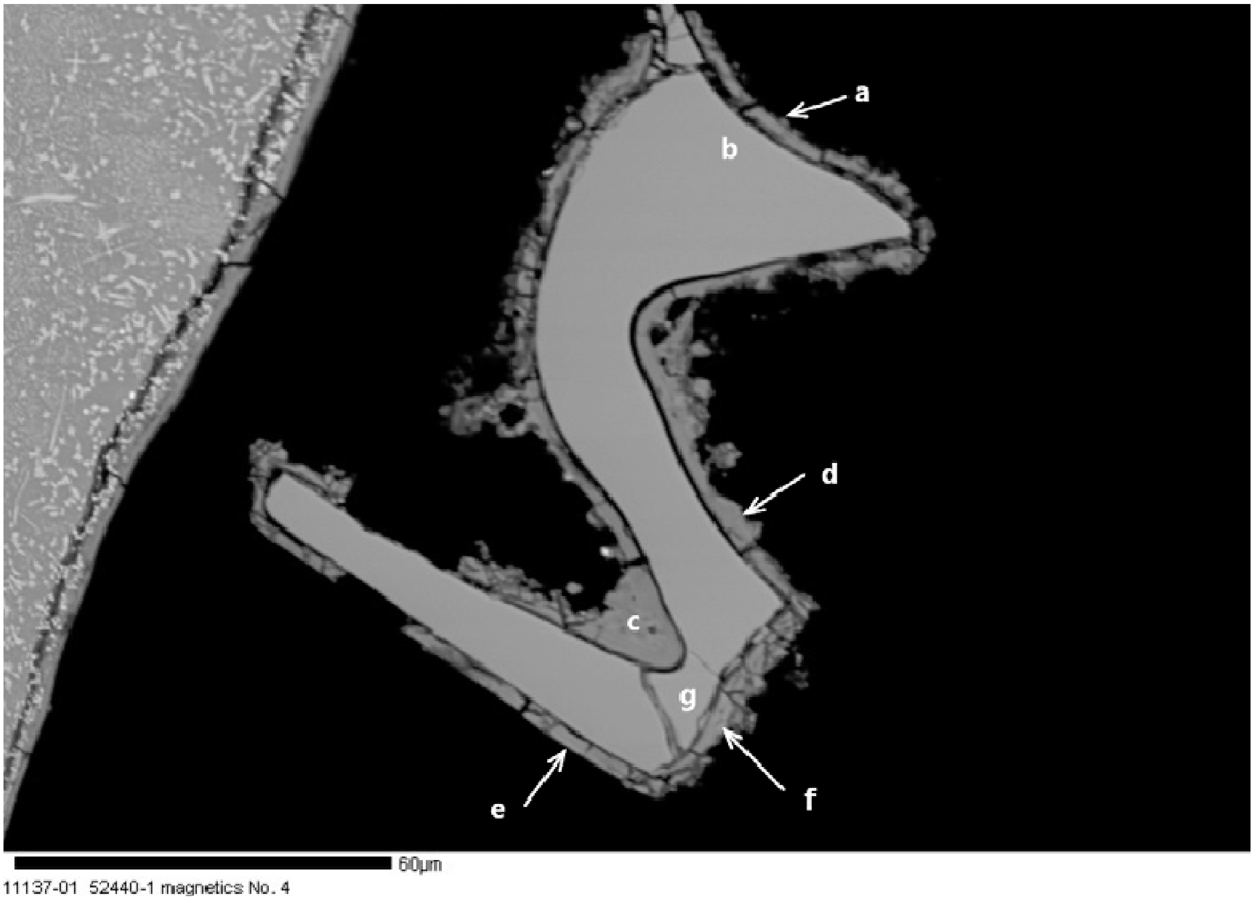
The discontinuous, cracked and peeling nature of the outer weathered layer indicates that it is continuously removed from the slag particle surfaces by abrasion. This process continuously exposes fresh slag surfaces to dissolution and leaching within the UCR.



Source: Riese 2011, Figure 16

Figure 20

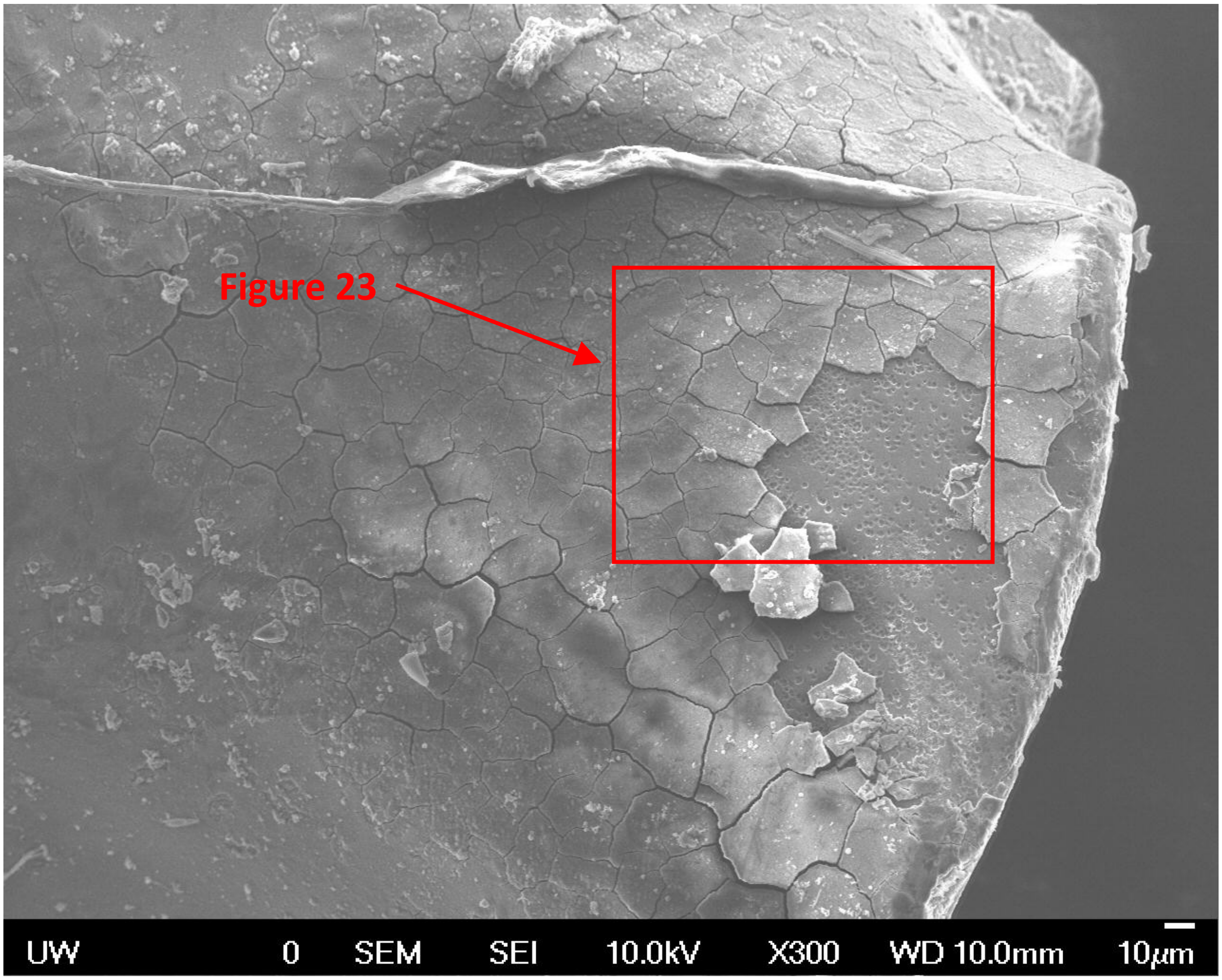
SEM Image of Slag Particle Showing Discontinuous, Cracked, and Peeling Outer Weathered Layer



