WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

# Cadmium, Lead, and Zinc in the Spokane River

Recommendations for Total Maximum Daily Loads
and Waste Load Allocations

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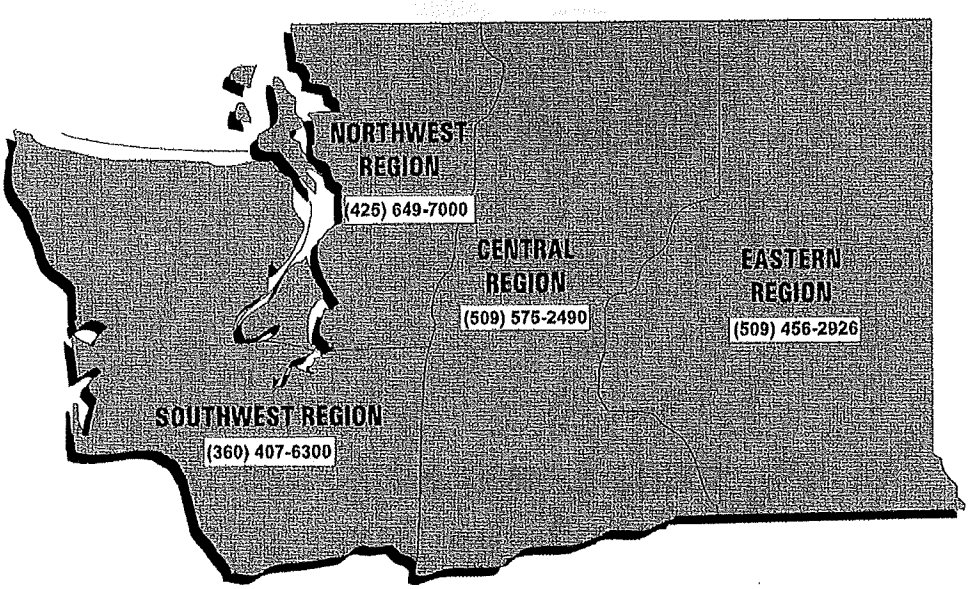


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# Cadmium, Lead, and Zinc in the Spokane River

## Recommendations for Total Maximum Daily Loads and Waste Load Allocations

by
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# Abstract

The Spokane River regularly violates water quality standards for zinc. Standards for lead and cadmium are also exceeded frequently, especially at higher flows. A procedure for determining Waste Load Allocations (WLAs) for all NPDES point source discharges to the Spokane River was developed based on meeting aquatic life criteria in the effluent. Permit limits for NPDES dischargers will be developed in the future for each individual discharger under Ecology's current schedule for permit cycles. Effluent limits for cadmium, lead, and zinc will be determined by comparing existing concentrations of metals in effluent, where adequate data exist, with the water quality criteria associated with the effluent hardness. Whichever results in the lower permit limits will be chosen.

This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system that is already exceeding the criteria. It is also an alternative to developing very stringent water quality-based effluent limits that are severely restricted due to excessive upstream and out-of-state metal sources. This approach is consistent with the intent of the anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...(AKART)".

Waste Load Allocations are established as a maximum discharge concentration (micrograms per liter) rather than a discharge loading (pounds per day). The federal Clean Water Act allows for the use of allocations in mass per time or other appropriate measure. In this case, a concentration measure is appropriate, because the relationship between the effluent-based criterion and receiving water quality holds for all effluent and river flow rates.

The Spokane River at the state line is the upstream boundary for the present Total Maximum Daily Load (TMDL) in Washington. The proposed TMDL and analysis to address point source discharges and other sources of metals in the Spokane River requires that the Spokane River will meet Washington state's water quality standards, at a point where the river enters Washington State, within a reasonable period of time. The ultimate success and appropriateness of this TMDL/WLA depends solely on whether the Idaho Department of Environmental Quality or EPA develops and implements an adequate TMDL/WLA and management plan that will result in meeting Washington's water quality standards at the upstream end of the Spokane River.

# Introduction

## Objective

The Spokane River regularly has elevated levels of zinc, and frequently has elevated levels of lead and cadmium. The river does not meet water quality standards for these metals. The Washington State Department of Ecology, Idaho's Division of Environmental Quality (IDEQ), and the U. S. Environmental Protection Agency (EPA) are evaluating regulatory actions to address this issue. The various entities that are permitted under NPDES to discharge to the Spokane River have also been active in proposing approaches to regulate water quality in the Spokane River.

The objective of this report is to propose an approach for regulating point source dischargers in Washington under a Total Maximum Daily Load (TMDL), instead of developing unreasonably stringent water quality-based effluent limits on a case-by-case basis when upstream concentrations of metals already exceed criteria. At the same time, Idaho and EPA are developing a TMDL to control pollution sources in Idaho. One of the necessary objectives of the Idaho and EPA TMDLs is to meet Washington's water quality criteria in the Spokane River. This TMDL by Ecology addresses NPDES discharges in Washington, and uses an approach that will preferably be similar to EPA's proposed regulation of NPDES dischargers in Idaho.

## Spokane River Dischargers and Hydrology

The source of the Spokane River is Lake Coeur d'Alene located in Idaho (Figure 1). The river flows in a westerly direction from Lake Coeur d'Alene, across the state line, to the city of Spokane. From Spokane, the river flows in a northwesterly direction to its confluence with the Columbia River. In Idaho, the following wastewater treatment plants (in order proceeding downstream from the river source) are permitted to discharge to the river:

- City of Coeur d'Alene Advanced Wastewater Treatment Plant (AWTP)
- Hayden Area Regional Sewer Board (HARSB) Publicly-owned Treatment Works (POTW)
- City of Post Falls POTW (also serves the City of Rathdrum)

Continuing downstream, the dischargers in Washington are as follows:

- Liberty Lake POTW
- Kaiser Aluminum Industrial Wastewater Treatment Plant (IWTP)
- Inland Empire Paper Company IWTP
- City of Spokane AWTP

The current and projected effluent design flows from the NPDES dischargers are presented in Table 1 (SRDG, 1997).

Substantial inflows of groundwater enter the river beginning downstream from the Liberty Lake outfall. The groundwater inflows significantly increase the river flow rate, especially when surface water flows are low. Table 2 presents the equations used to estimate the aquifer inflow and outflow to the river based on the compilation of data used for the phosphorus attenuation model of the basin (Patmont *et al.*, 1985; Patmont *et al.*, 1987).

Aquifer inflows and outflows were assumed to be correlated to river flows up to a flow of 4,000 cfs from Lake Coeur d'Alene based on the evaluations by Patmont *et al.* The total net aquifer inflows range between about 500 to 800 cfs depending on river flow. For comparison, the combined effluent flow from all current NPDES dischargers is about 128 cfs. The *lowest* 7-day average flow with a 10-year recurrence for the Spokane River at the upstream end near Post Falls (river mile 100.7) is approximately 187 cfs; the *highest* 7-day average flow with a 10-year recurrence is approximately 36,000 cfs; and the annual average flow is approximately 6,300 cfs.

A recent groundwater modeling study by CH2M-Hill suggests that aquifer exchange may be less than previous estimates (CH2M-Hill, 1998). However, the results of the CH2M-Hill study were not used for this study because their reach definitions were not as detailed, and their findings are still under review. Also, if future review of the aquifer exchange rates results in confirmation of CH2M-Hill estimates, then the recommended effluent limits to meet criteria for cadmium, lead, and zinc will not change because the concentrations of metals in the aquifer are much lower than water quality standards, and therefore the recommended effluent limits do not depend on the aquifer exchange rates. However, for future evaluations of limits for other constituents that are a function of available dilution (*e.g.* ammonia), it may be preferable to use the revised aquifer exchange rates by CH2M-Hill.

## TMDL Boundaries

Cadmium, lead, and zinc concentrations in the Spokane River at the state line often exceed water quality standards. The Bunker Hill Superfund site is the largest source to discharge heavy metals in the Idaho sub-basin (IDEQ, 1998). More than a century of deep-shaft mining activities for sulfide-based heavy metals has elevated levels of cadmium, lead, arsenic, and zinc in the South Fork Coeur d'Alene River, which discharges into Lake Coeur d'Alene. Although measures have been taken to dramatically reduce loading to the South Fork, existing concentrations of some metals are still above those in most surface waters of the nation.

IDEQ is currently developing a TMDL for metals and is initiating projects to further reduce metals loads to the South Fork. That TMDL also must have the objective of eventually meeting Washington's water quality standards in the Spokane River. The EPA is working closely with the IDEQ to ensure that progress in reducing loads of metals continues in Idaho.

Ecology is also monitoring the trend in water quality at the state line to detect expected decreases in metals concentrations.

The outlet of Lake Coeur d'Alene is a logical upstream boundary for a separate TMDL analysis to address point source discharges and other sources of metals in the Spokane River, provided that IDEQ develops an adequate TMDL and management plan to meet Washington's water quality standards at the border. However, delays in TMDL development in Idaho have caused Washington State to proceed with a TMDL/WLA which begins with the upstream reach of the Spokane River beginning at the Idaho-Washington state line, and the downstream boundary located below the outfall for the City of Spokane's AWTP. Spokane is the most downstream NPDES discharger, and is therefore considered to be the most downstream potential contributor of significant concentrations of cadmium, lead, and zinc.

# Data Analysis and Modeling

## Water Quality Criteria for Cadmium, Lead, and Zinc

Water quality criteria to protect aquatic life (established in WAC 173-201A-040) apply to the dissolved fraction for cadmium, lead, and zinc and are calculated with the following equations for chronic (4-day average concentration in micrograms per liter not to be exceeded more than once every three years) and acute (one-hour average concentration in micrograms per liter not to be exceeded more than once every three years based on hardness in milligrams per liter as $CaCO_3$):

*Dissolved Cadmium*

Chronic ≤ (1.101672-((LN(hardness))*(0.041838)))*EXP(0.7852*(LN(hardness))-3.49)
Acute ≤ (1.136672-((LN(hardness))*(0.041838)))*EXP(1.128*(LN(hardness))-3.828)

*Dissolved Lead*

Chronic ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-4.705)
Acute ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-1.46)

*Dissolved Zinc*

Chronic ≤ 0.986*EXP(0.8473*(LN(hardness))+0.7614)
Acute ≤ 0.978*EXP 0.8473*(LN(hardness))+0.8604)

Figures 2 and 3 depict two hypothetical waters in relation to the water quality criterion curve for cadmium, lead and zinc. If one were to mix the two waters, the resulting mixed concentration of metals and hardness would always fall on a straight line between the two points. Assuming Point A is the Spokane River, meeting the water quality criteria as it exits Lake Coeur d'Alene, a discharge (Point B) at or below the effluent-based criterion would result in a mixture that falls below the criterion curve. Because of the concave shape (bending downward) of the cadmium and zinc criteria curves, any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water (A) to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards.

However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3 and Appendix A). This approach is recommended to assure that limits are protective of state water quality standards.

If other sources of water with greater hardness than the river are also added to the mixture, for example groundwater or tributaries, then the resulting mixture including these multiple sources would also meet the criteria provided that no single source exceeds the criteria for cadmium or zinc, or exceeds the tangent line for lead. If the effluent concentrations of metals are below aquatic life criteria, then the metal toxicity in the river below the outfall is reduced by the hardness affect, which allows the river to either be closer to meeting the water quality standard or creates a small safety buffer.

## Effluent Data

Typical effluent data are presented in Appendix B. The Spokane River Dischargers Group (SRDG) is currently collecting samples to characterize effluent quality. Appendix B presents preliminary results from the November-December 1997 sampling, as well as sampling by the City of Spokane AWTP from July 1996 through April 1998. All samples of effluent from all dischargers have been found to meet the chronic aquatic life criteria for cadmium, lead, and zinc at the effluent hardness. Effluent lead has also been consistently below the tangent equation for lead shown in Figure 3.

## River Modeling

A mass-balance model of the Spokane River was developed to evaluate the effect of different effluent loading on metals and hardness. The model includes a flow balance that accounts for inflow of water from the outlet of Lake Coeur d'Alene, inflow from NPDES dischargers, and inflow/outflow from the aquifer and Hangman Creek. The model divides the river into reaches

as shown in Table 2. For each reach, the flow balance is calculated from the following equation:

$$Q_{down} = Q_{up} + Q_{npdes} + Q_{aquifer}$$

where:

$Q_{down}$ = flow at the downstream end of the reach (cfs)
$Q_{up}$ = flow at the upstream end of the reach (cfs)
$Q_{npdes}$ = flow from NPDES dischargers (Table 1) (cfs)
$Q_{aquifer}$ = flow from or to the aquifer or tributary (Table 2) (cfs)

The mass balance for hardness was calculated from the following equation:

$$H_{down} = [\ Q_{up} H_{up} + Q_{npdes} H_{npdes} + Q_{aquifer} H_{aquifer}\ ] / Q_{down}$$

where:

$H_{down}$ = hardness (mg/L as $CaCO_3$) at the downstream end of the reach
$H_{up}$ = hardness at the upstream end (assumed to be $H_{down}$ from previous reach)
$H_{npdes}$ = hardness of NPDES effluent
$H_{aquifer}$ = hardness of aquifer (if aquifer inflow) or $H_{up}$ (if aquifer outflow)

For metals, the mass balance was as follows:

$$M_{dis,down} = F_{down}[\ Q_{up} M_{trec,up} + Q_{npdes} M_{trec,npdes} + Q_{aquifer} M_{trec,aquifer}\ ] / Q_{down}$$

where:

$M_{dis,down}$ = dissolved metals (ug/L) at the downstream end of the reach
$F_{down}$ = fraction of dissolved/total recoverable metals at downstream end of reach
$M_{trec,up}$ = total recoverable metals at upstream end of reach (=$M_{dis,down}$ / $F_{down}$ from previous reach)
$M_{trec,npdes}$ = total recoverable metals of NPDES effluent
$M_{trec,aquifer}$ = total recoverable metals of aquifer (if aquifer inflow) or $M_{dis,up}$ (if aquifer outflow)

The fraction of dissolved/total recoverable metals was estimated to equal the conversion factor used to convert the total recoverable criteria to the dissolved criteria (EPA, 1996). It was not considered necessary to use site-specific ratios of dissolved/total recoverable metals because the conversion factors generally represent a worse-case scenario of higher fractions of dissolved metals, and the use of site-specific ratios was not expected to result in different conclusions provided that all sources meet water quality criteria at their respective hardness. Aquifer inflow of total recoverable metals to the river was assumed to equal the dissolved metals concentration estimated during model calibration.

## Model Calibration

Calibration of the model to actual conditions in the river involved estimation of aquifer hardness and metals to match observed concentrations in the river. All other inputs in the flow and mass balance equations were directly estimated from available data:

- The effluent flow rates were assumed to be the current flows presented in Table 1.

- Aquifer inflow/outflow rates were estimated as presented in Table 2.

- Outflow from Lake Coeur d'Alene was assumed to be various values between the normal range of 300 to 20,000 cfs.

- Effluent hardness was assumed to be approximately 145 mg/L as $CaCO_3$ based on the 10$^{th}$ percentile hardness for the Spokane AWTP (CH2M-Hill, 1997). Effluent hardness from Kaiser IWTP was assumed to be a lower value of 120 mg/L as $CaCO_3$ based on the mixture of river and groundwater used for the production process.

- Effluent total recoverable cadmium, lead, and zinc were assumed to be approximate maximum values reported by the SRDG (0.3 ug/L cadmium, 2.5 ug/L lead, and 100 ug/L zinc).