Source: Riese 2011, Figure 6

Figure 21

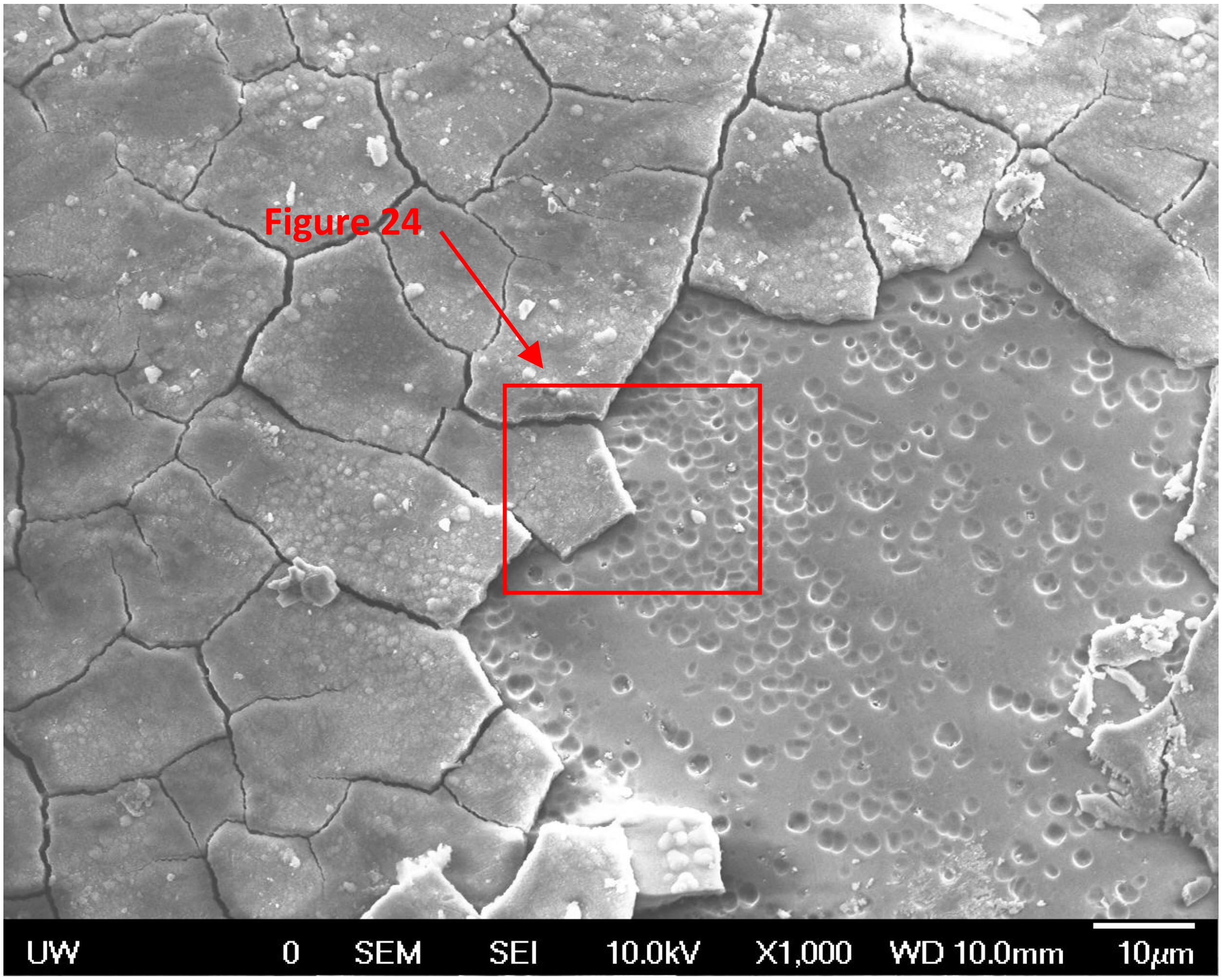
SEM Image of Trail Slag Particle Showing Discontinuous and Peeling Outer Weathered Layer



Source: Nelson 2011

Figure 22

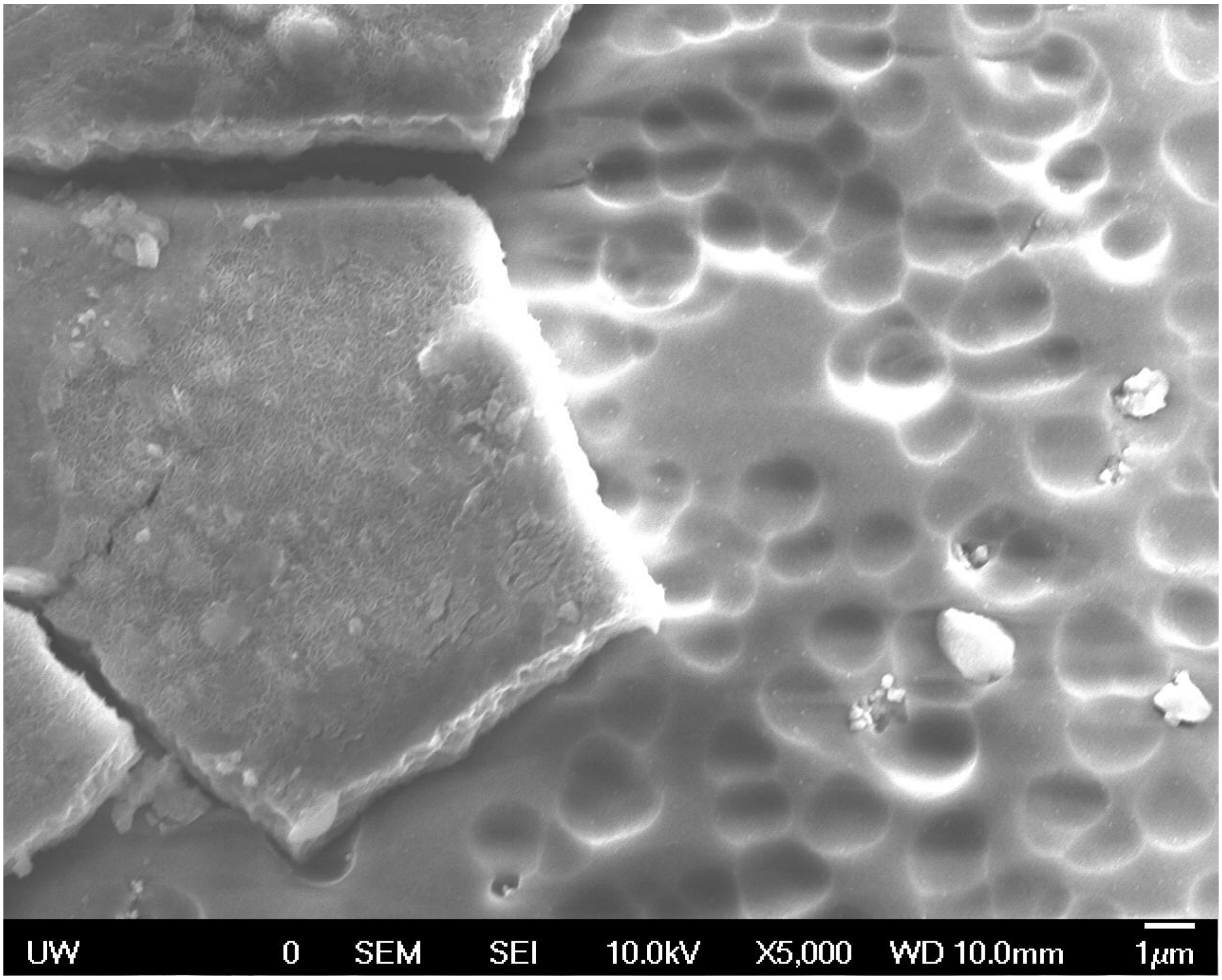
SEM Image of Trail Slag Particle, SCB15A Grain #1, Collected from UCR Sediment Near the International Border



Source: Nelson 2011

Figure 23

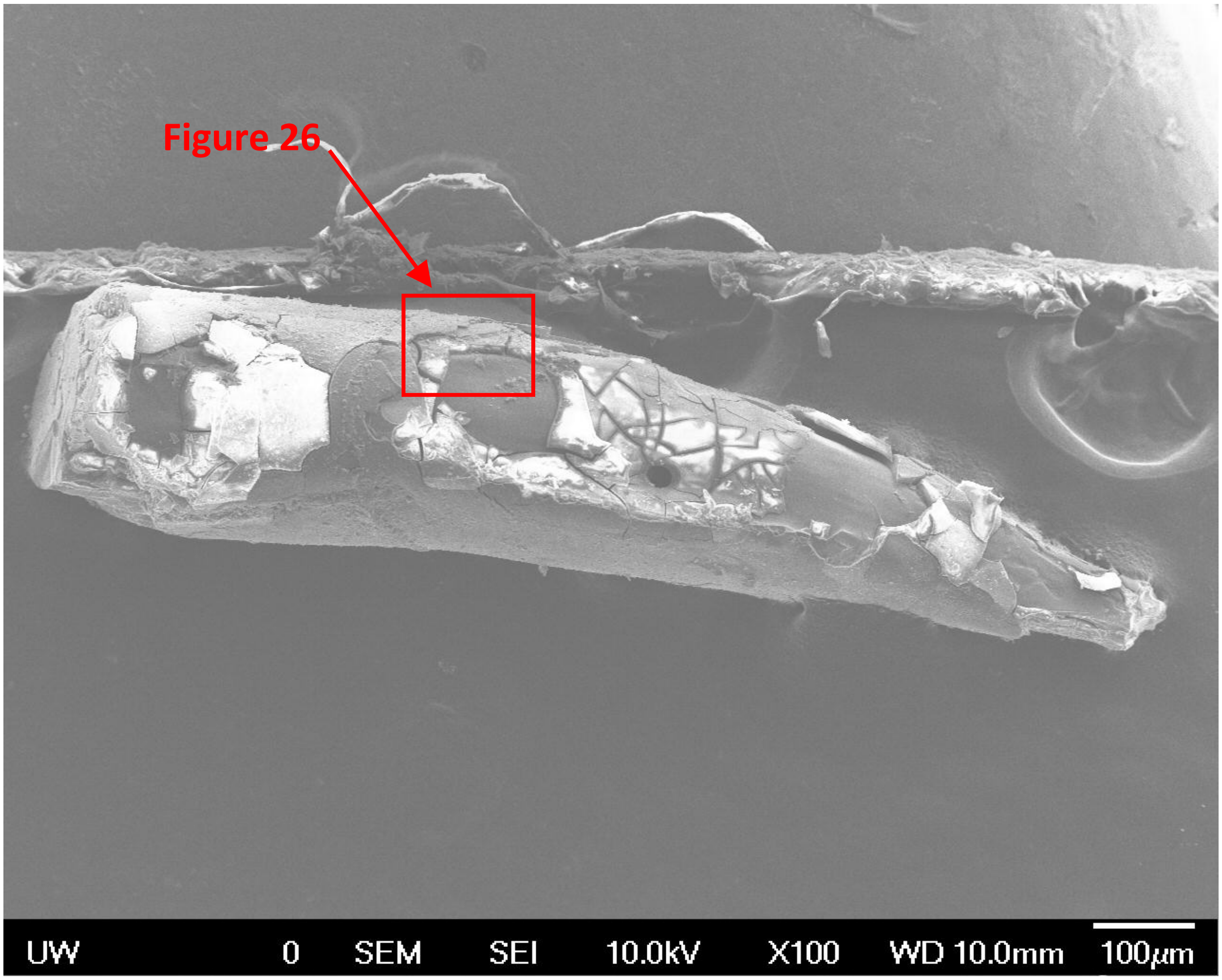
Higher Magnification View of Figure 22 Showing Discontinuous, Cracked, and Peeling Outer Weathered Layer Exposing Pitted Slag Surface Underneath



Source: Nelson 2011

Figure 24

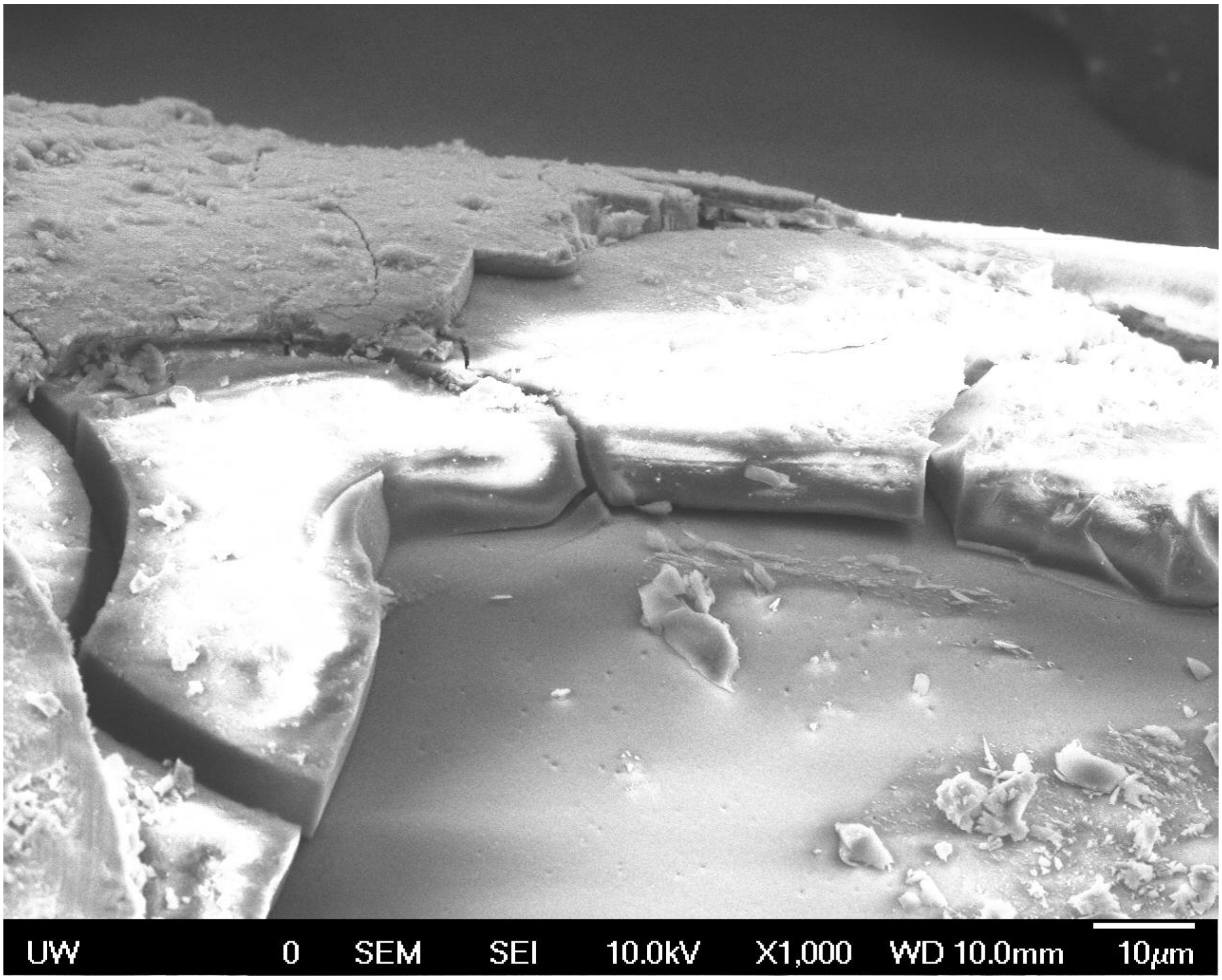
Close-up View of Figure 23 Showing Cracked and Peeling Outer Weathered Layer and Pitted Slag Surface Underneath



Source: Nelson 2011

Figure 25

SEM Image of Trail Slag Particle, BSB17A-4, from Black Sand Beach Showing Discontinuous and Cracked Nature of the Outer Weathered Layer



Source: Nelson 2011

Figure 26
Close-Up View of Figure 25 Showing Two Cracked and Peeling Weathered Layers Exposing Slag Underneath

2.2.1 Slag Leaching Study

A slag leaching study was conducted by Professor Joe Ryan at the University of Colorado to demonstrate the release of metals from slag to UCR water (Ryan et al. 2010). Dr. Riese criticizes the slag leaching study as being "scientifically indefensible and inapplicable to the actual river conditions". However, none of the reasons he provides are valid, nor do they detract from the inevitable conclusion based on multiple laboratory observations, including Teck's own leaching studies, that Trail slag releases toxic metals.

Dr. Riese did not conduct any direct studies to support his opinion that slag does not leach, as I did. Instead, he chose to dismiss the Teck leaching studies as unrepresentative and to criticize the Ryan leaching study. Dr. Riese asserts that crushing the slag prior to leaching somehow created unrepresentative conditions in the study by Ryan and others (2010). However, this assertion is unfounded, as leaching tests were performed on both crushed and uncrushed slag and showed similar releases for most of the elements analyzed.

Dr. Riese then turns to criticize the aerobic versus anaerobic conditions in the leach tests as not successfully representing conditions in the river. A wide range of environmental conditions can exist within the approximately 150-mile reach of the UCR/LR system. The suboxic to aerobic conditions obtained during the leaching study are in fact representative of a range of porewater and surface water conditions, as measured during the porewater sampling study (see Section 2.2.2).

Despite the lack of foundation for Dr. Riese's criticism of Ryan and others' (2010) leaching study, additional studies were conducted (Ryan and Mohanty 2011) to provide additional support and insight on the leaching and release of toxic metals from Trail slag recovered from UCR sediment. Uncrushed slag was subjected to 21-day batch leaching tests, which not only confirmed the results of the previous leaching study on crushed slag, but also shows that slag containing an outer weathered layer still leaches metals. In addition, slag leaching tests were also conducted in fluidized bed reactors with Columbia River water, which clearly documents a continuous release of major and trace elements, including iron, aluminum, manganese, cadmium, cobalt, copper, nickel, lead, zinc, antimony, arsenic, and selenium from slag.

As described in my expert report (Vlassopoulos 2011, p. 39), Teck's own slag leaching tests using simulated rainwater showed that very high metals concentrations in the leachate persisted over an extended period. While I agree with Dr. Riese that these test conditions were not representative of submerged slag in the river, they are relevant to slag deposits present at numerous beaches between the US-Canada border and Kettle Falls, which are exposed to precipitation. Teck's own slag leaching data suggests that infiltration of rain on beach slag deposits has the potential to release very high metals concentrations which would discharge directly to the river.

Dr. Riese uses river flow rates to calculate the residence time of river and lake water with bottom sediments and uses this to argue that the timescale of the leaching experiments was too long. However, there are two problems with this approach. First, water velocity in river channels decreases near the river bed due to friction, which results in slower than average velocities (and hence longer residence times) near the bed. Second, Dr. Riese fails to recognize that porewater velocities within sediments are much slower than river flow velocities (that is, water can remain in direct contact with slag particles for extended periods).

To reiterate my opinion, the leaching studies definitively and unequivocally prove that Trail slag releases toxic metals to water. In the closed-system batch tests (Ryan et al. 2010), some metals (for example, lead and nickel) were initially released and then removed from solution. The slag was determined to consist of approximately 60 percent glass and 40 percent ferrihydrite (Ryan et al. 2010). Ferrihydrite is a hydrous iron oxide mineral that has a strong affinity for adsorbing metals from solution. The behavior of lead and nickel most likely reflects adsorption to ferrihydrite present on the slag particles. Other metals (for example, arsenic and antimony) showed continuously increasing concentrations over the 28 day duration of the tests indicating that adsorption was not important for these elements under the test conditions. The process of adsorption does not prevent release from slag; rather, it results in the transfer of certain metals from the glassy slag matrix to the surface of ferrihydrite, where they would be available to partition back to water. In addition, the fluidized bed leaching experiments document the continuous release of a variety of toxic metals from Trail slag, including iron, aluminum, manganese, cadmium, cobalt, copper, nickel, lead, zinc, antimony, arsenic, and selenium (Ryan and Mohanty 2011).