- The ratio of dissolved/total recoverable metals was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the river water. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.

- The hardness for the outflow from Lake Coeur d'Alene was assumed to be 20 mg/L as $CaCO_3$. This represents the seasonal 10$^{th}$ percentiles for the low flow (July-February) and high flow (March-June) seasons (Pelletier, 1994), and also the 5$^{th}$ percentile of hardness from all seasons. Hardness was not found to be correlated with flow at the upstream end of the Spokane River (Appendix C).

- The hardness at river mile 85.3 and 66 was assumed to equal the 10% prediction limits from the regression equations with flow presented in Appendix C.

- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C for river mile 96-100.7.

- The dissolved cadmium, lead, and zinc at river mile 63.5-69.9 was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C.

Relationships between hardness, metals, and flow are known at various locations in the Spokane River based on long-term ambient monitoring data (Appendix C). The model was calibrated for hardness by starting with the known upstream hardness and trying various values for groundwater hardness until the mass balance model predicted the observed downstream hardness. After the hardness was calibrated, the same approach was used to estimate the dissolved cadmium, lead, and zinc of the aquifer/tributary inflow. Appendix C presents the results of model calibration of aquifer hardness and metals.

## Model Application to Various Scenarios of Effluent and River Flows

The calibrated mass balance model was next used to estimate concentrations of metals in the river for a variety of river flows and effluent flows (Appendix D). The model was used to evaluate whether water quality standards would be violated in the river if the effluent meets end-of-pipe limits based on effluent hardness. The following assumptions were made:

- The hardness for the outflow from Lake Coeur d'Alene was assumed to equal 20 mg/L as $CaCO_3$.

- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene were assumed to equal the chronic criteria for protection of aquatic life at the hardness of the river.

- The dissolved cadmium and zinc in the effluent from NPDES dischargers were assumed to equal the chronic criteria for protection of aquatic life for the hardness of the effluent (Figure 2).

- The ratio of dissolved/total recoverable cadmium and zinc was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the effluent or river water. The ratio of dissolved/total recoverable metals in the effluent was used to test whether criteria were met in the effluent. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.

- For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translators to a total recoverable lead limit. Appendix E presents a spreadsheet illustrating the problem. Two hypothetical waters are mixed, and total recoverable lead is tracked. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions. Therefore, the total recoverable lead in the effluent from NPDES dischargers was assumed to equal the value predicted from the tangent line for the chronic criteria for total recoverable lead shown in Figure 3. Appendix E presents a comparison of alternative methods for estimating the WLA for total recoverable lead.

- Aquifer inflow/outflow rates were estimated as presented in Table 2.

- Effluent hardness and aquifer hardness, dissolved cadmium, lead, and zinc were as estimated during calibration.

Various combinations of effluent and river flows were evaluated as follows:

- Current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs.

- 20-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for zinc were expected to be representative of cadmium and lead also).

- 50-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for Zinc were expected to be representative of cadmium and lead also).

- 20-times current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs. This scenario was chosen to show the potential effect of extremely high flow rates from NPDES dischargers.

The results of the model runs (Appendix D) show that the water quality standards for cadmium and zinc would not be exceeded in the river if the effluent meets end-of-pipe limits based on effluent hardness. The water quality criteria for lead would not be violated if the maximum concentration of total recoverable lead in the effluent does not exceed the value predicted from the tangent line for the equation for the chronic criteria for total recoverable lead shown in Figure 3. The relationship between effluent-based criteria and receiving water quality holds for all river and effluent flow rates.

# Proposed TMDL Approach

Permit limits for all point source discharges to the Spokane River will be established by comparing potential limits based on meeting aquatic life criteria at effluent hardness with AKART limits based on maintaining existing concentrations of metals in effluent, where adequate data exist. Whichever method results in lower limits will be selected for the permit. AKART based limits would be reevaluated at each permit re-issuance. These limits may change over time, but could never exceed the aquatic life criteria based limits. This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system already exceeding the criteria due to pollutant loading from an upstream state. This is consistent with the intent of anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...".

The use of effluent hardness in the criteria equations to determine the potential limits will be termed the "effluent-based criterion" approach. There are several ways to illustrate the effect of effluent hardness on river metals conditions. In simple terms, applying the effluent-based criterion is analogous to treating the effluent discharge as if it were a tributary that has higher hardness levels than the river. The tributary would be allowed to achieve less stringent (*i.e.*, higher) metals criteria by virtue of its elevated hardness levels. Similarly, the criteria applied to protect the mainstem would be more stringent due to its lower hardness levels. The focus of concern then becomes the point of mixing between the tributary and river.

The analogy to a tributary can be extended to selection of a load allocation (LA) for a tributary or a WLA for a point source. The LA for a tributary to a water quality-limited river would be the existing concentration in the tributary if it is lower than the criteria at the hardness of the tributary. Similarly, the permit limits for the NPDES dischargers will be either the potential limits based on meeting criteria at effluent hardness, or the potential limits based on maintaining existing concentrations (performance-based), whichever is more restrictive.

Waste load allocations (WLAs) are established as a maximum discharge concentration (micrograms per liter, or ug/L) rather than a discharge loading (pounds per day). TMDL regulations allow for the use of allocations in mass per time or "other appropriate measure" (40 CFR 130.2). In this case, a concentration measure is appropriate because the relationship between the effluent-based criterion and receiving water quality holds for all effluent flow rates. The use of effluent flow to establish a loading limit would not only be unnecessary, but also could be misconstrued to represent a restriction on effluent flow. Also, a loading limit could require unnecessary TMDL and permit modifications to change loading limits as communities grow and flows increase.

## Waste Load Allocations (based on meeting the aquatic life criteria at effluent hardness)

For cadmium and zinc, potential limits based on aquatic life criteria for all point source discharges to the Spokane River are estimated from the water quality criteria associated with the effluent hardness. For lead, limits based on aquatic life criteria are estimated from the point on a line tangent to the lead criterion curve (intersecting the curve at the river hardness value) associated with the effluent hardness. Figure 4 shows the recommended equations for each metal.

The chronic aquatic life criteria are expressed as 4-day-average dissolved metal concentrations. The 5th percentile value of the effluent hardness for each facility should be used by permit writers to establish aquatic life criteria at effluent hardness for derivation of potential limits. Permit writers will also translate the dissolved criteria into total recoverable metal limitations pursuant to the NPDES regulations and Ecology's Permit Writer's Manual.

The hardness of the wastewater effluent is significantly higher than the hardness of the Spokane River. The metals criteria for protection of aquatic life are based on hardness, because the toxicity of metals to aquatic life decreases as hardness increases. Thus, as the Spokane River flows downstream, its loading capacity (its total maximum daily load) for metals increases due to inflows of higher hardness water (mainly groundwater and to a lesser extent effluent discharges). While the loading capacity changes are relatively minor on the Idaho stretch of the river, changes in river hardness and flow due to groundwater inflows and effluent discharges result in significant loading capacity increases in Washington.

Because of the concave shape (bending downward) of the cadmium and zinc criteria curves (Figure 2), any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards. However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3).

The criterion curve for lead also affects the options available for translating a dissolved lead WLA into a total recoverable lead WLA for NPDES permitting. This issue is discussed later in this document in the "Example Calculations" section.

## Potential Limits (based on performance)

Washington State law (RCW 90.48) requires that dischargers use all known available and reasonable methods to prevent and control the pollution of the waters of the state (AKART). A performance-based assessment of existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). These performance-based limits would be reevaluated during each permit re-issuance.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals. The sampling and analysis methods should be conducted under a Quality Assurance/Quality Control Project Plan (QAPP) that describes the methods to be used. EPA's 1600-series methods (EPA, 1995) are recommended for sampling trace metal concentrations that are less than detection limits for the usual 40 CFR Part 136 methods, unless the QAPP demonstrates that alternative methods are sufficient the measure the expected concentrations.

## Implementation of WLAs in NPDES Permits

The WLAs will be implemented as permit limits in the NPDES permits for each facility. Using statistical permitting procedures, Ecology will determine whichever potential limits are more restrictive based on comparison of:

- Potential limits based on meeting aquatic life criteria at effluent hardness, or
- Potential limits based on maintaining existing concentrations of metals in effluent (AKART), where adequate data exist.

Whichever method results in lower limits will be selected for the permit limit.

## Example Calculations: WLAs for the Spokane AWTP

The following calculations are provided as an example of the waste load allocation method for each facility. The example calculation is performed for the City of Spokane Advanced Wastewater Treatment Plant (SAWTP). During permit development, similar calculations would be performed for each facility, based on the effluent hardness and metals data available to the permit writers.

A Microsoft Excel spreadsheet was developed to perform the calculations (Appendix F). The equations used in the spreadsheet are presented in Appendix G. Appendices F and G should be consulted to follow the calculations presented in this example.

The equations that were used in the spreadsheet to calculate permit limits were taken from the EPA Technical Support Document for Water Quality-based Toxics Control (EPA, 1991), and have been widely used in the Ecology NPDES program (Ecology, 1998; *e.g.*, Ecology's PWSPREAD and TSDCALC7 spreadsheets).

### WLAs (based on meeting the aquatic life criteria at effluent hardness)

1. *Estimated 5th percentile hardness*

   SAWTP has collected 234 samples of effluent hardness between 6/25/96 and 2/18/98. The 5th percentile hardness for this sample set is estimated to be 138 mg/L.

2. *Chronic aquatic life criteria*

   The following calculations were performed to establish the chronic aquatic life criteria (ALC) for cadmium, lead, and zinc for the SAWTP facility.

- Chronic ALC for dissolved cadmium = (1.101672-[ln(hardness)(.041838)]) * ($e^{(.7852[\ln(hardness)]-.3.49)}$) = 1.31 ug/L

- Chronic ALC for dissolved lead = 0.02378(hardness) - 0.05505 = 3.23 ug/L dissolved Lead

- Chronic ALC for dissolved zinc = $.986e^{(.8473[\ln(hardness)]+.7614)}$ = 137 ug/L

3. *Ratio of total recoverable/dissolved metals, and*

4. *Chronic aquatic life criteria for total recoverable metals*

For cadmium and zinc, default conversion factors in the federal criteria can be used to translate dissolved criteria to total recoverable metals. The conversion factors are 1/(1.101672-[ln(hardness)*(.041838)]) for cadmium, and 1/.986 for zinc. For the SAWTP facility, with a hardness of 138 mg/L $CaCO_3$, the default translators are 1.12 for cadmium and 1.01 for zinc.

Development of effluent-specific translators is also allowable, using parallel total recoverable and dissolved effluent samples to derive a conservative ratio of total recoverable-to-dissolved metals. Translators based on ratios in the river should be used if they are more restrictive than ratios for effluent.
The chronic aquatic life criteria, in terms of total recoverable cadmium and zinc, for the SAWTP example are as follows:

- Chronic ALC for total recoverable cadmium = 1.46 ug/L
- Chronic ALC for total recoverable zinc = 139 ug/L

For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translator to a total recoverable lead limit. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions (Appendix E).

As with cadmium and zinc, an effluent-specific translator is allowable. Development of this translator will require characterization of total recoverable and dissolved concentrations at a number of points between 0 and 100% effluent (diluted with ambient water, sampled at the same time) to ensure that the translator is protective of the dissolved criterion at all points of mixing.

Another option for developing total recoverable lead limits is to convert the dissolved criterion curve to the associated total recoverable criterion curve using the default conversion factor (see Figure 3). Then a tangent line to this curve at the river hardness value is used as the chronic aquatic life criterion for total recoverable lead, rather than using the dissolved criterion tangent (Figure 4) and an effluent-specific translator.

Using this approach and Figure 3 in the SAWTP example, the chronic aquatic life criterion for total recoverable Lead is:

- Chronic ALC for total recoverable lead = 3.49 ug/L total recoverable lead

5. *Number of samples (n2) required per month for compliance monitoring*

For the SAWTP example, 2 samples per month were assumed as a requirement for compliance monitoring. This number could be changed to any reasonable value between once per month and daily sampling.

6. *Coefficient of variation for effluent metals*

Effluent samples for metals were collected by SAWTP between 7/12/96 and 4/2/98. The coefficients of variation for cadmium, lead, and zinc were estimated from the 31 samples collected:

- CV for total recoverable cadmium = 0.431
- CV for total recoverable lead = 0.335
- CV for total recoverable zinc = 0.283

7. *Calculate maximum daily and average monthly permit limits from the aquatic life criteria*

The statistical method for calculating permit limits from the aquatic life criteria is presented in the EPA's Technical Support Document for Water Quality-based Toxics Control (EPA, 1991). A spreadsheet was developed to simplify the calculation procedure (Appendix F). Equations for the spreadsheet are presented in Appendix G.

The first step is to back-calculate a long-term average (LTA) concentration of metals that corresponds to the chronic aquatic life criteria (ALC). The LTAs for cadmium, lead, and zinc are as follows:

- LTA for total recoverable cadmium = 0.91 ug/L
- LTA for total recoverable lead = 2.4 ug/L
- LTA for total recoverable zinc = 101 ug/L

The next step is to calculate the maximum daily limit (MDL). The maximum daily limits (MDLs) for cadmium, lead, and zinc are as follows:

- MDL for total recoverable cadmium = 2.2 ug/L
- MDL for total recoverable lead = 4.9 ug/L
- MDL for total recoverable zinc = 186 ug/L

The last step is to calculate the average monthly limits (AML). The average monthly limits (AMLs) for cadmium, lead, and zinc are as follows:

- AML for total recoverable cadmium = 1.4 ug/L
- AML for total recoverable lead = 3.4 ug/L
- AML for total recoverable zinc = 138 ug/L

## Potential Limits Based on Performance

A performance-based assessment of the existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). This evaluation would occur during each permit re-issuance cycle and would be documented in the Fact Sheet. The Fact Sheet is the basis document for each permit. While these performance-based limits may change over time they could never exceed the aquatic life criteria based limits.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals.

## Waste Load Allocations (the most restrictive of limits based on aquatic life criteria or performance)

The last step is to assign permit limits in terms of maximum daily and average monthly limits for the NPDES permits. The potential limits based on steps I and II above will be compared, and the most restrictive values will be chosen. This would be documented in the Fact Sheet during each permit re-issuance cycle.