2.2.2 Porewater Study

The purpose of the porewater study was to document metals concentrations in porewater of slag-containing sediments and to compare those with results of the leaching study as a means of confirming that the expected trace elements released by slag leaching could also be observed under field conditions.[2] The porewater data generally confirmed expectations of elevated metals concentrations based on the leaching studies, including arsenic, antimony, cadmium, copper, lead, and zinc. In a particularly striking example, elevated antimony and copper in porewater from the Deadman's Eddy area mirrored the leaching behavior of slag recovered from the same area (Vlassopoulos 2010, p. 41).

Riese attempts to dismiss the significance of the porewater data by claiming that the sampling depth of 4 feet is too deep to be relevant due to the long diffusion pathway. The porewater sampling depth of 4 feet was selected to be far enough below the sediment-water interface to minimize the potential for surface water entrainment during porewater sampling, which would affect concentrations and sample representativeness. Furthermore, Dr. Riese's assertion is simply not credible because slag is present to depths of several feet within the sediment column in the areas sampled, and metals release to porewater can occur at any depth where slag is present, as he himself admits (Riese 2011, p. 61, second paragraph).

Furthermore, in estimating porewater metals flux from UCR sediments, he only considers the upper five centimeters of sediment as contributing to the flux. This is arbitrary and incorrect, because it ignores the fact that metals release to porewater will occur below 5 cm wherever slag is present, and benthic organisms present below this depth can be exposed to toxic metals in porewater (see for example, Blum [2011]).

Most importantly, Dr. Riese considers the transport of metals in porewater is only due to diffusion. He fails to consider the importance of advection, as well as sediment erosion and scouring on the flux of metals out of the sediment porewater. Advection is the process by which substances are transported through the motion of water and can include both hyporheic flow (the exchange of surface water and porewater as surface water flows in and out of the pore space of sediment deposits), as well as groundwater discharge. The

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[2] After submittal of my expert report, it was discovered that the cited method reporting limit (MRL) of 0.00005 microgram per liter (µg/L) for mercury in porewater (Vlassopoulos 2010, Table 4) was incorrect. The correct MRL is 0.01 µg/L. A corrected lab report has been issued by the laboratory.

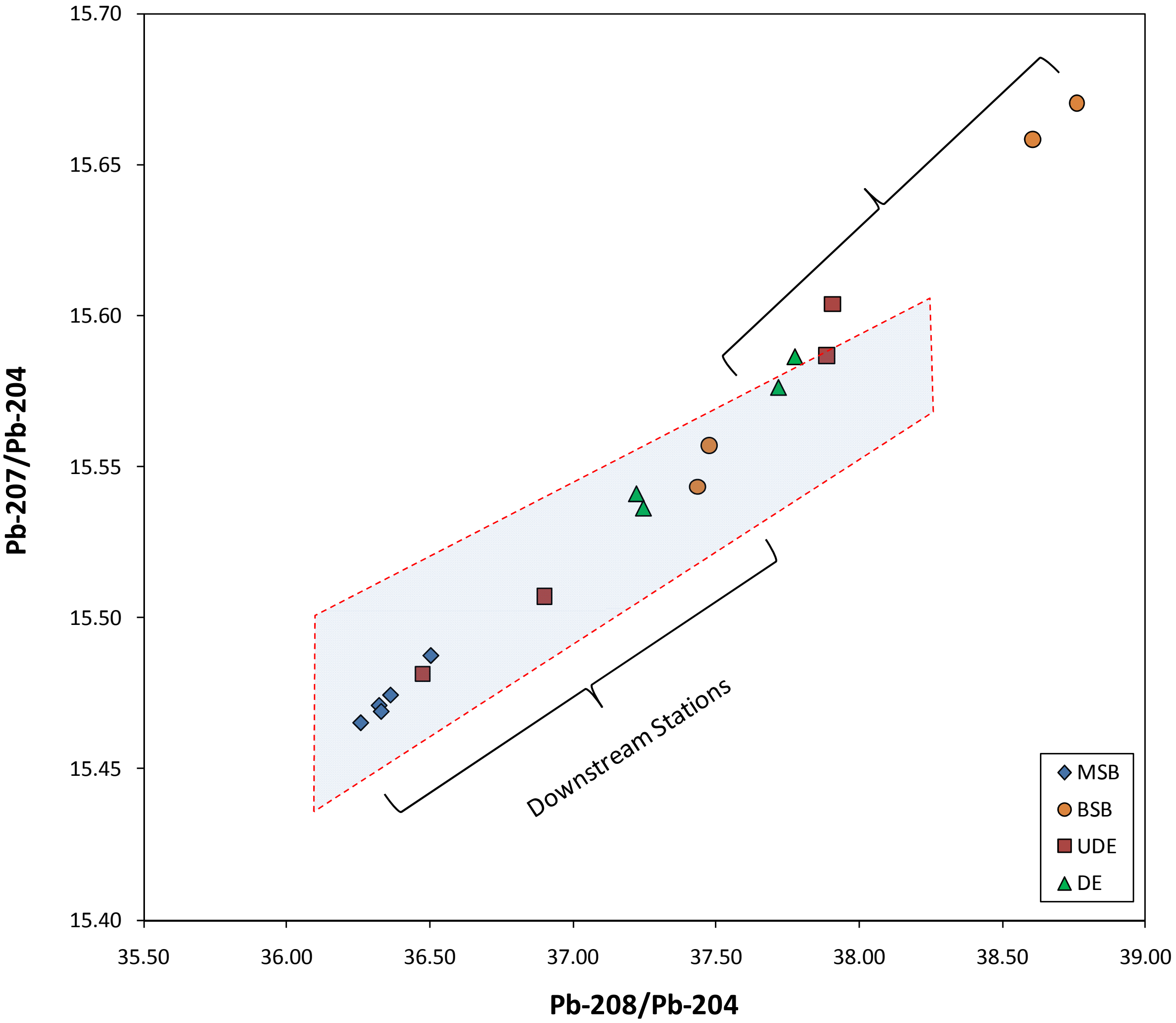
magnitude of these advective transport processes will vary greatly throughout the UCR site, but will generally act to enhance the flux of metals out of porewater.

Subsequent to the submittal of my expert report in September 2010, archived porewater samples were analyzed for lead isotope ratios. The porewater isotope data provide additional proof and further insight into the release of Trail-derived metals from slag–bearing sediments.

The porewater isotope results are summarized in Figure 27. Samples were collected at four locations, from upstream to downstream in the UCR, as previously described in Vlassopoulos (2010):

- MSB – mid-stream bar at the International border
- BSB – Black Sand Beach
- UDE – upstream of Deadman's Eddy
- DE – Deadman's Eddy

At each location, samples were collected at two stations: one upgradient and one downgradient. At the MSB location, porewater samples from both stations are isotopically similar to the Trail lead source indicating all the lead in porewater is derived from slag. At the other locations, systematic differences were noted between upgradient and downgradient stations. The upstream or upland stations appear to have a significant component of more radiogenic background lead (six samples that plot outside the Trail envelope in Figure 27). As the water travels through the slag-bearing sediments, it takes on a more Trail-like lead isotopic signature. The downstream stations plot consistently within the Trail envelope. This indicates that Trail lead is the dominant source of lead in these sediment porewaters.



Note: Red dashed outline is the Trail source envelope

Figure 27

Lead Isotope Ratios in Sediment Porewater

2.3 Dr. Riese's Comments on Opinion 3

My third opinion relates to the fate of Trail effluent metals that have entered and accumulated with sediments of the UCR site:

> *Metals associated with sewer effluents from the Trail smelter (including arsenic, cadmium, copper, mercury, lead, and zinc) have been discharged in both dissolved and particulate forms. Particulate-bound metals are carried downriver and eventually settle out of the water column as fine-grained sediment in depositional areas. Part of the dissolved metals load released to the river system will adsorb onto suspended particulate matter and is also carried downriver and eventually deposited as sediment. Biogeochemical processes occurring within these sediments result in the remobilization of sediment-bound metals, and their release into sediment porewater and the aquatic environment. The rate and extent of metals release is a function of biogeochemical redox conditions within the sediments, which are expected to vary across the Upper Columbia River site, depending in part on factors such as sediment grain size, organic matter content, metal concentrations, and burial depth.*

None of Dr. Riese's comments has any impact on my conclusion regarding the fate of Trail effluent metals in the UCR system. If anything, my opinion is supported by chemical extraction data produced by Dr. Riese.

In Section 4.1.3 of his report, Dr. Riese takes the position that all particle-bound metals would flow past the Grand Coulee Dam. This is simply unrealistic and unsupported by any scientific principle or facts. As addressed in other sections of this report, it is a fact that fine-grained sediment (including silt, clay, and colloids) has accumulated within the reservoir (Figure 6).

He then goes on to state that my opinion regarding the release of metals from sediments to porewater to overlying river or lake water lacks verifiable proof at this site. My conclusions are based on widely accepted biogeochemical principles, which Dr. Riese himself does not dispute (Riese 2011, p. 63). As described previously in my expert report, these are well documented processes that occur in river systems (Vlassopoulos 2010, p. 43-44).

In addition, the porewater chemical and lead isotope data demonstrate beyond doubt that Trail-sourced metals are released from sediment to porewater. However, a variety of additional geochemical analyses would have to be performed in order to accurately quantify the release of effluent metals from sediments. Such an evaluation by its very nature would be very complicated.

Dr. Riese obtained sequential chemical extraction (SCE) data on UCR sediment samples that provide important clues into the potential for metals release from sediment. SCE is an analytical process that sequentially leaches metals from a sediment sample to quantify the fraction of each metal associated with different matrix components, such as soluble, exchangeable, iron oxide-associated, and organic-associated. Dr. Riese's SCE data on sediment samples from across the UCR site indicate a significant portion of the metals content is associated with the iron-manganese oxide fraction. For example, 31 to 56 percent of zinc, 36 to 65 percent of lead, and 16 to 43 percent of cadmium are associated with the oxide fraction (Riese 2011, Table 7). During burial and diagenesis, iron and manganese oxides are susceptible to reductive dissolution. This leads to release of the associated trace metals as well. Therefore, an alarmingly substantial proportion of the total sediment content of toxic metals including zinc, lead, and cadmium in UCR sediments is potentially available for re-release subsequent to accumulation in Lake Roosevelt.

Although Dr. Riese's comments are focused on metals release to surface water, this is by no means the only, or even the most important, potential exposure route. For example, exposure to benthic organisms may be directly from porewater, while bottom-feeding fish may also be exposed through ingestion of metals-contaminated sediment and slag particles. Dissolution and metal release from these particles would be greatly enhanced under acidic gut conditions.

3 COMMENTS ON DR. RIESE'S EXPERT REPORT

3.1 Comments on Dr. Riese's Opinion 7

> *Trail metal-bearing liquid effluent, which is typically in dissolved, colloidal and/or particulate form, would have moved out of the UCR prior to installation of the Grand Coulee Dam in the 1940s, and thereafter will have continued to flow with the river to reaches downstream of Lake Roosevelt.*

In his opinion 7, Dr. Riese appears to be claiming that Trail effluent metals have not come to be located at the UCR site. For a number of reasons (explained in Section 2.2 of this rebuttal report), this assertion is not possible from either a scientific or factual standpoint.

Dissolved metals in surface water will partition to and from the surfaces of suspended particles as they are transported through the UCR site. Metals will partition to all size particles, but concentrations will tend to be higher on smaller particles because of their higher surface area to weight ratio relative to larger particles. This is a continuous and dynamic process, driven by the system trying to achieve a steady state between the rates of adsorption and desorption. As the suspended particles are transported through the UCR site, they will settle out of the water column, depending on particle size and flow velocity. The accumulating reservoir sediments provide a sink for many metals that preferentially partition to particle surfaces.

As noted earlier, Dr. Riese incorrectly uses the mean river flow velocity to estimate the minimum size of settling particles. The simple fact that silt, clay and colloid sized particles have accumulated in the reservoir behind the Grand Coulee Dam disproves his opinion (EPA 2006). The results of my factor analysis show that Teck's effluent metals have accumulated with fine-grained sediments at the UCR site (Figure 13).

Using cadmium as an example, which has a median solid-water partition coefficient (log Kd) of 4.7 (USEPA 2005), for suspended solids concentrations in the range of 1 to 25 mg/L, between 5 and 55 percent of cadmium in surface water should be associated with particulate matter. This is generally consistent with water quality data from the Columbia River at Waneta (Figure 1). This particulate load is potentially available to accumulate as fine sediment behind the dam. According to the revised estimates of Queneau (2011), on the order of 1,790 tons of cadmium were discharged to the UCR in Teck's liquid effluents between 1923 and 2005. Therefore, on the order of 70 to 800 tons of cadmium associated with liquid effluents could have been deposited with sediments behind the dam.

3.2 Comments on Dr. Riese's Opinion 8

> *Multivariate statistical analyses such as principal component analysis (PCA) can distinguish the compositional influence of slag, irrespective of source, from background sediment and mine and mill tailings in the UCR. However, PCA cannot uniquely identify Trail barren slag. Consequently, PCA is not a viable method for fingerprinting Trail as a specific source of metals to the UCR.*

Dr. Riese presents results of a PCA in support of this opinion. In performing this analysis, he added new data from samples of slag, tailings and sediment found in Hazen (2010a, b). Although his main conclusion—that PCA can identify a slag signature in the sediment data—agrees with my own opinion, he is incorrect in concluding that PCA cannot be used to identify Trail as the source of the slag in the UCR. Dr. Riese's PCA Component 1— the component that accounts for the greatest amount of variance in the UCR sediment data—corresponds to a slag signature, similar to my own findings. Trail is the only known source of slag to the UCR upstream of the Northport/Leroi smelter site; therefore PCA Component 1 signatures in UCR sediments upstream of Northport can only be attributed to Trail slag. The Component 1 signature continues to dominate the sediment chemistry downstream of Northport as well.

Dr. Riese's interpretation of his second principal component, however, is flawed. He identifies two types of slag signatures: "*1) Northport-Le Roi slag with negative Component 2 values (driven by lesser amounts of lead, cadmium, mercury, arsenic, and zinc) and 2) Northport-Le Roi and Trail barren slag with positive Component 2 values driven by greater amounts of chromium, barium, nickel, and cobalt*" (Riese 2011, p. 40). One of the limitations of PCA is that the second and higher component loading patterns can become difficult to interpret physically in terms of recognizable chemical compositions. FA can overcome this limitation and that is why I conducted an FA instead to support interpretations and opinions in my expert report. This limitation aside, for samples with high Component 1 scores (that is, slag signature), Component 2 does appear to distinguish between two types of slag. As Dr. Riese points out, Component 2 is characterized by depletion in arsenic, cadmium, lead, mercury, and zinc (see Figure 28).

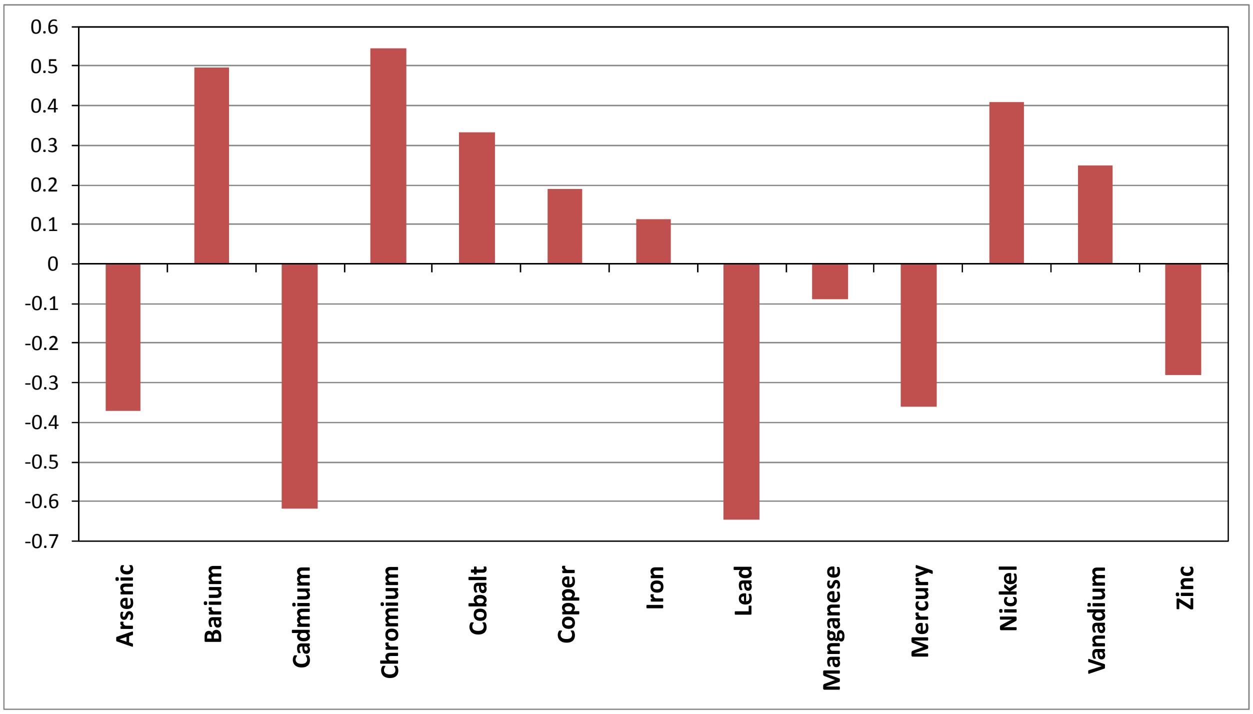


Figure 28
Metals Loadings on Riese's PCA Component 2

This pattern of relative depletion in "volatile" elements is characteristic of the chemical composition of fumed slag and may therefore be interpreted as an indicator of Trail fumed slag as opposed to Northport/LeRoi slags, which were not fumed. Therefore, bulk sediment samples with high scores for both Components 1 and 2 would indicate the presence of Trail slag, while samples with high scores for Component 1 and low scores for Component 2 would be indicative of the presence of Northport/Leroi slag. Inspection of Dr. Riese's Figures 22 and 23 indicates that samples having a strong unfumed slag signature that would be characteristic of Northport/LeRoi slag (low Component 2 scores) are restricted to the immediate vicinity of Northport, while samples with fumed slag signature occur upstream of and downstream of Northport. This apparent distribution of slag is also consistent with the estimated quantities of granulated slag produced by the two smelters (see Section 2.1.3).