# References


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# Figures

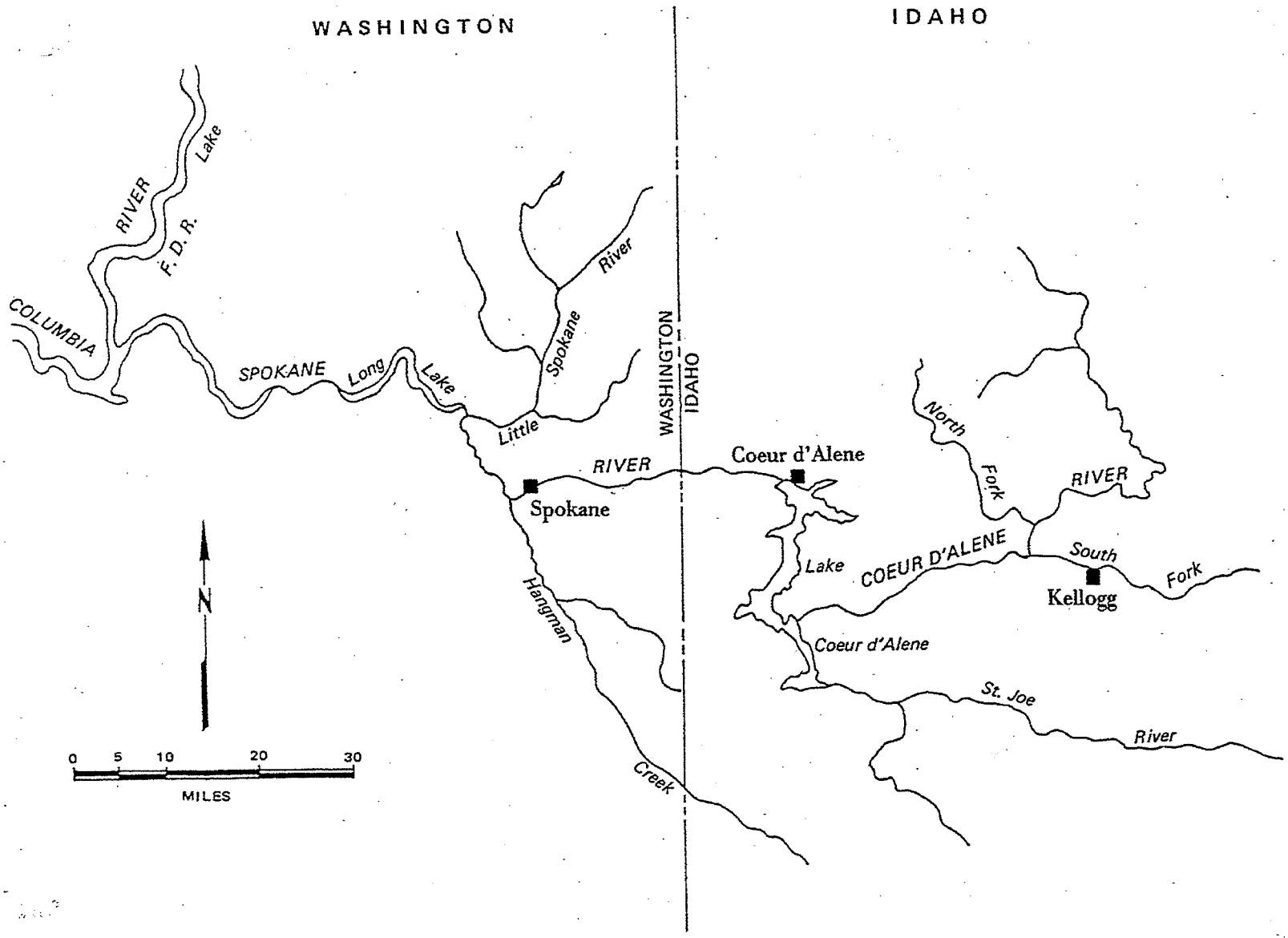



Figure 1. SPOKANE RIVER DRAINAGE SYSTEM

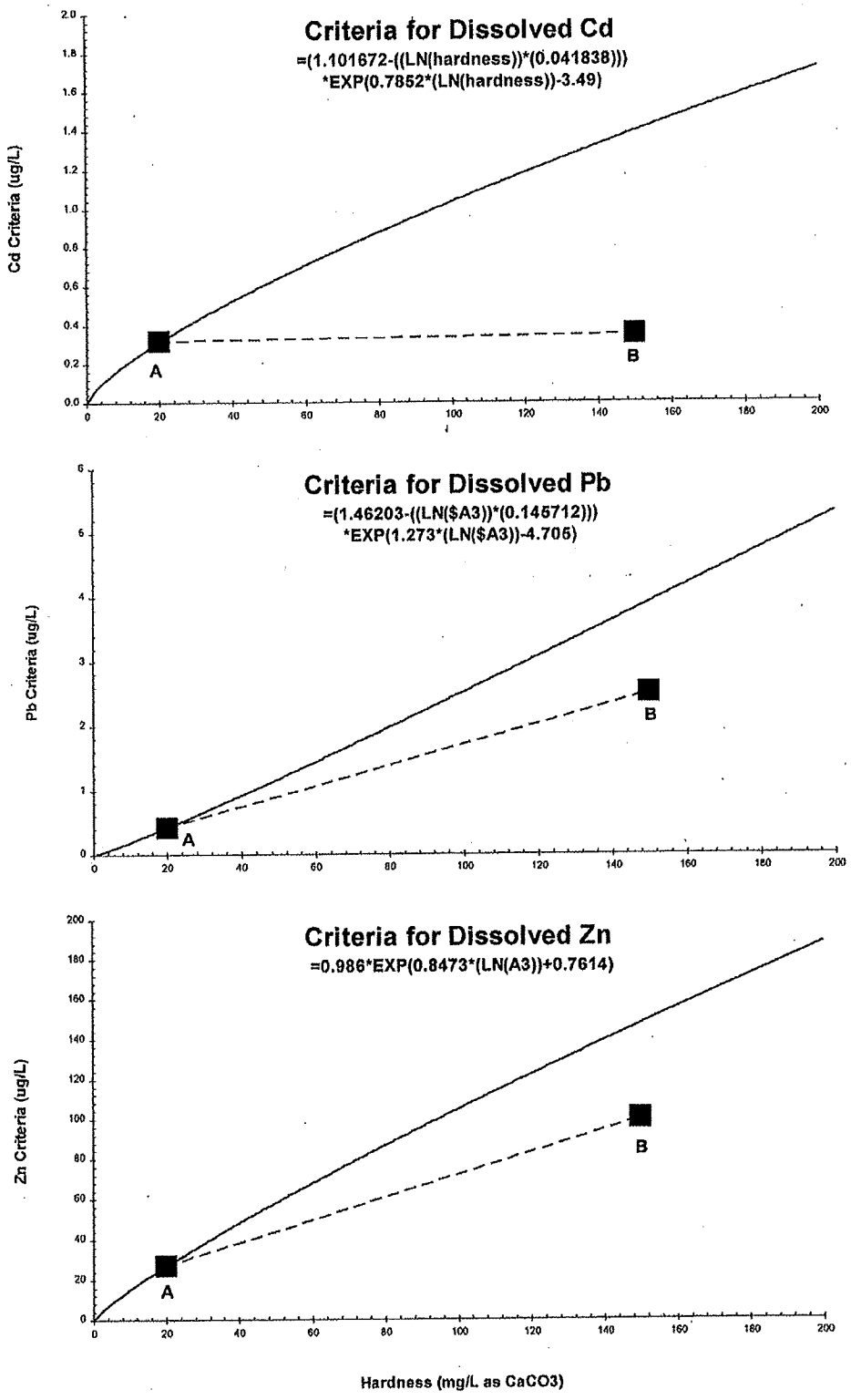



Figure 2. Chronic aquatic life criteria for dissolved Cd, Pb, and Zn.

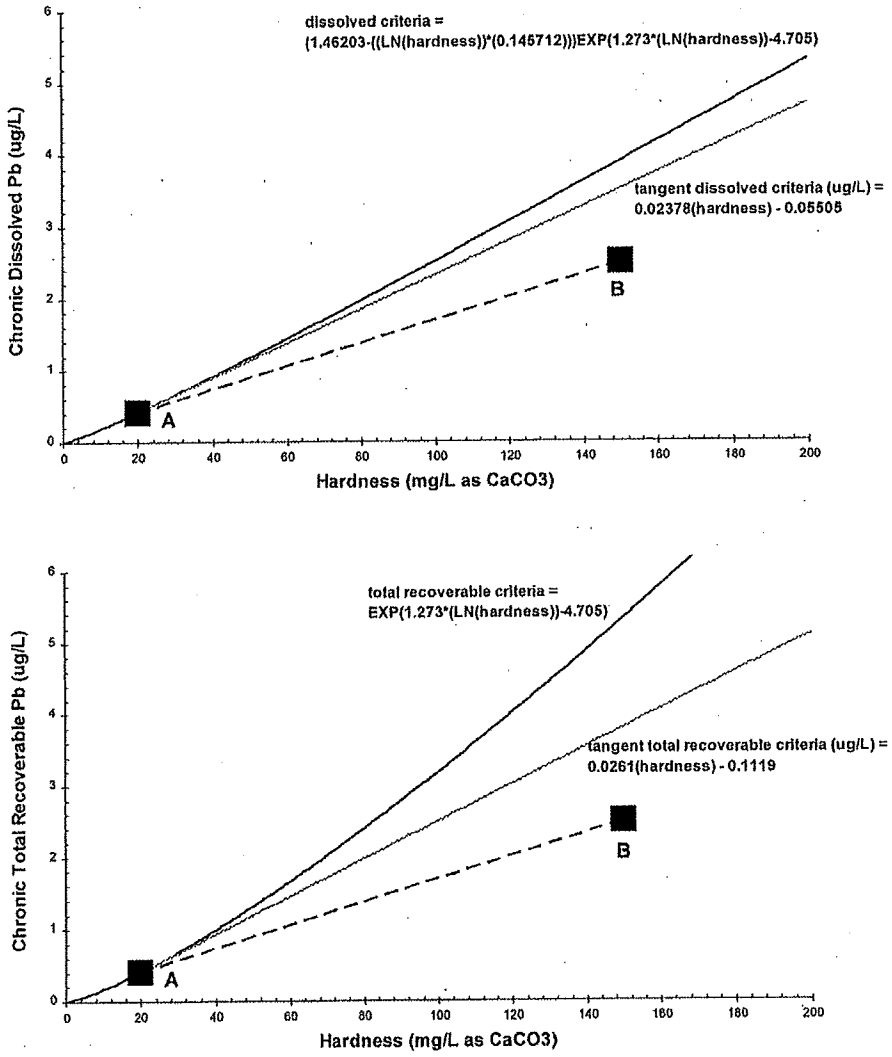



Figure 3. Chronic aquatic life criteria for dissolved Pb and total recoverable Pb (assuming the translator equals the conversion factor).

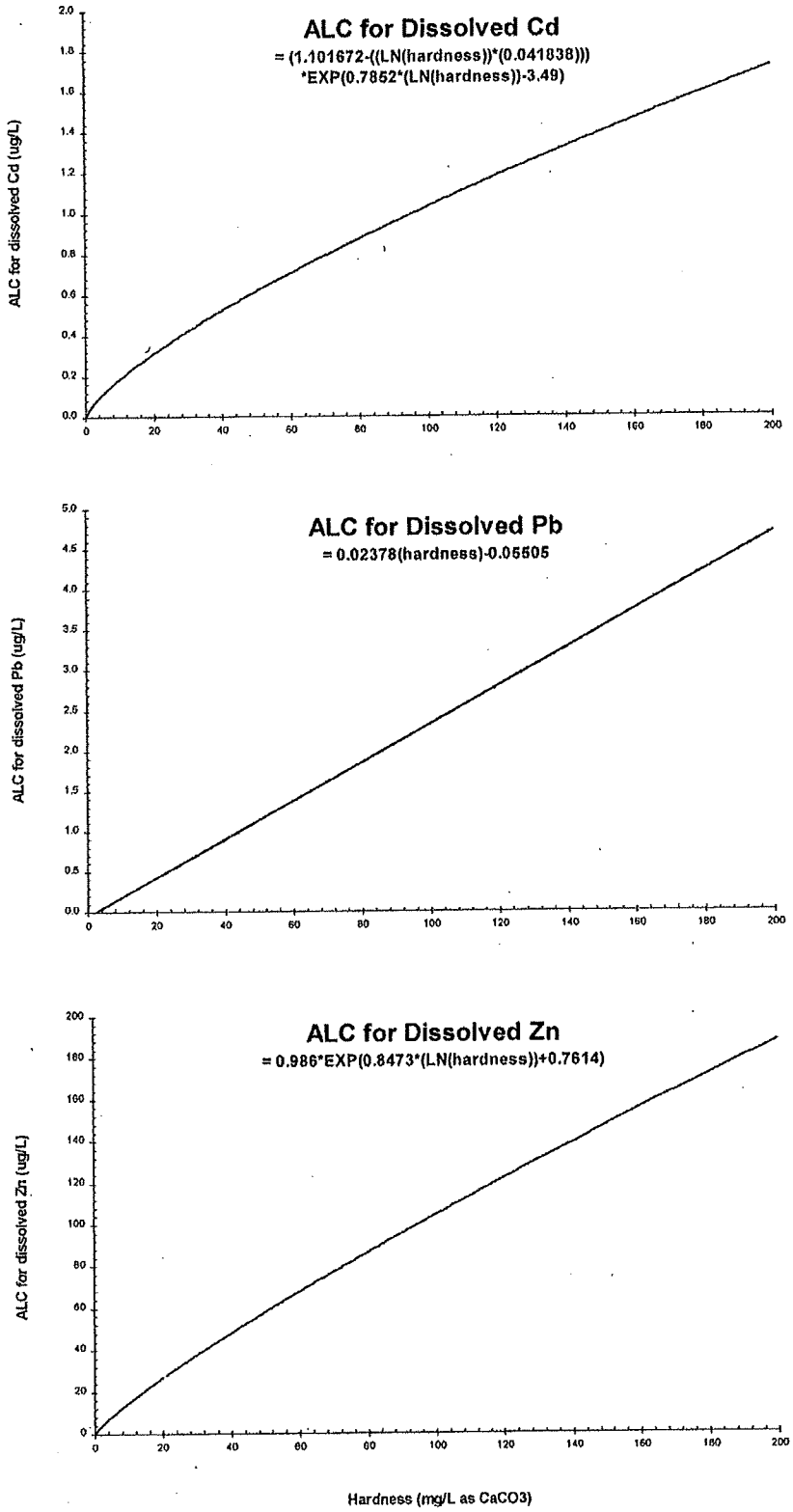



Figure 4. Recommended aquatic life criteria (ALC) for effluent dissolved Cd, Pb, and Zn for calculation of permit limits.

# Tables

Table 1. Current and projected future effluent design flows from NPDES dischargers to the Spokane River.

| NPDES Discharger | Current mgd | Current cfs | 20-Year Projection cfs | 50-Year Projection cfs | 20-Times Current (1) cfs |
|---|---|---|---|---|---|
| City of Coeur d'Alene AWTP | 6 | 9.3 | 13 | 18 | 186 |
| HARSB POTW | 1.3 | 2.0 | 3.4 | 8.4 | 40 |
| City of Post Falls (includes City of Rathdrum) POTW | 3.1 | 4.8 | 6.3 | 21 | 96 |
| Liberty Lake POTW | 1 | 1.5 | 1.9 | 2.6 | 31 |
| Kaiser Aluminum IWTP | 23.3 | 36 | 45 | 54 | 72 |
| Inland Empire Paper Company IWTP | 4 | 6.2 | 7.7 | 9.3 | 12 |
| City of Spokane AWTP | 44 | 68 | 84 | 118 | 1362 |
| Total: | 83 | 128 | 161 | 231 | 1799 |

1) for "20-times current", the current flow rates from industrial dischargers were doubled instead of multiplying by 20 to provide and extreme worst-case for illustrative purposes.

Table 2. Estimated aquifer and tributary inflows and outflows at various scenarios of outflow from Lake Coeur d'Alene.

| Spokane River Model Reach Number | Up-stream River Mile | Down-stream River Mile | Equation to Estimate Aquifer Inflow/Outflow from Lake Coeur d'Alene Outflow (cfs) | Inflow/ Outflow (cfs) | Inflow/ Outflow (cfs) | Inflow/ Outflow (cfs) |
|---|---|---|---|---|---|---|
| 0 | -- | 111.7 | Lake Coeur d'Alene Outflow (Qcda): | 300 | 2,000 | 20,000 |
| 1 | 111.7 | 106.6 | | | | |
| 2 | 106.6 | 101.7 | | | | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow =37.46-(0.031367*Qcda)* | 28 | -25 | -88 |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow =15.77-(0.013207*Qcda)* | 12 | -11 | -37 |
| 5 | 93.0 | 90.4 | | | | |
| 6 | 90.4 | 87.8 | | | | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow =288.97+(0.048167*Qcda)* | 303 | 385 | 482 |
| 8 | 85.3 | 82.6 | | | | |
| 9 | 82.6 | 79.8 | *Aquifer Inflow = -256.2* | -256 | -256 | -256 |
| 10 | 79.8 | 78.0 | *Aquifer Inflow =338.54+(0.056428*Qcda)* | 355 | 451 | 564 |
| 11 | 78.0 | 74.1 | *Aquifer Outflow =-179.7* | -180 | -180 | -180 |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer =3.3+(0.007237*Qcda)+135.53+(0.012548*Qcda)* | 145 | 178 | 218 |
| 13 | 69.8 | 67.6 | *Aquifer Inflow =42.75* | 43 | 43 | 43 |
| 14 | 67.6 | 64.6 | *Aquifer Inflow =58.3* | 58 | 58 | 58 |
| | | | **Total net aquifer infow/outflow over all reaches:** | **509** | **644** | **804** |

# Appendices

# Appendix A

**Derivation of the tangent equation for the chronic criteria for dissolved Lead**

The tangent to the Lead criterion curve for any point can be found by taking the first derivative and evaluating it at that point. The numerical formula for the first derivative of the criterion curve at a hardness of 20 mg/L as CaCO3 is as follows using the symmetrical central difference approximation:

dy/dx = (f(x+h) - f(x-h)) / 2h

where:

y = chronic Lead criteria equation = f(x)
= (1.46203-((Ln(x))*(0.145712)))*EXP(1.273*(Ln(x))-4.705)
x = hardness (20 mg/L as CaCO3 for the critical river hardness)
h = small deviation in hardness (0.001 mg/L as CaCO3)
dy/dx = first derivative of the Lead criteria equation, which is the slope of the tangent equation

for x=20 and h=0.001, the first derivative is calculated from the following steps:

f(x+h) = (1.46203-((Ln(20.001))*(0.145712)))*EXP(1.273*(Ln(20.001))-4.705)
= 0.420554791
f(x-h) = (1.46203-((Ln(19.999))*(0.145712)))*EXP(1.273*(Ln(19.999))-4.705)
= 0.420507233
dy/dx = (f(x+h) - f(x-h)) / 2h
= (0.420554791 - 0.420507233) / (0.002)
= 0.023779
≅ 0.02378

Therefore, the slope of the tangent equation at a hardness of 20 mg/L is 0.02378. The intercept (b) for the equation for the tangent is calculated from the equation for a straight line:

y = x(dy/dx) + b

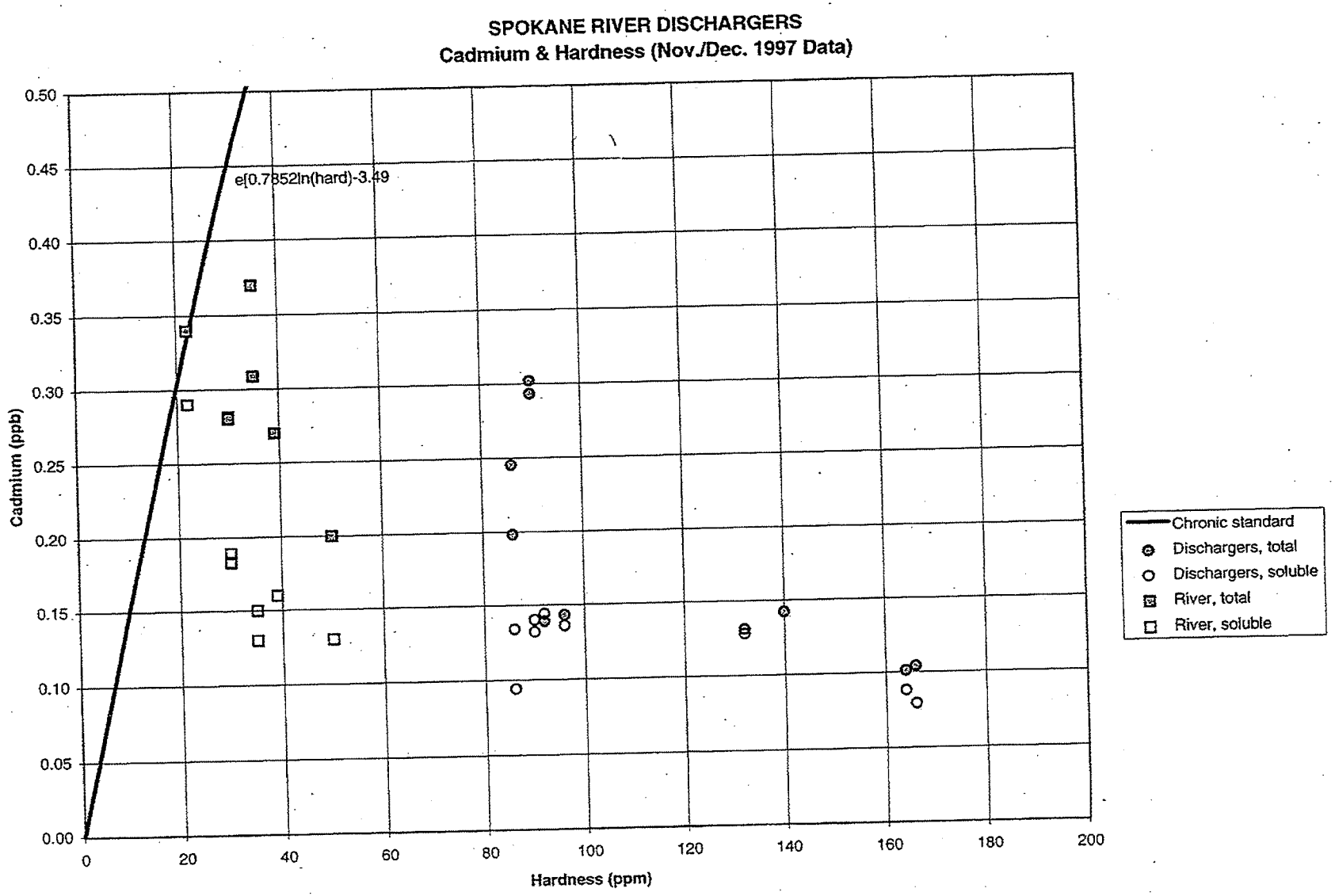
which can be rearranged to solved for the intercept b:

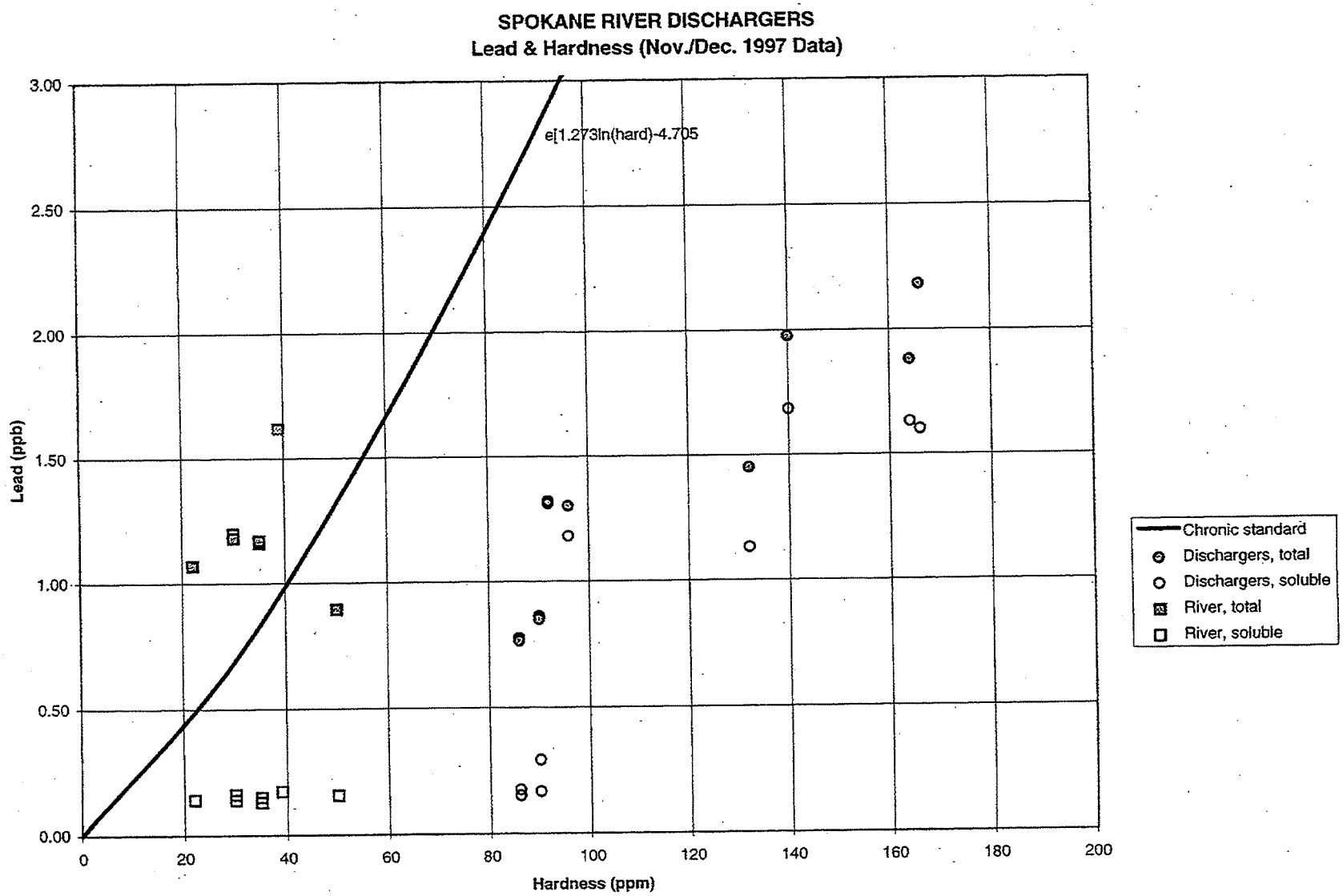
x = hardness (20 mg/L as CaCO3 for the critical river hardness)
y = (1.46203-((Ln(20))*(0.145712)))*EXP(1.273*(Ln(20))-4.705)
= 0.420531012
dy/dx = 0.023779
b = y - x(dy/dx)
= 0. 420531012 - 20(0.023779)
= -0.05505