3.3 Comments on Dr. Riese's Opinion 10

> *Substantial concentrations of heavy metals and related elements have historically been discharged and continue to be discharged to the UCR from sources other than Teck. Many of these metal-bearing solids have come to rest in the sediments of the UCR. Diffusion of metals from sediments, irrespective of original source, to the water column of the UCR is not significant relative to background above the site, and for many metals is either not measurable, or within the range of laboratory analytical error, or outside the range of valid statistical treatment.*

Dr. Riese attempts to calculate the flux of zinc from UCR sediments based on extrapolation of data from incubation experiments of Paulson and others (2006), and compare this to estimates of the zinc load at several locations in the UCR system. As has been pointed out by plaintiffs' expert Professor Joel Blum (Blum 2011), several serious shortcomings with this approach make the exercise of very little value. First, Dr. Riese's calculation of the sediment flux is based on only eight sediment incubation experiments and cannot possibly capture the variability within the 150-mile reach of the UCR. As a result, his flux estimate has such a high uncertainty that it is not possible to make meaningful comparisons with river load data. Second, Paulson himself states that the incubation experiments were not meant to be representative of UCR conditions (as also pointed out by Dr. Riese in Appendix I of his expert report [2011]). Third, there is a high degree of uncertainty in any metals release rates calculated from the incubation experiment data. Fourth, in applying the data to the UCR, Dr. Riese assumes that metals in porewater are transported only by diffusion and from the uppermost 5 cm of the sediment, and therefore this underestimates the true flux. Inclusion of advection, bioturbation, and other transport processes that occur in sediments would result in a higher calculated flux. As a result, he underestimates the actual rate of zinc release.

Dr. Riese then compares his calculated zinc flux from sediments to the estimated 2004 zinc load in surface water at various locations upstream and downstream of Trail, B.C. He does not mention, however, that the surface water data show an approximately half order of magnitude increase in zinc load between Birchbank, B.C., and the Columbia River at Waneta, which is largely attributable to Teck's effluent discharges.

In conducting this analysis, Dr. Riese is not disputing whether metals are released from contaminated sediments in the UCR, but attempts to quantify the magnitude of this release. However, he only does this for zinc and ignores the fact that other metals are also being released.

By focusing on what is ultimately released to surface water, he ignores subsurface sediment as part of the impacted environment. As proven at the UCR site, metals releases from sediment to porewater occur at depths greater than 5 cm, where benthic organisms are also present, and can be exposed to toxic metals (Blum 2011, Vlassopoulos 2010).

Given the size of the UCR site and its complexity, quantifying these releases with any degree of certainty would be a monumental undertaking that would require substantial additional studies.

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Mclean, D., 2011. Memorandum from Dave McLean of Northwest Hydraulic Consultants. Regarding Background Information on Hydraulic and Sedimentation Characteristics of Columbia River Upstream of Grand Coulee Dam. April 13, 2011.

McNulty, T.P., 2011. Expert Report of Terence P. McNulty on *Joseph A. Pakootas, et al. v Tech Cominco Metals, Ltd.* January 14, 2011.

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Ryan, J.N., Mohanty, S., and Bingham, M.E., 2010. Release of Major and Trace Elements from Smelter Slag Separated from Upper Columbia River Sediments. Report. Prepared for the State of Washington Attorney General Office and Colville Confederated Tribes.

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APPENDIX A
RESUME

DIMITRIOS VLASSOPOULOS, Ph.D.

Principal Scientist

PROFESSIONAL HISTORY

Anchor QEA, LLC, Principal Scientist, January 2011 to present

Anchor QEA, Senior Associate, July 2010 to December 2010

S.S. Papadopulos & Associates, Inc., Senior Staff Geochemist to Associate, 1992 to June 2010

University of Virginia, Doctoral Fellow, 1995 to 1998

California Institute of Technology Division of Geological and Planetary Sciences, Graduate Research Assistant, 1989 to 1992

Mineral Exploration Research Institute, Research Associate, 1988 to 1990

McGill University Department of Geological Sciences, Research Assistant, 1985 to 1988

Quebec Ministry of Energy and Natural Resources, Senior Field Geologist, 1985

Concordia University, Department of Geology, Research Assistant, 1984 to 1989

EDUCATION

University of Virginia, Ph.D., Environmental Sciences, 2000

California Institute of Technology, M.S., Geochemistry, 1993

McGill University, M.S., Geological Sciences, 1989

Concordia University, B.S., Geology (Honors), 1986

PROFESSIONAL ORGANIZATIONS

American Geophysical Union

Geochemical Society

Geological Society of America

International Association of Geochemistry

National Ground Water Association

EXPERIENCE SUMMARY

Dimitrios Vlassopoulos, Ph.D., has more than 20 years experience in environmental geochemistry with focus on evaluating natural and anthropogenic effects on soil, sediment, and water quality, isotope geochemistry, geochemical and reactive transport modeling, environmental forensics, and in situ monitoring and treatment technologies.

REPRESENTATIVE PROJECT EXPERIENCE

Columbia Basin Ground Water Management Area – Washington

Evaluation of regional and locally enhanced groundwater recharge to basalt aquifers through multivariate statistical analysis of regional hydrochemistry data, collection, and interpretation of ambient geochemical and isotope tracer data, and groundwater age dating.

Colorado Oil and Gas Conservation Commission – Garfield County, Colorado

Conducted geochemical evaluations of groundwater and recharge sources in the Piceance Basin as part of a baseline water quality study prior to start of coalbed methane production in a 30-square-mile study area.

Mamm Creek Hydrogeologic Evaluation – Garfield County, Colorado

Conducted a critical review of a Garfield County consultant report on groundwater quality impacts related to gas drilling and production activities on behalf of the Colorado Oil and Gag Conservation Commission (COGCC). Review evaluated the report's conclusions by analyzing an updated groundwater quality database for the study area provided by COGCC to assess whether dissolved methane and chloride concentrations showed statistically significant trends over time. Findings were presented before the COGCC.

Gilliam and Morrow Counties – Oregon

For a confidential client, evaluated source and origin of dissolved hydrocarbon gases in the Columbia River Basalt aquifers based on gas geochemistry, stable isotope signatures, and age dating methods.

Western Snake River Plain Malheur County – Oregon

For a confidential client, evaluated source and origin of dissolved hydrocarbon gases and their relationship to the groundwater system by using stable isotopes, noble gases, and age dating methods.

Port of Vancouver – Washington

Retained as expert witness in environmental remediation cost recovery litigation. Evaluated role of surface water on the groundwater flow system and groundwater contamination from multiple chlorinated solvent sources using compound-specific stable isotope signatures to allocate commingled groundwater plume.

Palermo Wellfield Superfund Site – Tumwater, Washington

Evaluated source of groundwater contamination by chlorinated solvents using compound-specific stable isotope analysis for cost recovery case. Testified in U.S. Federal Court.

Port of Seattle – Washington

Conducted geochemical evaluations of arsenic and mercury exceedances in groundwater, and demonstrated a natural background origin influenced by seasonal redox fluctuations in the vicinity of subsurface peat deposits.

Des Moines Creek Basin Commission – King County, Washington

Provided technical oversight and guidance to mitigate potential environmental impacts from arsenic-bearing soils at a stormwater detention facility construction site. Services included development of sampling and monitoring plans, evaluation of arsenic mobility data, development, and treatability testing of in situ process for soil amendment to mitigate arsenic mobility during construction and subsequent operation of the facility.

Barbee Mill – Renton, Washington

Provided technical guidance and remedial design assistance for arsenic-contaminated groundwater at a former industrial site undergoing restoration for residential redevelopment. Evaluation of site conditions and remedial alternatives including in situ redox manipulation and permeable reactive barriers to ensure restoration within the client's required timeframe.

Sherwin Williams – Emeryville, California

Retained to provide technical guidance and peer-review of remedial feasibility investigations at a former lead arsenate pesticide manufacturing facility.

Rhone-Poulenc, Inc. – California and New Jersey

Evaluated former industrial sites contaminated with arsenic. Activities included demonstration of natural attenuation of groundwater arsenic plume, in situ arsenic fixation of soil by chemical treatment, and design and pilot testing of an in situ groundwater treatment system using zero-valent iron.

Seattle-Tacoma International Airport – Washington

Conducted a vadose zone fate and transport modeling analysis to evaluate potential water quality impacts from fill materials used for construction of the third runway embankment, in support of permit applications and Pollution Control Hearings Board (PCHB) hearings.

Noveon – Kalama, Washington

Conducted an evaluation of natural and enhanced attenuation for diphenyl ether and other chemicals in groundwater at an operating chemical plant, and developed an in situ bioremediation scheme to shorten cleanup timeframe. Cleanup Action Plan was submitted and approved. Project is currently in design phase.

Oregon Steel Mill – Portland, Oregon

Conducted a geochemical evaluation of impacts from slag fill on shallow groundwater quality and demonstrated to the Oregon Department of Environmental Quality (ODEQ) that off-site migration of dissolved metals was being mitigated by natural attenuation.

Electric Power Research Institute

Developed a geochemical reaction database for modeling adsorption of oxyanion-forming elements (antimony, arsenic, boron, chromium, molybdenum, selenium, sulfate, vanadium) on iron hydroxides.

Columbia Basin Ground Water Management Area – Washington

Evaluated seasonal, geologic, and hydrologic controls on nitrate concentration trends in domestic wells completed in the suprabasalt sediment aquifers in the Pasco and Quincy Basins, demonstrating the importance of recharge from unlined canals in mitigating nitrate levels in some areas within the Columbia Basin Irrigation Project.

Confederated Tribes of the Colville Reservation – Washington

As part of a groundwater resource areas study, conducted a geochemical evaluation of sources and controls on arsenic concentrations in groundwater on the Colville Indian Reservation. Developed site selection guidelines to minimize potential risk of arsenic exceedances in future supply wells.