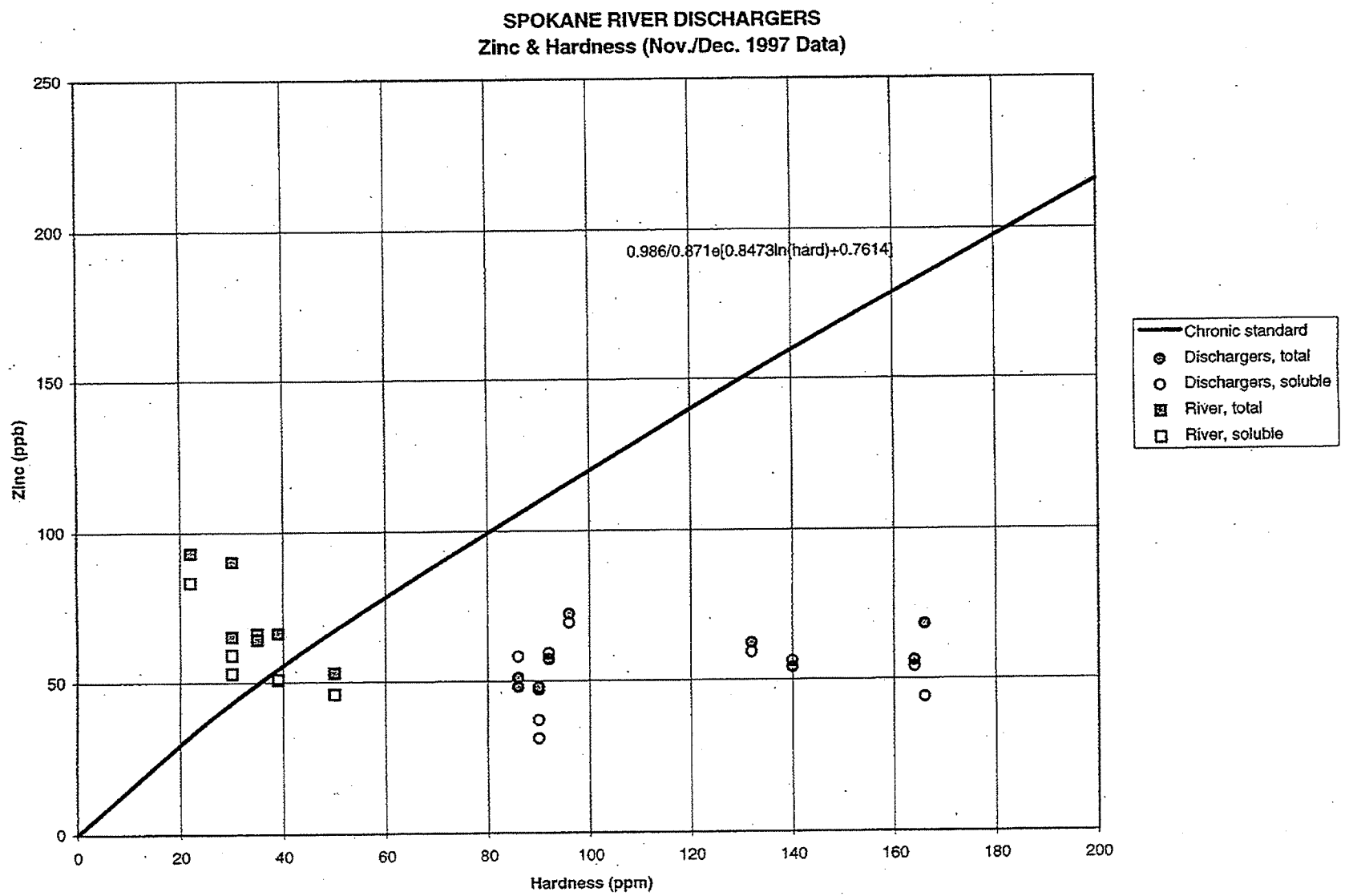
# Appendix B

# Spokane AWTP effluent dissolved and total recoverable metal data by Battelle (7/96 - 4/98)

| Date | Dissolved Metals | | | | | | Total Recoverable Metals | | | | | | Ratio of Diss/Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zn | | Pb | | Cd | | Zn | | Pb | | Cd | | Zn | Pb | Cd |
| | Concen-tration (ug/L) | Ln (Concen-tration) | Concen-tration (ug/L) | Ln (Concen-tration) | Concen-tration (ug/L) | Ln (Concen-tration) | Concen-tration (ug/L) | Ln (Concen-tration) | Concen-tration (ug/L) | Ln (Concen-tration) | Concen-tration (ug/L) | Ln (Concen-tration) | | | |
| 7/12/96 | 42.2312 | 3.7431593 | 1.0994 | 0.0947646 | 0.0882 | -2.4281483 | 41.9353 | 3.736128 | 1.2472 | 0.220901 | 0.0884 | -2.4258833 | 1.000 | 0.881 | 0.998 |
| 7/19/96 | 35.1556 | 3.5597839 | 0.8897 | -0.116871 | 0.0668 | -2.7060522 | 38.8083 | 3.6586341 | 1.2254 | 0.2032673 | 0.0911 | -2.3957975 | 0.906 | 0.726 | 0.733 |
| 7/26/96 | 35.7777 | 3.5773248 | 0.8637 | -0.1465298 | 0.0804 | -2.5207411 | 40.1882 | 3.6935734 | 1.12 | 0.1133287 | 0.0858 | -2.4557363 | 0.890 | 0.771 | 0.937 |
| 8/12/96 | 27.6477 | 3.3195425 | 0.5602 | -0.5794614 | 0.0614 | -2.7903454 | 27.7292 | 3.322486 | 0.7302 | -0.3144368 | 0.053 | -2.9374634 | 0.997 | 0.767 | 1.000 |
| 8/19/96 | 23.1963 | 3.1439928 | 0.4731 | -0.7484485 | 0.0372 | -3.2914465 | 25.9452 | 3.2559866 | 0.6435 | -0.4408333 | 0.053 U | -3.6306105 | 0.894 | 0.735 | |
| 9/5/96 | 54.8 | 4.0036902 | 0.9654 | -0.0352128 | 0.0542 | -2.9150744 | 57.6135 | 4.0537569 | 1.3119 | 0.2714765 | 0.0623 | -2.7757939 | 0.951 | 0.736 | 0.870 |
| 9/12/96 | 43.3733 | 3.769844 | 1.0302 | 0.029753 | 0.0845 | -2.4710037 | 45.7439 | 3.8230584 | 1.4578 | 0.3769284 | 0.1016 | -2.2867117 | 0.948 | 0.707 | 0.832 |
| 4/26/97 | 41.08 | 3.7155214 | 0.8132 | -0.2057782 | 0.1155 | -2.1584847 | 42.18 | 3.7419462 | 1.001 | 0.0009995 | 0.1268 | -2.0651442 | 0.974 | 0.812 | 0.911 |
| 5/6/97 | 29.02 | 3.3679852 | 0.4684 | -0.7584326 | 0.0543 | -2.9132311 | 31.27 | 3.4426592 | 0.7466 | -0.2922257 | 0.0638 | -2.7520021 | 0.928 | 0.627 | 0.851 |
| 5/20/97 | 25.9883 | 3.2576464 | 0.3688 | -0.9975008 | 0.0832 | -2.4865079 | 29.7154 | 3.3916654 | 1.0898 | 0.0859942 | 0.0952 | -2.3517753 | 0.875 | 0.338 | 0.874 |
| 6/3/97 | 31.015 | 3.434471 | 0.5942 | -0.5205393 | 0.1168 | -2.1472922 | 33.2076 | 3.5027788 | 0.8389 | -0.1756838 | 0.121 | -2.1119647 | 0.934 | 0.708 | 0.965 |
| 6/17/97 | 44.2646 | 3.7901853 | 0.8694 | -0.139952 | 0.0713 | -2.640859 | 49.1768 | 3.895422 | 1.0907 | 0.0868197 | 0.0826 | -2.4937456 | 0.900 | 0.797 | 0.863 |
| 6/26/97 | 43.44 | 3.7713807 | 1.115 | 0.1088544 | 0.08209 | -2.4999391 | 54.25 | 3.993603 | 1.393 | 0.3314597 | 0.09787 | -2.3241152 | 0.801 | 0.800 | 0.839 |
| 7/8/97 | 52.94 | 3.9691592 | 0.9546 | -0.0464629 | 0.09635 | -2.3397679 | 54.28 | 3.9941558 | 1.073 | 0.0704585 | 0.09037 | -2.4038429 | 0.975 | 0.890 | 1.000 |
| 7/22/97 | 35.37 | 3.565864 | 0.8901 | -0.1164215 | 0.06532 | -2.728457 | 36.88 | 3.6076694 | 1.127 | 0.1195592 | 0.0714 | -2.6394574 | 0.959 | 0.790 | 0.915 |
| 8/7/97 | 37.6146 | 3.6273923 | 1.1348 | 0.1264564 | 0.0861 | -2.4522459 | 35.5036 | 3.5696341 | 1.1473 | 0.1374114 | 0.0886 | -2.4464555 | 1.000 | 0.989 | 0.994 |
| 8/19/97 | 31.3673 | 3.4457659 | 0.821 | -0.1972322 | 0.0903 | -2.4046178 | 44.0603 | 3.7855592 | 1.286 | 0.2515366 | 0.1401 | -1.9653988 | 0.712 | 0.638 | 0.645 |
| 9/9/97 | 45.88 | 3.8262472 | 1.326 | 0.2821669 | 0.1281 | -2.0549441 | 93.8 | 4.5411649 | 1.597 | 0.4681269 | 0.1225 | -2.0996442 | 0.489 | 0.830 | 1.000 |
| 9/26/97 | 43.43 | 3.7711504 | 1.315 | 0.2738367 | 0.09242 | -2.3814119 | 46.44 | 3.8381612 | 1.526 | 0.4226499 | 0.1072 | -2.233059 | 0.935 | 0.862 | 0.862 |
| 10/10/97 | 49.03 | 3.8924324 | 1.531 | 0.4259211 | 0.1004 | -2.2985931 | 50.36 | 3.9191972 | 1.889 | 0.6360476 | 0.1002 | -2.3005871 | 0.974 | 0.810 | 1.000 |
| 10/24/97 | 46.94 | 3.8488702 | 1.258 | 0.2295232 | 0.1257 | -2.0738572 | 49.77 | 3.9074124 | 1.47 | 0.3852624 | 0.1172 | -2.1438734 | 0.943 | 0.856 | 1.000 |
| 11/21/97 | 54.14 | 3.9915733 | 1.627 | 0.4867378 | 0.08762 | -2.434746 | 55.67 | 4.0194414 | 1.875 | 0.6286087 | 0.1008 | -2.2946169 | 0.973 | 0.868 | 0.869 |
| 11/7/97 | 49.03 | 3.8924324 | 1.492 | 0.4001175 | 0.06841 | -2.6822363 | 50.44 | 3.9207845 | 1.759 | 0.5647455 | 0.0909 | -2.3979953 | 0.972 | 0.848 | 0.753 |
| 12/5/97 | 44.3 | 3.7909847 | 1.601 | 0.4706284 | 0.07472 | -2.5940075 | 67.89 | 4.2178887 | 2.175 | 0.7770287 | 0.1037 | -2.2662532 | 0.653 | 0.736 | 0.721 |
| 12/19/97 | 47.381 | 3.8582213 | 1.1157 | 0.109482 | 0.082 | -2.501036 | 56.0879 | 4.0269201 | 1.3803 | 0.3223009 | 0.11 | -2.2072749 | 0.845 | 0.808 | 0.745 |
| 1/9/98 | 55.1638 | 4.0103069 | 1.5945 | 0.4665602 | 0.1224 | -2.1004609 | 60.266 | 4.0987681 | 1.9968 | 0.6915459 | 0.1473 | -1.915284 | 0.915 | 0.799 | 0.831 |
| 1/30/98 | 41.8396 | 3.7338433 | 1.6225 | 0.4839662 | 0.2219 | -1.5055284 | 49.209 | 3.8960765 | 2.5398 | 0.9320853 | 0.2338 | -1.4532892 | 0.850 | 0.639 | 0.949 |
| 2/12/98 | 54.1045 | 3.9909174 | 1.8175 | 0.5974619 | 0.2359 | -1.4443473 | 57.3717 | 4.0495512 | 2.478 | 0.9074518 | 0.2789 | -1.276902 | 0.943 | 0.733 | 0.846 |
| 3/3/98 | 50.9 | 3.9298629 | 1.034 | 0.0334348 | 0.08676 | -2.4446096 | 60.09 | 4.0958434 | 1.314 | 0.2730759 | 0.09799 | -2.3228898 | 0.847 | 0.787 | 0.885 |
| 3/19/98 | 56.94 | 4.0419981 | 1.5 | 0.4054651 | 0.1368 | -1.9892353 | 59.78 | 4.0906712 | 1.693 | 0.5265021 | 0.1752 | -1.7418271 | 0.952 | 0.886 | 0.781 |
| 4/2/98 | 48.68 | 3.8852683 | 1.123 | 0.1160037 | 0.081 U | -3.2064533 | 52.24 | 3.9558485 | 1.394 | 0.3321773 | 0.1202 | -2.1185983 | 0.932 | 0.806 | |
| Average | 42.64679 | 3.726672 | 1.092529 | 0.017138 | 0.096067 | -2.438893 | 48.31942 | 3.840208 | 1.406974 | 0.287567 | 0.11022 | -2.297871 | 0.8989 | 0.7736 | 0.8782 |
| Std Dev | 9.374353 | 0.240658 | 0.385699 | 0.405220 | 0.042348 | 0.401821 | 13.65446 | 0.280317 | 0.471836 | 0.336450 | 0.047533 | 0.423974 | 0.1096 | 0.1137 | 0.0986 |
| Variance | 87.8785 | 0.057916 | 0.148764 | 0.164203 | 0.001793 | 0.161460 | 186.4444 | 0.078578 | 0.222629 | 0.113199 | 0.002259 | 0.179754 | 0.0120 | 0.0129 | 0.0097 |
| CV | 0.219814 | | 0.353033 | | 0.44082 | | 0.282587 | | 0.335355 | | 0.431251 | | 0.1219 | 0.1470 | 0.1123 |
| n | 31 | | 31 | | 31 | | 31 | | 31 | | 31 | | 31 | 31 | 29 |
| rank 90% | 54.14 | | 1.601 | | 0.1281 | | 60.09 | | 1.9968 | | 0.1473 | | 0.975 | 0.881 | 1.000 |
| max | 56.94 | | 1.8175 | | 0.2359 | | 93.8 | | 2.5398 | | 0.2789 | | 1.000 | 0.989 | 1.000 |
| Log normal | | | | | | | | | | | | | | | |
| 99.9%tile | 87.39 | | 3.56 | | 0.30 | | 110.66 | | 3.77 | | 0.37 | | | | |
| 99%tile | 72.71 | | 2.61 | | 0.22 | | 89.33 | | 2.92 | | 0.27 | | | | |
| 95%tile | 61.72 | | 1.98 | | 0.17 | | 73.80 | | 2.32 | | 0.20 | | | | |
| 90%tile | 56.55 | | 1.71 | | 0.15 | | 66.65 | | 2.05 | | 0.17 | | | | |
| Arcsin sqrt | | | | | | | | | | | | | | | |
| 99.9%tile | | | | | | | | | | | | | 1.0000 | 0.9971 | 1.0000 |
| 99%tile | | | | | | | | | | | | | 1.0000 | 0.9744 | 1.0000 |
| 95%tile | | | | | | | | | | | | | 0.9999 | 0.9361 | 1.0000 |
| 90%tile | | | | | | | | | | | | | 0.9951 | 0.9092 | 0.9964 |


SPOKANE RIVER DISCHARGERS
Cadmium & Hardness (Nov./Dec. 1997 Data)
e[0.7852ln(hard)-3.49
Cadmium (ppb)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120
140
160
180
200
Hardness (ppm)
Chronic standard
Dischargers, total
Dischargers, soluble
River, total
River, soluble


SPOKANE RIVER DISCHARGERS
Lead & Hardness (Nov./Dec. 1997 Data)
e[1.273ln(hard)-4.705
Lead (ppb)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
140
160
180
200
Hardness (ppm)
Chronic standard
Dischargers, total
Dischargers, soluble
River, total
River, soluble


SPOKANE RIVER DISCHARGERS
Zinc & Hardness (Nov./Dec. 1997 Data)
0.986/0.871e[0.8473ln(hard)+0.7614]
Zinc (ppb)
Hardness (ppm)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200
Chronic standard
Dischargers, total
Dischargers, soluble
River, total
River, soluble

**SPOKANE RIVER DISCHARGERS**
**OUTFALL CADMIUM & HARDNESS CONCENTRATIONS**

CHRONIC STANDARD

| HARD (PPM) | CAD STND. (PPB) |
|---|---|
| 0.001 | 0.00 |
| 30 | 0.44 |
| 60 | 0.76 |
| 90 | 1.04 |
| 120 | 1.31 |
| 150 | 1.56 |
| 180 | 1.80 |
| 200 | 1.95 |

| DATE | OUTFALL | OUTFALL CONC. | | RIVER CONC. | | FILTERED? |
|---|---|---|---|---|---|---|
| | | CADMIUM (PPB) | HARDNESS (PPM) | CADMIUM (PPB) | HARDNESS (PPM) | |
| 11/21/97 | SPK | 0.101 | 164 | 0.20 | 50 | NO |
| | SPK | 0.088 | 164 | 0.13 | 50 | YES |
| 12/5/97 | SPK | 0.104 | 166 | 0.27 | 39 | NO |
| | SPK | 0.079 | 166 | 0.16 | 39 | YES |
| 12/9/97 | CDA | 0.142 | 140 | 0.34 | 22 | NO |
| | CDA | 0.142 | 140 | 0.29 | 22 | YES |
| | KAI | 0.198 | 86 | 0.281 | 30 | NO |
| | KAI | 0.245 | 86 | 0.28 | 30 | NO |
| | KAI | 0.134 | 86 | 0.189 | 30 | YES |
| | KAI | 0.094 | 86 | 0.183 | 30 | YES |
| 12/12/97 | KAI | 0.14 | 90 | 0.13 | 35 | YES |
| | KAI | 0.132 | 90 | 0.15 | 35 | YES |
| | KAI | 0.293 | 90 | 0.37 | 35 | NO |
| | KAI | 0.302 | 90 | 0.309 | 35 | NO |
| 12/18/97 | CDA | 0.131 | 132 | | | NO |
| | CDA | 0.128 | 132 | | | YES |
| | HAY | 0.139 | 92 | | | NO |
| | HAY | 0.144 | 92 | | | YES |
| | POST | 0.143 | 96 | | | NO |
| | POST | 0.136 | 96 | | | YES |

**SPOKANE RIVER DISCHARGERS**
**OUTFALL LEAD & HARDNESS CONCENTRATIONS**

CHRONIC STANDARD

| HARD (PPM) | LEAD STND. (PPB) |
|---|---|
| 0.001 | 0.00 |
| 30 | 0.69 |
| 60 | 1.66 |
| 90 | 2.78 |
| 120 | 4.01 |
| 150 | 5.33 |
| 180 | 6.72 |
| 200 | 7.69 |

| DATE | OUTFALL | OUTFALL CONC. | | RIVER CONC. | | FILTERED? |
|---|---|---|---|---|---|---|
| | | LEAD (PPB) | HARDNESS (PPM) | LEAD (PPB) | HARDNESS (PPM) | |
| 11/21/97 | SPK | 1.88 | 164 | 0.894 | 50 | NO |
| | SPK | 1.63 | 164 | 0.156 | 50 | YES |
| 12/5/97 | SPK | 2.18 | 166 | 1.62 | 39 | NO |
| | SPK | 1.6 | 166 | 0.173 | 39 | YES |
| 12/9/97 | CDA | 1.975 | 140 | 1.07 | 22 | NO |
| | CDA | 1.684 | 140 | 0.141 | 22 | YES |
| | KAI | 0.775 | 86 | 1.2 | 30 | NO |
| | KAI | 0.764 | 86 | 1.18 | 30 | NO |
| | KAI | 0.173 | 86 | 0.161 | 30 | YES |
| | KAI | 0.149 | 86 | 0.139 | 30 | YES |
| 12/12/97 | KAI | 0.291 | 90 | 0.13 | 35 | YES |
| | KAI | 0.165 | 90 | 0.15 | 35 | YES |
| | KAI | 0.861 | 90 | 1.16 | 35 | NO |
| | KAI | 0.849 | 90 | 1.17 | 35 | NO |
| 12/18/97 | CDA | 1.45 | 132 | | | NO |
| | CDA | 1.13 | 132 | | | YES |
| | HAY | 1.32 | 92 | | | NO |
| | HAY | 1.31 | 92 | | | YES |
| | POST | 1.3 | 96 | | | NO |
| | POST | 1.18 | 96 | | | YES |