Higgins Farm Superfund Site – New Jersey

Retained to support remedial systems takeover and scope of work negotiations with the U.S. Environmental Protection Agency (USEPA) on behalf of an industrial client. Project involved compilation and scrubbing of a multiyear groundwater quality database including data collected by multiple entities, and development and application of an automated process for evaluating and reporting robust trend statistics for constituent concentrations in many wells over time. Results of this analysis provided the basis for optimizing long-term monitoring efforts at the site.

Mexicali Valley Aquifer

Evaluated geochemical relationships between ground water and surface water in a regional aquifer. The effect of surface water recharge on regional groundwater quality was investigated by examining geospatial distributions of groundwater chemistry, using multivariate statistical methods to identify sources of water and solutes, and geochemical modeling to understand chemical evolution in the regional flow system.

City of Portland Bureau of Water Works – Portland, Oregon

Evaluated occurrence, origin, and treatment options for manganese in the city’s well field.

Soda Lake – Casper, Wyoming

Developed a biogeochemical fate and transport model for selenium in an artificially maintained playa lake to predict future ecological impacts for use in decision analysis of management options.

Agrico – Pensacola, Florida

Provided technical support for litigation involving groundwater contamination from a former fertilizer production plant. Reconstructed historical fluoride concentrations in wastewater through geochemical modeling and used radioisotope data to evaluate sources of radium in groundwater.

Union Pacific Railroad – Eugene, Oregon

Evaluated potential for chlorinated Volatile Organic Compounds (CVOC) exposure through soil vapor intrusion pathway in homes adjacent to a rail yard and successfully demonstrated to ODEQ that CVOCs in ambient air, and not groundwater, were responsible for the majority of the contamination detected in crawl space air samples.

Orion Safety Products – California

Conducted a state-wide evaluation of potential for stormwater quality impacts from perchlorate present in safety flares used on California highways.

Wah Chang Superfund Site – Albany, Oregon

Evaluated effectiveness of natural attenuation in meeting record-of-decision-(ROD)-required cleanup time frame for chlorinated solvents in groundwater. The analysis was accepted by USEPA Region 10.

General Electric – Rome, Georgia

Developed and applied a laboratory soil-water partitioning procedure for polychlorinated biphenyl-(PCB)-contaminated soils to determine site-specific risk-based soil cleanup levels for groundwater protection.

Interstate Technology Regulatory Council

Developed and co-authored the regulatory guidance document *A Systematic Approach to In Situ Bioremediation, Including Nitrate, Carbon Tetrachloride and Perchlorate.* Served as instructor for training class based on this document.

City of Tigard – Oregon

Conducted water quality/compatibility evaluation for operating aquifer storage recovery (ASR) system.

Sunrise Water Authority – Oregon

Conducted water quality compatibility evaluation for ASR pilot study.

City of Salem – Oregon

Evaluated disinfection byproduct formation potential during storage phase in an operating ASR system.

Baker City – Oregon

Evaluated water quality compatibility for ASR project, using geochemical modeling to predict potential effects of subsurface mixing of source water with native groundwater

U.S. Environmental Protection Agency

Developed framework for characterizing and assessing risks of exposure and environmental effects risk associated with geologic carbon sequestration, in support of regulatory guidance development.

Pier 64, San Francisco – California

Evaluated the biodegradation of petroleum hydrocarbons and origin of methane in groundwater along the shore of San Francisco Bay. Study involved dissolved gas sampling and use of compound-specific isotope signatures to identify sources and degradation pathways and rates.

Nestlé Waters America

Conducted water quality evaluations related to development and production quality control of spring water bottling operations.

Town of Poolesville – Maryland

Investigated causes of elevated gross alpha radioactivity in several of the community's water supply wells, and developed a monitoring and treatment plan to ensure compliance with federal drinking water regulations.

Crompton – Elmira, Ontario

Retained as expert witness in liability allocation of a commingled groundwater ammonia plume. Allocated ammonia between two sources based on stable nitrogen isotope signatures. The case was settled to the satisfaction of the client.

U.S. Department of Justice

Served as expert for environmental torts claims related to groundwater contamination by chlorinated solvents at military installations and other government facilities.

Photographic Imaging Manufacturers Association

Conducted an independent review of the USEPA's human exposure risk assessment for silver-bearing wastes.

Multiple Sites and Clients

Evaluated nature, sources and reconstructed release histories at several sites affected by petroleum hydrocarbons using hydrocarbon fingerprinting techniques, stable isotopes, and simulation modeling.

Transco – Eastern United States

Provided technical support for development of remedial investigation plan for a large number of natural gas transport facilities across the eastern United States. Project involved the definition of risk-based action levels, based on a detailed compositional fate and transport model for petroleum hydrocarbon fractions.

ChemDyne Superfund Site

Evaluated contaminant mass removal by a pump-and-treat system operating for 15 years and estimated subsurface contaminant distribution for use in transport modeling. Prepared a report that was submitted and approved by USEPA.

Panhandle Eastern Pipeline Company

Developed a protocol for evaluating subsurface natural attenuation of PCBs and petroleum hydrocarbons at multiple sites along a major pipeline system. Developed a specialized field filtration technique for sampling PCBs in groundwater.

Berkeley Pit – Butte, Montana

Provided technical support in litigation over allocation of liability for cleanup costs between primary responsible parties (PRPs). Evaluated the impact of historical and ongoing operations on pit-lake water quality and cleanup costs based on field, laboratory, and geochemical modeling studies.

Atlantic Richfield Company – Clark Fork River, Montana

Provided technical support for natural resource damage litigation at historical mining and smelting operations. Evaluations included field sampling, characterization and modeling studies of metals attenuation in groundwater, estimation of background (pre-mining) groundwater quality in the Butte mining district, and identification and separation of mining-waste-related sulfate from natural geothermal sulfate loading to the Clark Fork River using stable isotope signatures.

U.S. National Park Service – Kentucky

Designed and implemented an extensive field investigation at a historic coal mining district to identify and characterize multiple mine drainage sources discharging to a designated Wild and Scenic River. The project included evaluation of pollutant loadings through long-term and storm-event monitoring, and prioritizing point sources for remediation. Isotope tracers were used to estimate seepage rates from coal spoil piles.

AWARDS AND HONORS

Research Grant: Sequestration and Immobilization of Metal and Metalloid Contaminants in Sediments. National Institute of Health (NIH) Grant No. R01 ES016201 (Superfund Research Program), 2007-2011 (co-PI)
Pegau Geology Award, University of Virginia, 1997
Dupont Fellowship, University of Virginia, 1996 to 1998
University of Virginia President’s Fellowship, 1995 to 1998
Reinhardt Research Fellowship, McGill University, 1986 to 1987

PUBLICATIONS

Book

O'Day, P., D. Vlassopoulos, X. Meng, and L.G. Benning, editors. 2005. Advances in Arsenic Research: Integration of Experimental and Observational Studies and Implications for Mitigation. ACS Symposium Series Vol. 915. Washington, DC: American Chemical Society/Oxford University Press. 450 p.

Articles

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Vlassopoulos, D., B. Bessinger, and P. O’Day. 2010. Aqueous solubility of As_2S_3 and thermodynamic stability of thioarsenites. In Water-Rock Interaction. Birkle, P., and I.S. Torres-Alvarado, editors. Boca Raton: CRC Press. 823-826.

Root, R.A, D. Vlassopoulos, N.A. Rivera, M.T. Rafferty, C. Andrews, and P.A. O’Day. 2009. Speciation and Natural Attenuation of Arsenic and Iron in a Tidally Influenced Shallow Aquifer. Geochimica et Cosmochimica Acta. 73: 5528-5553.

Serrano, S., P.A. O'Day, D. Vlassopoulos, M.T. Garcia-Gonzalez, and F. Garrido. 2009. A Surface Complexation and Ion Exchange Model of Pb and Cd Competitive Sorption on Natural Soils: Geochimica et Cosmochimica Acta. 73: 543-558.

Adams, D.J., B. Faris, and D. Vlassopoulos. 2006. Evaluating In Situ Bioremediation for Groundwater Cleanup: Chemical Engineering Progress. 102, no. 2: 20-28.

Vlassopoulos, D., N. Rivera, P.A. O'Day, M.T. Rafferty, and C.B. Andrews. 2005. Arsenic Removal by Zerovalent Iron: A Field Study of Rates, Mechanisms, and Long-Term Performance. In Advances in Arsenic Research: Integration of Experimental and Observational Studies and Implications for Mitigation. O'Day, P.A., D. Vlassopoulos, X. Meng, and L.G. Benning, editors. ACS Symposium Series Vol. 915. Washington, DC: American Chemical Society. 344-360.

O'Day, P.A., D. Vlassopoulos, R. Root, and N. Rivera. 2004. The Influence of Sulfur and Iron on Dissolved Arsenic Concentrations in the Shallow Subsurface Under Changing Redox Conditions: Proceedings of the National Academy of Sciences of the United States of America. 101: 13703-13708.

Faris, B., and D. Vlassopoulos. 2003. A Systematic Approach to In Situ Bioremediation in Groundwater: Remediation. 13: 27-52.

Raffensperger, J.P., and D. Vlassopoulos. 1999. The Potential for Free and Mixed Convection in Sedimentary Basins: Hydrogeology Journal. 7: 505-520.