**SPOKANE RIVER DISCHARGERS**
**OUTFALL ZINC & HARDNESS CONCENTRATIONS**

CHRONIC STANDARD

| HARD (PPM) | Zn STND. (PPB) |
|---|---|
| 0.001 | 0 |
| 30 | 43 |
| 60 | 78 |
| 90 | 110 |
| 120 | 140 |
| 150 | 169 |
| 180 | 197 |
| 200 | 216 |

| DATE | OUTFALL | OUTFALL CONC. | | RIVER CONC. | | FILTERED? |
|---|---|---|---|---|---|---|
| | | ZINC (PPB) | HARDNESS (PPM) | ZINC (PPB) | HARDNESS (PPM) | |
| 11/21/97 | SPK | 56 | 164 | 53 | 50 | NO |
| | SPK | 54 | 164 | 46 | 50 | YES |
| 12/5/97 | SPK | 68 | 166 | 66 | 39 | NO |
| | SPK | 44 | 166 | 51 | 39 | YES |
| 12/9/97 | CDA | 54 | 140 | 93 | 22 | NO |
| | CDA | 56 | 140 | 83 | 22 | YES |
| | KAI | 51 | 86 | 65 | 30 | NO |
| | KAI | 48 | 86 | 90 | 30 | NO |
| | KAI | 51 | 86 | 53 | 30 | YES |
| | KAI | 58 | 86 | 59 | 30 | YES |
| 12/12/97 | KAI | 37 | 90 | 64 | 35 | YES |
| | KAI | 31 | 90 | 64 | 35 | YES |
| | KAI | 47 | 90 | 66 | 35 | NO |
| | KAI | 48 | 90 | 64 | 35 | NO |
| 12/18/97 | CDA | 62 | 132 | | | NO |
| | CDA | 59 | 132 | | | YES |
| | HAY | 57 | 92 | | | NO |
| | HAY | 59 | 92 | | | YES |
| | POST | 72 | 96 | | | NO |
| | POST | 69 | 96 | | | YES |

# Appendix C.1

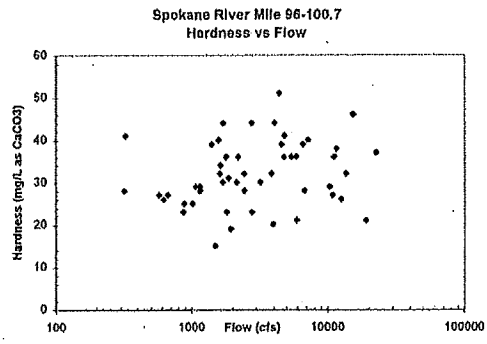
# Hardness data and relationship with flow (Pelletier, 1994)

Appendix C1. Hardness data from the Spokane River near Stateline and Post Falls (RM 96-100.7) (Pelletier, 1994).

Spokane River 96-100.7, Hardness (mg/L as CaCO3), 1983-94
FILE = hard8394.txt Column = 1

RESULTS:

| | |
|---|---|
| Number of data ..... | 92 |
| .... Conf Limit (U) .. | 31.4158 |
| Mean ... (95% CI) ..... | 29.4348 |
| .... Conf Limit (L) .. | 27.4538 |
| Std Err Mean ..... | 0.9973 |
| Std Daviation ..... | 9.5656 |
| Coef of Variation ..... | 0.3250 |
| Coef of Skewness ..... | 2.3469 |
| n-Kurtosis ..... | 10.4564 |
| Geom Mean ..... | 28.2261 |
| Maximum ..... | 84.0000 |
| 0.950 perc ..... | 44.7000 |
| Median ..... | 27.0000 |
| 0.050 perc ..... | 20.0000 |
| Minimum ..... | 15.0000 |
| IQR ..... | 13.0000 |
| .... Conf Limit (U) .. | 28.9108 |
| Trim. Mean (2x10%) ..... | 28.3243 |
| .... Conf Limit (L) .. | 27.7379 |
| Trim Mean Std Err ..... | 0.8652 |
| Wins. Mean (2x10%) ..... | 28.7500 |
| Winsored Std Dev ..... | 8.2928 |
| Tukey Trimean ..... | 28.2500 |
| MedAD*1.483 ..... | 6.6735 |
| MnAD*1.483 ..... | 9.5428 |




| Station | River Mile | Date | Time | Hardness (mg/L as CaCO3) | Flow (cfs) |
|---|---|---|---|---|---|
| 57A190 | 100.7 | 26-Oct-83 | 920 | 19 | 1960 |
| 57A190 | 100.7 | 30-Nov-83 | 910 | 39 | 4620 |
| 57A190 | 100.7 | 21-Dec-83 | 800 | 36 | 4820 |
| 57A190 | 100.7 | 18-Jan-84 | 730 | 36 | 5440 |
| 57A190 | 100.7 | 08-Feb-84 | 715 | 28 | 6820 |
| 57A190 | 100.7 | 07-Mar-84 | 750 | 36 | 5900 |
| 57A190 | 100.7 | 11-Apr-84 | 825 | 36 | 11200 |
| 57A190 | 100.7 | 09-May-84 | 840 | 84 | 11200 |
| 57A190 | 100.7 | 13-Jun-84 | 820 | 46 | 15300 |
| 57A190 | 100.7 | 11-Jul-84 | 815 | 32 | 2460 |
| 57A190 | 100.7 | 15-Aug-84 | 815 | 27 | 670 |
| 57A190 | 100.7 | 12-Sep-84 | 830 | 44 | 1730 |
| 57A190 | 100.7 | 10-Oct-84 | 855 | 36 | 1810 |
| 57A190 | 100.7 | 14-Nov-84 | 910 | 44 | 2780 |
| 57A190 | 100.7 | 12-Dec-84 | 840 | 44 | 4100 |
| 57A190 | 100.7 | 16-Jan-85 | 905 | 32 | 1630 |
| 57A190 | 100.7 | 06-Feb-85 | 850 | 40 | 1600 |
| 57A190 | 100.7 | 13-Mar-85 | 830 | 36 | 2220 |
| 57A190 | 100.7 | 03-Apr-85 | 655 | 40 | 7240 |
| 57A190 | 100.7 | 08-May-85 | 825 | 21 | 19300 |
| 57A190 | 100.7 | 12-Jun-85 | 835 | 999999 | 16300 |
| 57A190 | 100.7 | 14-Aug-85 | 810 | 23 | 873 |
| 57A190 | 100.7 | 18-Sep-85 | 805 | 999999 | 2240 |
| 57A190 | 100.7 | 23-Oct-85 | 810 | 23 | 1830 |
| 57A190 | 100.7 | 20-Nov-85 | 830 | 51 | 4440 |
| 57A190 | 100.7 | 11-Dec-85 | 815 | 999999 | 4110 |
| 57A190 | 100.7 | 15-Jan-86 | 805 | 34 | 1650 |
| 57A190 | 100.7 | 12-Feb-86 | 835 | 39 | 6620 |
| 57A190 | 100.7 | 12-Mar-86 | 810 | 37 | 22900 |
| 57A190 | 100.7 | 16-Apr-86 | 815 | 20 | 12600 |
| 57A190 | 100.7 | 14-May-86 | 810 | 999999 | 9070 |
| 57A190 | 100.7 | 11-Jun-86 | 830 | 20 | 4000 |
| 57A190 | 100.7 | 09-Jul-86 | 755 | 39 | 1420 |
| 57A190 | 100.7 | 13-Aug-86 | 715 | 41 | 325 |
| 57A190 | 100.7 | 10-Sep-86 | 730 | 28 | 320 |
| 57A190 | 100.7 | 22-Oct-86 | 630 | 999999 | 2310 |
| 57A190 | 100.7 | 05-Nov-86 | 735 | 999999 | 2960 |
| 57A190 | 100.7 | 10-Dec-86 | 730 | 32 | 3690 |
| 57A190 | 100.7 | 14-Jan-87 | 800 | 28 | 2470 |
| 57A190 | 100.7 | 11-Feb-87 | 730 | 23 | 2800 |
| 57A190 | 100.7 | 18-Mar-87 | 820 | 32 | 13700 |
| 57A190 | 100.7 | 15-Apr-87 | 705 | 38 | 11600 |
| 57A190 | 100.7 | 08-May-87 | 800 | 46 | 15500 |
| 57A190 | 100.7 | 03-Jun-87 | 650 | 30 | 3230 |
| 57A190 | 100.7 | 08-Jul-87 | 735 | 31 | 1900 |
| 57A190 | 100.7 | 05-Aug-87 | 740 | 27 | 576 |
| 57A190 | 100.7 | 09-Sep-87 | 800 | 29 | 1160 |
| 57A190 | 100.7 | 07-Oct-87 | 730 | 25 | 884 |
| 57A190 | 100.7 | 04-Nov-87 | 745 | 28 | 1160 |
| 57A190 | 100.7 | 09-Dec-87 | 740 | 30 | 2160 |
| 57A190 | 100.7 | 13-Jan-88 | 745 | 30 | 1720 |
| 57A190 | 100.7 | 03-Feb-88 | 735 | 15 | 1510 |
| 57A190 | 100.7 | 09-Mar-88 | 740 | 41 | 4860 |
| 57A190 | 100.7 | 06-Apr-88 | 610 | 27 | 10900 |
| 57A190 | 100.7 | 04-May-88 | 645 | 29 | 10400 |
| 57A190 | 100.7 | 08-Jun-88 | 710 | 21 | 5980 |
| 57A190 | 100.7 | 06-Jul-88 | 715 | 25 | 1020 |
| 57A190 | 100.7 | 03-Aug-88 | 720 | 26 | 621 |
| 57A190 | 100.7 | 14-Sep-88 | 705 | 29 | 1080 |
| 57A190 | 100.7 | 05-Oct-88 | 720 | 29 | 1080 |

| Station | River Mile | Date | Time | Hardness (mg/L as CaCO3) | Flow (cfs) |
|---|---|---|---|---|---|
| 57A190 | 100.7 | 08-Nov-88 | 720 | 28 | 2180 |
| 57A190 | 100.7 | 07-Dec-88 | 715 | 20 | 4060 |
| 57A190 | 100.7 | 04-Jan-89 | 705 | 30 | 2920 |
| 57A190 | 100.7 | 08-Feb-89 | 720 | 26 | 2810 |
| 57A190 | 100.7 | 08-Mar-89 | 735 | 37 | 2030 |
| 57A190 | 100.7 | 05-Apr-89 | 725 | 25 | 12700 |
| 57A190 | 100.7 | 03-May-89 | 715 | 25 | 21300 |
| 57A190 | 100.7 | 07-Jun-89 | 800 | 27 | 11900 |
| 57A190 | 100.7 | 06-Jul-89 | 715 | 31 | 11700 |
| 57A190 | 100.7 | 09-Aug-89 | 720 | 38 | 477 |
| 57A190 | 100.7 | 06-Sep-89 | 735 | 23 | 1120 |
| 57A190 | 100.7 | 04-Oct-89 | 715 | 24 | 1910 |
| 57A190 | 100.7 | 08-Nov-89 | 705 | 22 | 2140 |
| 57A190 | 100.7 | 06-Dec-89 | 720 | 30 | 11300 |
| 57A190 | 100.7 | 10-Jan-90 | 735 | 25 | 9800 |
| 57A190 | 100.7 | 07-Feb-90 | 735 | 24 | 5240 |
| 57A190 | 100.7 | 07-Mar-90 | 720 | 25 | 7500 |
| 57A190 | 100.7 | 04-Apr-90 | 750 | 24 | 14400 |
| 57A190 | 100.7 | 09-May-90 | 735 | 20 | 16400 |
| 57A190 | 100.7 | 06-Jun-90 | 730 | 17 | 24100 |
| 57A190 | 100.7 | 11-Jul-90 | 710 | 21 | 2480 |
| 57A190 | 100.7 | 08-Aug-90 | 745 | 24 | 695 |
| 57A190 | 100.7 | 05-Sep-90 | 655 | 23 | 395 |
| 57A190 | 100.7 | 10-Oct-90 | 725 | 23 | 1470 |
| 57A190 | 100.7 | 07-Nov-90 | 720 | 23 | 2980 |
| 57A150 | 96.0 | 05-Dec-90 | 720 | 24 | 15600 |
| 57A150 | 96.0 | 09-Jan-91 | 730 | 23 | 4500 |
| 57A150 | 96.0 | 06-Feb-91 | 710 | 23 | 5730 |
| 57A150 | 96.0 | 06-Mar-91 | 700 | 23 | 17100 |
| 57A150 | 96.0 | 03-Apr-91 | 710 | 23 | 6040 |
| 57A150 | 96.0 | 08-May-91 | 720 | 22 | 13000 |
| 57A150 | 96.0 | 05-Jun-91 | 645 | 23 | 13500 |
| 57A150 | 96.0 | 10-Jul-91 | 700 | 20 | 4550 |
| 57A150 | 96.0 | 07-Aug-91 | 645 | 20 | 1950 |
| 57A150 | 96.0 | 04-Sep-91 | 705 | 21 | 749 |
| 57A150 | 96.0 | 09-Oct-91 | 705 | 999999 | 1910 |
| 57A150 | 96.0 | 06-Nov-91 | 710 | 20 | 2150 |
| 57A150 | 96.0 | 04-Dec-91 | 710 | 21 | 2600 |
| 57A150 | 96.0 | 08-Jan-92 | 710 | 999999 | 3030 |
| 57A150 | 96.0 | 05-Feb-92 | 715 | 22 | 6810 |
| 57A150 | 96.0 | 04-Mar-92 | 645 | 999999 | 10400 |
| 57A150 | 96.0 | 08-Apr-92 | 645 | 999999 | 6890 |
| 57A150 | 96.0 | 06-May-92 | 630 | 999999 | 5050 |
| 57A150 | 96.0 | 03-Jun-92 | 635 | 999999 | 2530 |
| 57A150 | 96.0 | 08-Jul-92 | 640 | 999999 | 1150 |
| 57A150 | 96.0 | 05-Aug-92 | 610 | 999999 | 647 |
| 57A150 | 96.0 | 10-Sep-92 | 640 | 999999 | 237 |
| 57A150 | 96.0 | 07-Oct-92 | 700 | 999999 | 1440 |
| 57A150 | 96.0 | 04-Nov-92 | 643 | 999999 | 2030 |
| 57A150 | 96.0 | 03-Dec-92 | 730 | 999999 | 3260 |
| 57A150 | 96.0 | 06-Jan-93 | 750 | 999999 | 2070 |
| 57A150 | 96.0 | 03-Feb-93 | 700 | 999999 | 2280 |
| 57A150 | 96.0 | 03-Mar-93 | 620 | 999999 | 1820 |
| 57A150 | 96.0 | 07-Apr-93 | 645 | 999999 | 18000 |
| 57A150 | 96.0 | 05-May-93 | 730 | 999999 | 16000 |
| 57A150 | 96.0 | 09-Jun-93 | 805 | 999999 | 5700 |
| 57A150 | 96.0 | 07-Jul-93 | 700 | 999999 | 4050 |
| 57A150 | 96.0 | 04-Aug-93 | 710 | 999999 | 1230 |
| 57A150 | 96.0 | 08-Sep-93 | 710 | 999999 | 1160 |

Regression of hardness and flow for station 54A120 (HARDREGR.WK1, 07-Apr-94 )

(RM66)

| Data from Oct-83 to Sep-93 sorted by flow | Log base 10 [Flow (cfs)] Xi | Log base 10 [Hardness (mg/L as CaCO3)] Yi | XiYi | Xi^2 | Yi^2 |
|---|---|---|---|---|---|
| | 2.480006 | 1.991226 | 4.938254 | 6.150434 | 3.964981 |
| | 2.875061 | 2.041392 | 5.869129 | 8.265977 | 4.167284 |
| | 2.963315 | 2.012837 | 5.964671 | 8.781238 | 4.051513 |
| | 3.041392 | 2.041392 | 6.208676 | 9.250069 | 4.167284 |
| | 3.096910 | 1.982271 | 6.138915 | 9.590851 | 3.929399 |
| | 3.103803 | 1.886490 | 5.855296 | 9.633597 | 3.558847 |
| | 3.107209 | 1.929418 | 5.995109 | 9.654753 | 3.722657 |
| | 3.133538 | 2.012837 | 6.307303 | 9.819066 | 4.051513 |
| | 3.136720 | 1.897627 | 5.952325 | 9.839015 | 3.600988 |
| | 3.173186 | 1.869231 | 5.931420 | 10.06911 | 3.494027 |
| | 3.176091 | 1.924279 | 6.111686 | 10.08755 | 3.702850 |
| | 3.225309 | 2.082785 | 6.717626 | 10.40261 | 4.337994 |
| | 3.255272 | 1.832508 | 5.965315 | 10.59679 | 3.358088 |
| | 3.260071 | 1.863322 | 6.074565 | 10.62806 | 3.471972 |
| | 3.271841 | 1.845098 | 6.036868 | 10.70494 | 3.404386 |
| | 3.287801 | 1.903089 | 6.256982 | 10.80984 | 3.621751 |
| | 3.303196 | 1.838849 | 6.074079 | 10.91110 | 3.381365 |
| | 3.330413 | 1.763427 | 5.872944 | 11.09165 | 3.109678 |
| | 3.359835 | 1.778151 | 5.974295 | 11.28849 | 3.161821 |
| | 3.369215 | 1.778151 | 5.990975 | 11.35161 | 3.161821 |
| | 3.372912 | 1.857332 | 6.264619 | 11.37653 | 3.449684 |
| | 3.385606 | 1.763427 | 5.970272 | 11.46232 | 3.109678 |
| | 3.432969 | 1.792391 | 6.153225 | 11.78527 | 3.212667 |
| | 3.445604 | 1.755874 | 6.050049 | 11.87218 | 3.083096 |
| | 3.510545 | 1.785329 | 6.267480 | 12.32392 | 3.187402 |
| | 3.513217 | 1.792391 | 6.297062 | 12.34269 | 3.212667 |
| | 3.523746 | 1.740362 | 6.132596 | 12.41678 | 3.028862 |
| | 3.530199 | 1.778151 | 6.277229 | 12.46230 | 3.161821 |
| | 3.541579 | 1.707570 | 6.047495 | 12.54278 | 2.915795 |
| | 3.618048 | 1.602059 | 5.796330 | 13.09027 | 2.566596 |
| | 3.659916 | 1.763427 | 6.453998 | 13.39498 | 3.109678 |
| | 3.683947 | 1.681241 | 6.193603 | 13.57146 | 2.826572 |
| | 3.690196 | 1.653212 | 6.100678 | 13.61754 | 2.733111 |
| | 3.722633 | 1.653212 | 6.154304 | 13.85800 | 2.733111 |
| | 3.732393 | 1.643452 | 6.134012 | 13.93076 | 2.700936 |
| | 3.778151 | 1.579783 | 5.968661 | 14.27442 | 2.495716 |
| | 3.783903 | 1.681241 | 6.361654 | 14.31792 | 2.826572 |
| | 3.806858 | 1.591064 | 6.056957 | 14.49216 | 2.531486 |
| | 3.860338 | 1.579783 | 6.098498 | 14.90220 | 2.495716 |
| | 3.883661 | 1.579783 | 6.135344 | 15.08282 | 2.495716 |
| | 3.894869 | 1.579783 | 6.153051 | 15.17000 | 2.495716 |
| | 4.004321 | 1.431363 | 5.731640 | 16.03458 | 2.048802 |
| | 4.041392 | 1.623249 | 6.560187 | 16.33285 | 2.634938 |
| | 4.045322 | 1.612783 | 6.524231 | 16.36463 | 2.601071 |
| | 4.064457 | 1.477121 | 6.003697 | 16.51981 | 2.181887 |
| | 4.064457 | 1.462397 | 5.943855 | 16.51981 | 2.138607 |
| | 4.107209 | 1.462397 | 6.006375 | 16.86917 | 2.138607 |
| | 4.110589 | 1.633468 | 6.714518 | 16.89694 | 2.668219 |
| | 4.110589 | 1.491361 | 6.130376 | 16.89694 | 2.224159 |
| | 4.161368 | 1.531478 | 6.373047 | 17.31698 | 2.345427 |
| | 4.198657 | 1.568201 | 6.584341 | 17.62872 | 2.459256 |
| | 4.204119 | 1.462397 | 6.148096 | 17.67462 | 2.138607 |
| | 4.209515 | 1.414973 | 5.956351 | 17.72001 | 2.002149 |
| | 4.281033 | 1.462397 | 6.260574 | 18.32724 | 2.138607 |
| | 4.332438 | 1.447158 | 6.269723 | 18.77002 | 2.094266 |
| | 4.382017 | 1.342422 | 5.882519 | 19.20207 | 1.802098 |
| SUM : | 201.6389 | 96.25844 | 342.3931 | 736.2885 | 167.4095 |
| N : | 56 | | | | |
| MEAN : | 3.600696 | 1.718900 | | | |

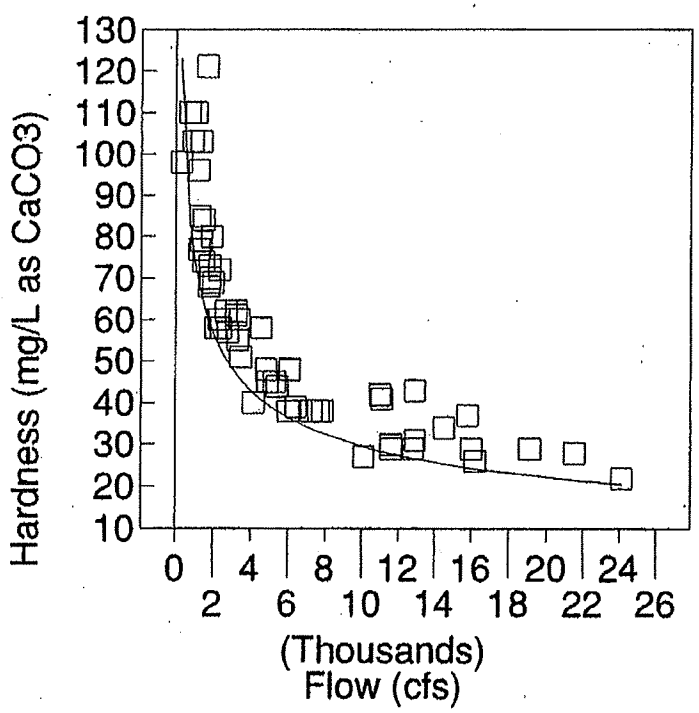
Regression of hardness and flow for station 54A120 (HARDREGR.WK1, 07-Apr-94 )

| SOURCE OF VARIATION | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE |
|---|---|---|---|
| TOTAL | 1.950829 | 55 | |
| LINEAR REGRESSION | 1.724865 | 1 | 1.7248654 |
| RESIDUAL | 0.225963 | 54 | 0.0041845 |

| | |
|---|---|
| Slope (B): | -0.41026 |
| Y intercept: | 3.196130 |
| R squared: | 0.884170 |
| F Statistic: | 412.2020 |
| Std Err of B: | 0.020207 |
| Std Err of Y estimate: | 0.064687 |

Plot of observed hardness and lower 90% confidence limit of predicted hardness (using 1-tailed t-statistic, probability=0.10) at Station 54A120

Hardness vs Flow at 54A120 (Km 66)




□Observation —Lwr 90% Pred. Limit

Comparison of hardness at Ecology
stations 54A120 and 57A145, WY 1973 (sorted by 54A120)
File HARDHARD.WK1
06-Apr-94

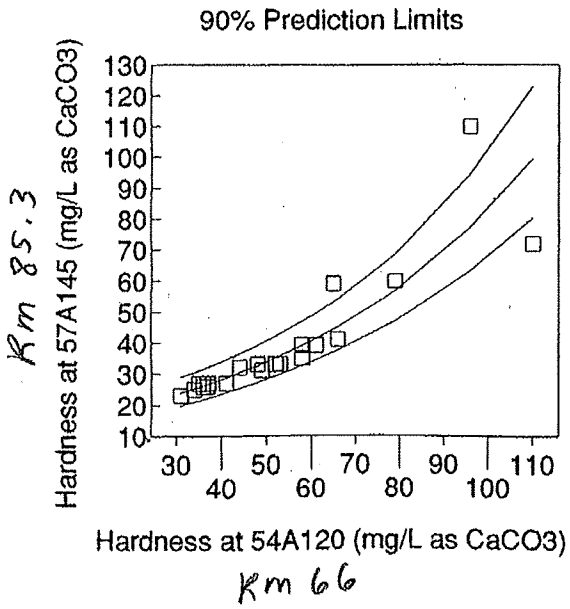
| Date | Hardness (mg/L as CaCO3) at 54A120 | Hardness (mg/L as CaCO3) at 57A145 |
|---|---|---|
| | Rm 66 | Rm 85.3 |
| 730424 | 31 | 23 |
| 721227 | 34 | 25 |
| 730327 | 35 | 27 |
| 730410 | 36 | 27 |
| 730313 | 36 | 26 |
| 721212 | 36 | 26 |
| 730320 | 37 | 26 |
| 730118 | 37 | 27 |
| 730612 | 41 | 27 |
| 730222 | 44 | 32 |
| 730925 | 48 | 33 |
| 730227 | 49 | 31 |
| 730626 | 52 | 33 |
| 730912 | 53 | 33 |
| 721010 | 58 | 35 |
| 721119 | 58 | 39 |
| 721031 | 61 | 39 |
| 730711 | 65 | 59 |
| 721129 | 66 | 41 |
| 730821 | 79 | 60 |
| 730724 | 96 | 110 |
| 730807 | 110 | 72 |

Regression of hardness at station 57A145 vs 54A120 (HARDREG2.WK1)

| Data from Oct-72 to Sep-73 sorted by 54A120 | Hardness (mg/L as CaCO3) @ 54A120 (RM 66.0) Xi | Log base 10 [Hardness (mg/L as CaCO3)] @ 57A145 (RM 85.3) Yi | XiYi | Xi^2 | Yi^2 |
|---|---|---|---|---|---|
| | 31 | 1.361727 | 42.21356 | 961 | 1.854302 |
| | 34 | 1.397940 | 47.52996 | 1156 | 1.954236 |
| | 35 | 1.431363 | 50.09773 | 1225 | 2.048802 |
| | 36 | 1.431363 | 51.52909 | 1296 | 2.048802 |
| | 36 | 1.414973 | 50.93904 | 1296 | 2.002149 |
| | 36 | 1.414973 | 50.93904 | 1296 | 2.002149 |
| | 37 | 1.414973 | 52.35401 | 1369 | 2.002149 |
| | 37 | 1.431363 | 52.96045 | 1369 | 2.048802 |
| | 41 | 1.431363 | 58.68591 | 1681 | 2.048802 |
| | 44 | 1.505149 | 66.22659 | 1936 | 2.265476 |
| | 48 | 1.518513 | 72.88866 | 2304 | 2.305884 |
| | 49 | 1.491361 | 73.07672 | 2401 | 2.224159 |
| | 52 | 1.518513 | 78.96272 | 2704 | 2.305884 |
| | 53 | 1.518513 | 80.48123 | 2809 | 2.305884 |
| | 58 | 1.544068 | 89.55594 | 3364 | 2.384146 |
| | 58 | 1.591064 | 92.28174 | 3364 | 2.531486 |
| | 61 | 1.591064 | 97.05494 | 3721 | 2.531486 |
| | 65 | 1.770852 | 115.1053 | 4225 | 3.135916 |
| | 66 | 1.612783 | 106.4437 | 4356 | 2.601071 |
| | 79 | 1.776151 | 140.4739 | 6241 | 3.161821 |
| | 96 | 2.041392 | 195.9736 | 9216 | 4.167284 |
| | 110 | 1.857332 | 204.3065 | 12100 | 3.449684 |
| SUM : | 1162 | 34.05880 | 1870.080 | 70390 | 53.38038 |
| N : | 22 | | | | |
| MEAN : | 52.81818 | 1.548582 | | | |