Wood, S.A., C.D. Tait, D. Vlassopoulos, and D.R. Janecky. 1994. Solubility and Spectroscopic Studies of the Interaction of Palladium with Simple Carboxylic Acids and Fulvic Acid at Low Temperature: Geochimica et Cosmochimica Acta. 58: 625-637.

Vlassopoulos, D., G.R. Rossman, and S.E. Haggerty. 1993. Coupled Substitution of H and Minor Elements in Rutile and Implications of High OH Contents in Nb- and Cr-Rich Rutile from the Upper Mantle: American Mineralogist. 78: 1181-1191.

St-Seymour, K., and D. Vlassopoulos. 1992. The Importance of Magma Mixing at Nisyros Volcano, Greece, as Inferred from Incompatible Trace Element Systematics: Journal of Volcanology and Geothermal Research. 50: 273-299.

St-Seymour, K., D. Vlassopoulos, T.H. Pearce, and C. Rice. 1990. The Record of Magma Chamber Processes in Plagioclase Phenocrysts at Thera Volcano, Aegean Volcanic Arc, Greece: Contributions to Mineralogy and Petrology. 104: 73-84.

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Vlassopoulos, D., S.A. Wood, and A. Mucci. 1990. Gold Speciation in Natural Waters II. The Importance of Organic Complexing - Experiments with Some Simple Model Ligands: Geochimica et Cosmochimica Acta. 54: 1575-1586.

Wood, S.A., and D. Vlassopoulos. 1990. The Dispersion of Pt, Pd, and Au in Surficial Media about Two PGE-Cu-Ni Prospects in Quebec: Canadian Mineralogist. 28: 649-663.

Wood, S.A., D. Vlassopoulos, and A. Mucci. 1990. Effects of Concentrated Matrices on the Determination of Trace Levels of Palladium and Gold in Aqueous Samples Using Solvent Extraction-Zeeman Effect Graphite Furnace Atomic Absorption Spectrometry and Inductively Coupled Plasma-Mass Spectrometry: Analytica Chimica Acta. 229: 227-318.

St-Seymour, K., and D. Vlassopoulos. 1989. The Potential for Future Explosive Volcanism Associated with Dome Growth at Nisyros, Aegean Volcanic Arc, Greece: Journal of Volcanology and Geothermal Research. 37: 351-364.

Wood, S.A., and D. Vlassopoulos. 1989. Experimental Determination of the Hydrothermal Solubility and Speciation of Tungsten at 500º C and 1 kbar: Geochimica et Cosmochimica Acta. 53: 303-312.

St-Seymour, K., S. Kumarapeli, and D. Vlassopoulos. 1988. Petrotectonics of Achaean Yasinski Metabasalts, Superior Province, Canada: Implications for Genesis of Achaean Greenstone Belts: Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen. 177: 165-183.

Theses

Vlassopoulos, D. 2000. The Origins of Molecular Nitrogen in the Subsurface: Thermodynamic, Kinetic and Isotopic Constraints. PhD dissertation. University of Virginia.

Vlassopoulos, D. 1989. Some Experimental Studies Bearing on the Solubility and Speciation of Gold in Natural Waters. MS thesis. McGill University.

Selected Conference Presentations

Vlassopoulos, D., J. Goin, M. Zeliff, K. Lindsey, T. Tolan, and V. Johnson. 2009. Regional Groundwater Geochemistry of the Columbia River Basalt Aquifer System, South-Central Washington. GSA Annual Meeting, Portland, Oregon, October 18-21.

Vlassopoulos, D., M. Karanovic, V. Johnson, C.A. Gazis, T. Tolan, and K. Lindsey. 2009. Groundwater Recharge and Residence Times in the Columbia River Basalt Aquifer System, Washington. GSA Annual Meeting, Portland, Oregon, October 18-21.

Goin, J., D. Vlassopoulos, and M. Nielson. 2009. Factors Influencing Nitrate Distribution in Groundwater of the Columbia Basin Ground Water Management Area. GSA Annual Meeting, Portland, Oregon, October 18-21.

Serrano, S., P.A. O’Day, B. Bessinger, and D. Vlassopoulos. 2009. Immobilization of Mercury(II) by Ettringite-Type Phases: Modeling and Experiments. GSA Annual Meeting, Portland, Oregon, October 18-21.

Vlassopoulos, D., B. Bessinger, V. Illera and P. O'Day. 2009. Lithologic, Hydrologic, and Biogeochemical Influences on Spatio-Temporal Variability of As and Hg Concentrations in Groundwater. Geochimica et Cosmochimica Acta, vol 73, p. A1389. Goldschmidt 2009, Davos, Switzerland.

O'Day, P.A., S. Serrano, B. Bessinger, V. Illera and D. Vlassopoulos. 2009. Sediment Remediation of Metal and Metalloid Contaminants with Reactive Amendments. Geochimica et Cosmochimica Acta, vol 73, p. A959. Goldschmidt 2009, Davos, Switzerland.

Vlassopoulos, D., J. Goin, C. Gazis, and V. Johnson. 2009. Environmental Isotope and Age Tracer Studies in the Columbia Basin Ground Water Management Area. Presentation at the 7th Washington Hydrogeology Symposium, Tacoma, Washington, April 27-30.

Bessinger, B., and D. Vlassopoulos. 2009. A Geochemical Reactive Transport Model of Arsenic and Trihalomethanes in Aquifer Storage & Recovery Systems. Presentation at the 7th Washington Hydrogeology Symposium, Tacoma, Washington, April 27-30.

Goin, J.C., and D. Vlassopoulos. 2009. Distribution and Seasonal Trends of Nitrate in Unconfined Aquifers of the Pasco and Quincy Basins, Washington. Presentation at the 7th Annual Washington Hydrogeology Symposium, Tacoma, Washington, April 27-30.

Vlassopoulos, D. 2009. The Age of Groundwater in Columbia River Basalt Aquifers, East-Central Washington. Invited Presentation at the Oregon Ground Water Association Spring Technical Meeting, Silverton, Oregon, March 7.

Bessinger, B., D. Vlassopoulos, S. Serrano, and P. O'Day. 2009. Reactive Transport Modeling of Arsenic and Mercury in a Chemically Amended Sediment Cap. Presentation at the Fifth International Conference on Remediation of Contaminated Sediments. Jacksonville, Florida, February 2-5, 2009.

Vlassopoulos, D., S. Serrano, D.G. Kinniburgh, and D.L. Parkhurst. 2008. A CD-MUSIC Surface Complexation Database for Modeling Oxyanion Sorption on Iron Oxyhydroxides. Geochimica et Cosmochimica Acta, vol 72, p. A986. Goldschmidt 2008, Vancouver, BC.

Root, R. A., P.A. O'Day, J. Hering, K.M. Campbell, and D. Vlassopoulos (2008) Predicting arsenic behavior in high iron subsurface environments. Geochimica et Cosmochimica Acta, vol 72, p. A805. Goldschmidt 2008, Vancouver, BC.

Vlassopoulos, D. 2008. Application of Stable Isotopes to Site Characterization: CVOC Sources, Commingled Plumes, and Groundwater-Surface Water Interactions. Invited Presentation at the U.S. Environmental Protection Agency Ground water Forum, Portland Oregon, July 8-10.

Vlassopoulos, D., M. Conrad, M.J. Riley, T. Belunes, and P. Boyden. 2007. Environmental and Compound-Specific Stable Isotopes: Geochemical Forensic Tools with Application to Site Characterization in a Complex Hydrogeologic Situation. Oral presentation at the 6th Washington Hydrogeology Symposium, May 1-3, Tacoma, Washington.

Vlassopoulos, D., M.J. Riley, J. Strunk, and P. Agid. 2007. Biogeochemical Controls on Spatial and Temporal Variability of Arsenic Concentrations in Shallow Groundwater, Seattle-Tacoma International Airport. Oral presentation at the 6th Washington Hydrogeology Symposium, May 1-3, Tacoma, Washington.

Vlassopoulos, D., M. Conrad, and M.J. Riley. 2007. Source Identification and Allocation of Chlorinated Solvent Contamination Among Multiple Sources: Use and Limitations of Compound-Specific Isotope Analysis. Abstract and Oral Presentation at the Groundwater Resources Association Symposium on Applications of Isotope Tools to Groundwater Studies, March 28-29, Concord, California. Concord, CA. March 23-29.

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Illera, V., P.A. O'Day, S. Cho, N.A. Rivera, R. Root, M. Rafferty, and D. Vlassopoulos. 2006. Immobilization of Arsenic in a Contaminated Soil Using Ferrous Sulfate and Type V Portland Cement. Poster presentation at the 232nd American Chemical Society National Meeting, September 10-14, San Francisco, California. San Francisco, California.

Vlassopoulos, D., D. Sorel, T. Luong, M. Karanovic, M. Tonkin, K. Chiang, M. Rafferty, and M. Riley. 2006. Assessment of Potential Perchlorate Impacts from Use of Safety Flares Along California Roadways. Presented at the Groundwater Resources Association (GRA) 16th Symposium in the Contaminants in Groundwater Series--Perchlorate 2006: Progress Toward Understanding and Cleanup, January 26, 2006, Santa Clara, California.

Illera, V., P.A. O'Day, N. Rivera, R. Root, M.T. Rafferty, and D. Vlassopoulos. 2005. Soil Remediation of an Arsenic-Contaminated Site With Ferrous Sulfate and Type V Portland Cement: EOS Transactions American Geophysical Union. 86, no. 52, Fall Meeting Supplement: Abstract B31A-0954.

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