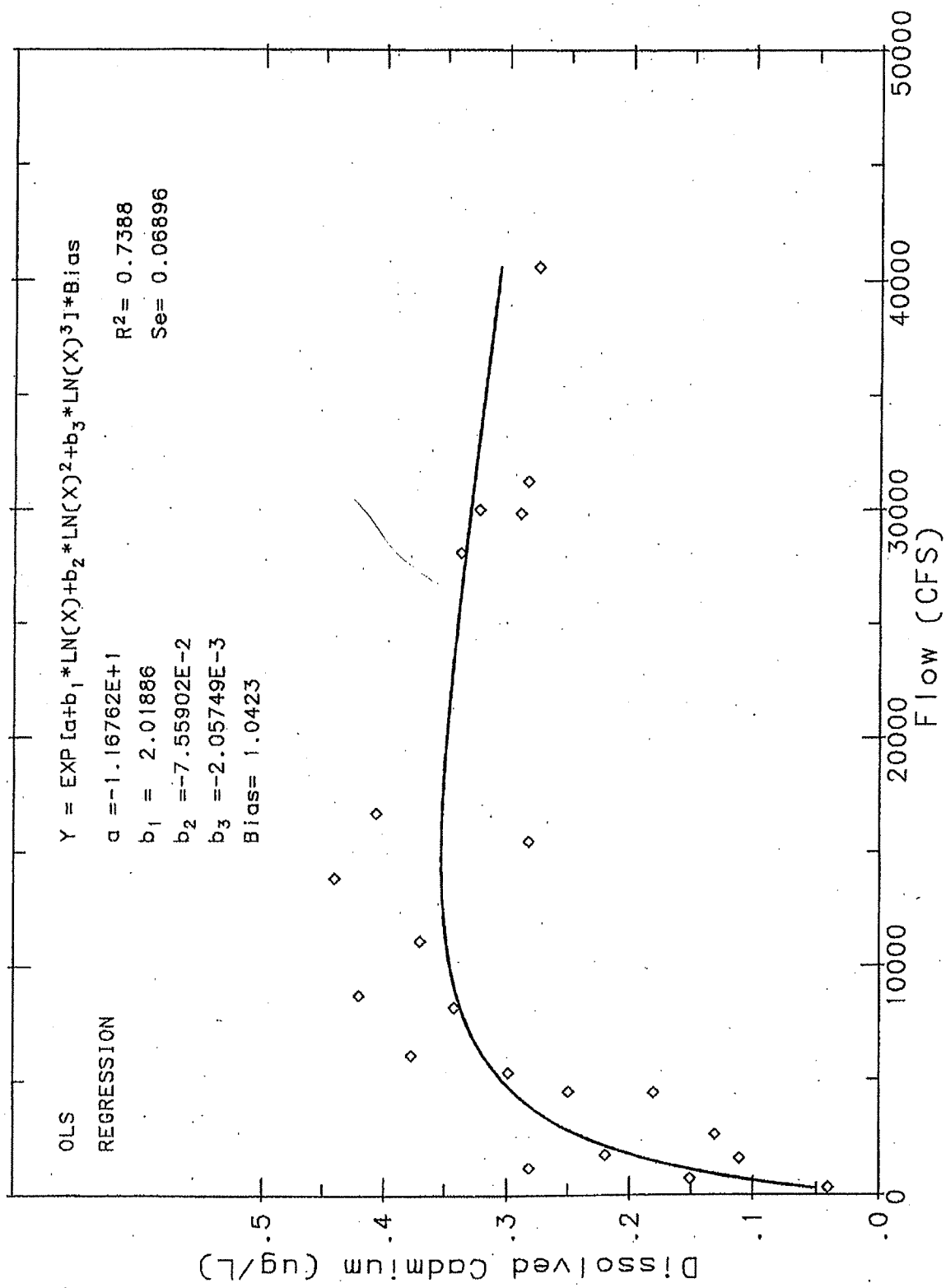
| SOURCE OF VARIATION | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE |
|---|---|---|---|
| TOTAL | 0.622041 | 21 | |
| LINEAR REGRESSION | 0.553323 | 1 | 0.553323 |
| RESIDUAL | 0.068717 | 20 | 0.003435 |

| | |
|---|---|
| Slope (B): | 0.007834 |
| Y-Intercept: | 1.134788 |
| R squared: | 0.889528 |
| F Statistic: | 161.0423 |
| Std Err of B: | 0.000617 |
| Std Err of Y estimate: | 0.058616 |

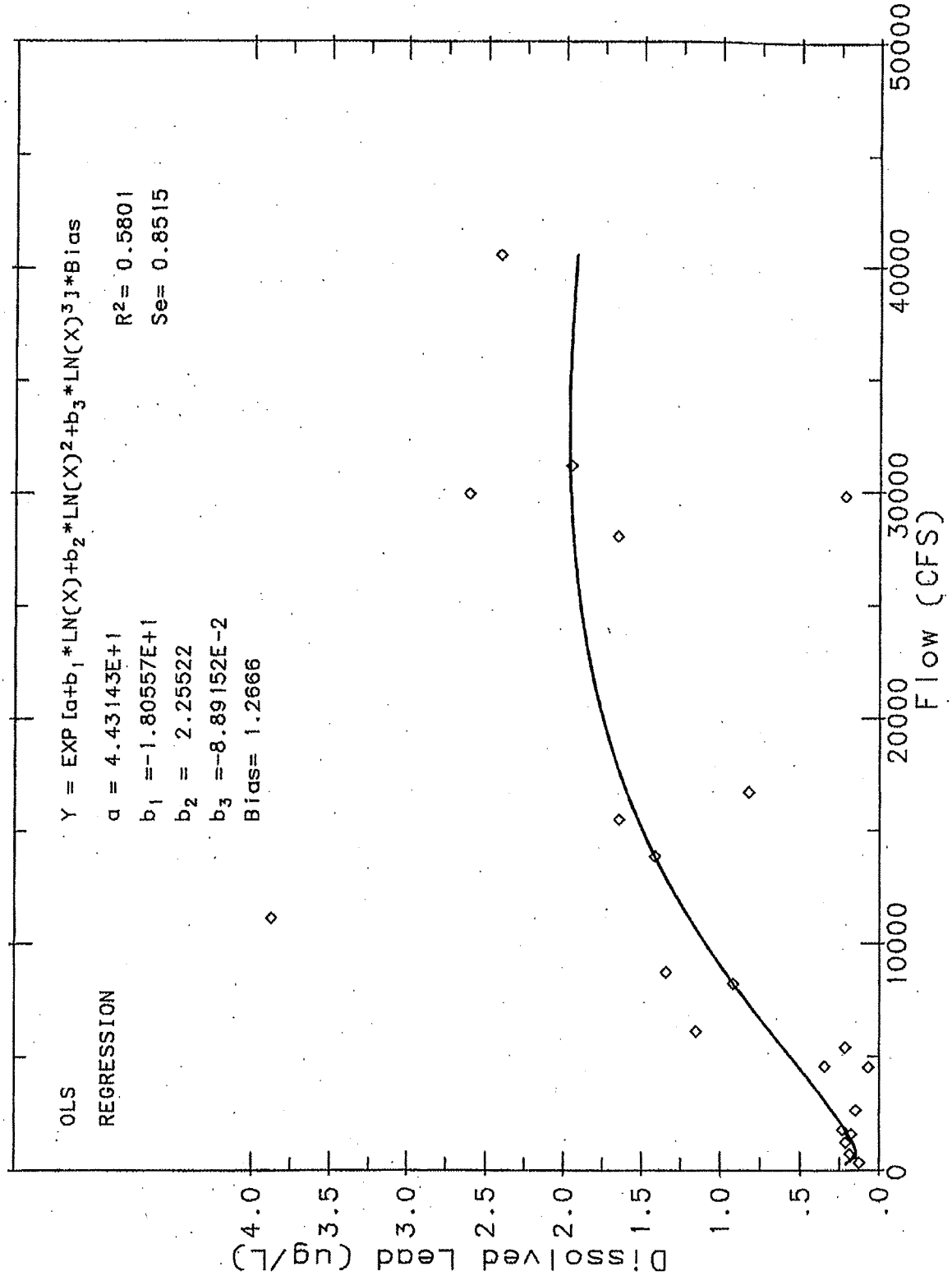


# Appendix C.2

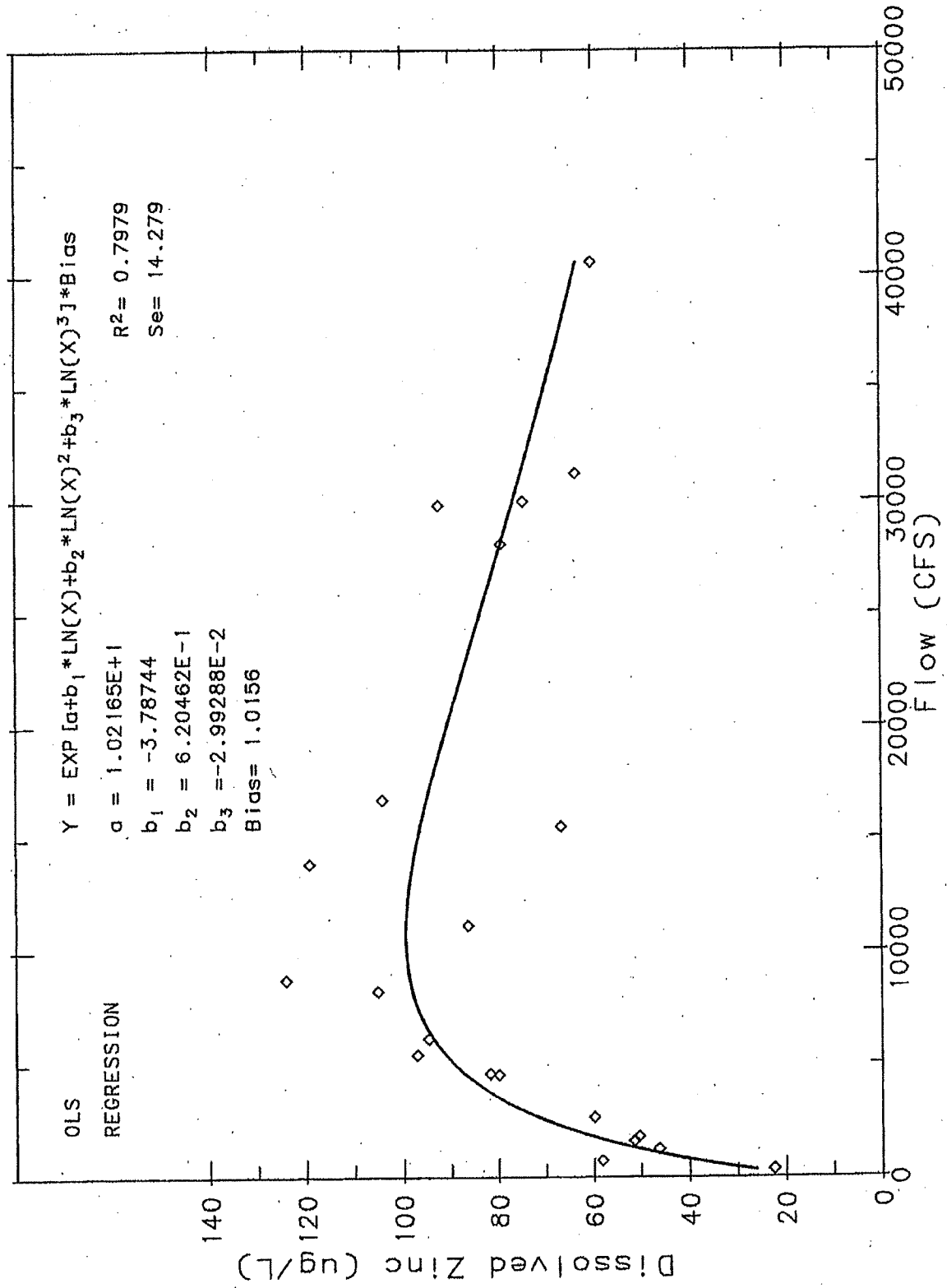
## Metals data from the Spokane River at the Stateline Bridge at river mile 96 (compiled by Hopkins and Johnson, 1997)




Dissolved Cadmium vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997




Dissolved Lead vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997




Dissolved Zinc vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997

**Ecology Spokane River Metals Data, April - June 1997**

| Date | Location | Sample Number | Hardness (mg/L) | Dissolved Metals (ug/L) Zinc | Lead | Cadmium | Copper | EPA 1995 Water Quality Criteria (ug/L) Zinc (acute) | Lead (chronic) | Cadmium (chronic) | Copper (chronic) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-Apr | Stateline Bridge - center | 156172 | 23.2 | **119** | **1.41** | **0.440** | **0.860** | 33 | 0.50 | 0.35 | 3.3 |
| | filter blank | 156175 | -- | 0.53 | < 0.02 | < 0.02 | < 0.05 | | | | |
| 6-May | Stateline Bridge - center | 196172 | 20.3 | **74.5** | **2.69** | **0.318** | **0.632** | 29 | 0.42 | 0.31 | 2.9 |
| | field split of above sample | 196174 | 20.0 | **74.1** | **2.50** | **0.326** | **0.617** | 29 | 0.42 | 0.31 | 2.9 |
| | Riverside State Park - right bank | 196177 | 25.1 | **73.9** | **2.47** | **0.307** | **0.659** | 35 | 0.54 | 0.37 | 3.5 |
| | filter blank | 196176 | -- | 0.25 | < 0.02 | < 0.02 | < 0.05 | | | | |
| | bottle blank | 196175 | -- | < 0.2 | < 0.02 | < 0.02 | < 0.05 | | | | |
| 12-May | 2.5 mi. above stateline - right bank | 208085 | 19.0 | **61.8** | **2.01** | **0.283** | **0.549** | 28 | 0.40 | 0.30 | 2.8 |
| | 2.5 mi. above stateline - left bank | 208084 | 18.3 | **63.7** | **2.01** | **0.278** | **0.599** | 27 | 0.37 | 0.29 | 2.6 |
| | Stateline - right bank, above bridge | 208083 | 18.8 | **62.7** | **1.97** | **0.283** | **0.610** | 28 | 0.40 | 0.30 | 2.8 |
| | Stateline Bridge - right | 208080 | 18.8 | **64.8** | **1.89** | **0.282** | **0.580** | 28 | 0.40 | 0.30 | 2.8 |
| | Stateline Bridge - center | 208081 | 19.3 | **61.0** | **1.93** | **0.275** | **0.576** | 28 | 0.40 | 0.30 | 2.8 |
| | lab split of above sample | 208090 | 18.4 | **62.7** | **1.93** | **0.289** | **0.740** | 27 | 0.37 | 0.29 | 2.6 |
| | Stateline Bridge - left | 208082 | 18.9 | **63.9** | **1.99** | **0.284** | **0.658** | 28 | 0.40 | 0.30 | 2.8 |
| | T.J. Meenach Bridge - center | 208086 | 22.4 | **61.3** | **1.93** | **0.282** | **0.636** | 32 | 0.47 | 0.34 | 3.1 |
| | Riverside State Park - right bank | 208087 | 23.4 | **61.3** | **1.84** | **0.281** | **0.628** | 33 | 0.50 | 0.35 | 3.3 |
| | lab split of above sample | 208093 | 18.4 | **59.9** | **1.87** | **0.289** | **0.570** | 27 | 0.37 | 0.29 | 2.6 |
| | Bridge bw. Long Lk. Dam - center | 208089 | 27.8 | **42.0** | **1.38** | **0.120** | **0.653** | 39 | 0.61 | 0.40 | 3.8 |
| | filter blank | 208091 | -- | 0.78 | < 0.02 | < 0.02 | < 0.05 | | | | |
| | transfer blank | 208094 | -- | < 0.2 | < 0.02 | < 0.02 | < 0.05 | | | | |
| | bottle blank | 208092 | -- | 8.79 | 0.021 | < 0.02 | 0.370 | | | | |
| 20-May | 2.5 mi. above stateline - right bank | 218005 | 18.3 | **58.0** | **2.47** | **0.277** | **0.582** | 27 | 0.37 | 0.29 | 2.6 |
| | Stateline - right bank, above bridge | 218006 | 18.2 | **59.9** | **2.41** | **0.275** | **0.591** | 27 | 0.37 | 0.29 | 2.6 |
| | Riverside State Park- right bank | 218008 | 21.6 | **54.2** | **2.17** | **0.250** | **0.728** | 32 | 0.47 | 0.34 | 3.1 |
| 3-Jun | Stateline Bridge - center | 236172 | 16.3 | **78.9** | **1.65** | **0.337** | **0.640** | 24 | 0.33 | 0.27 | 2.4 |
| | T.J. Meenach Bridge - center | 236177 | 38.0 | **67.2** | **1.41** | **0.288** | **0.771** | 50 | 0.87 | 0.50 | 5.0 |
| | Riverside State Park - right bank | 236176 | 24.0 | **72.1** | **1.51** | **0.310** | **0.608** | 33 | 0.50 | 0.35 | 3.3 |

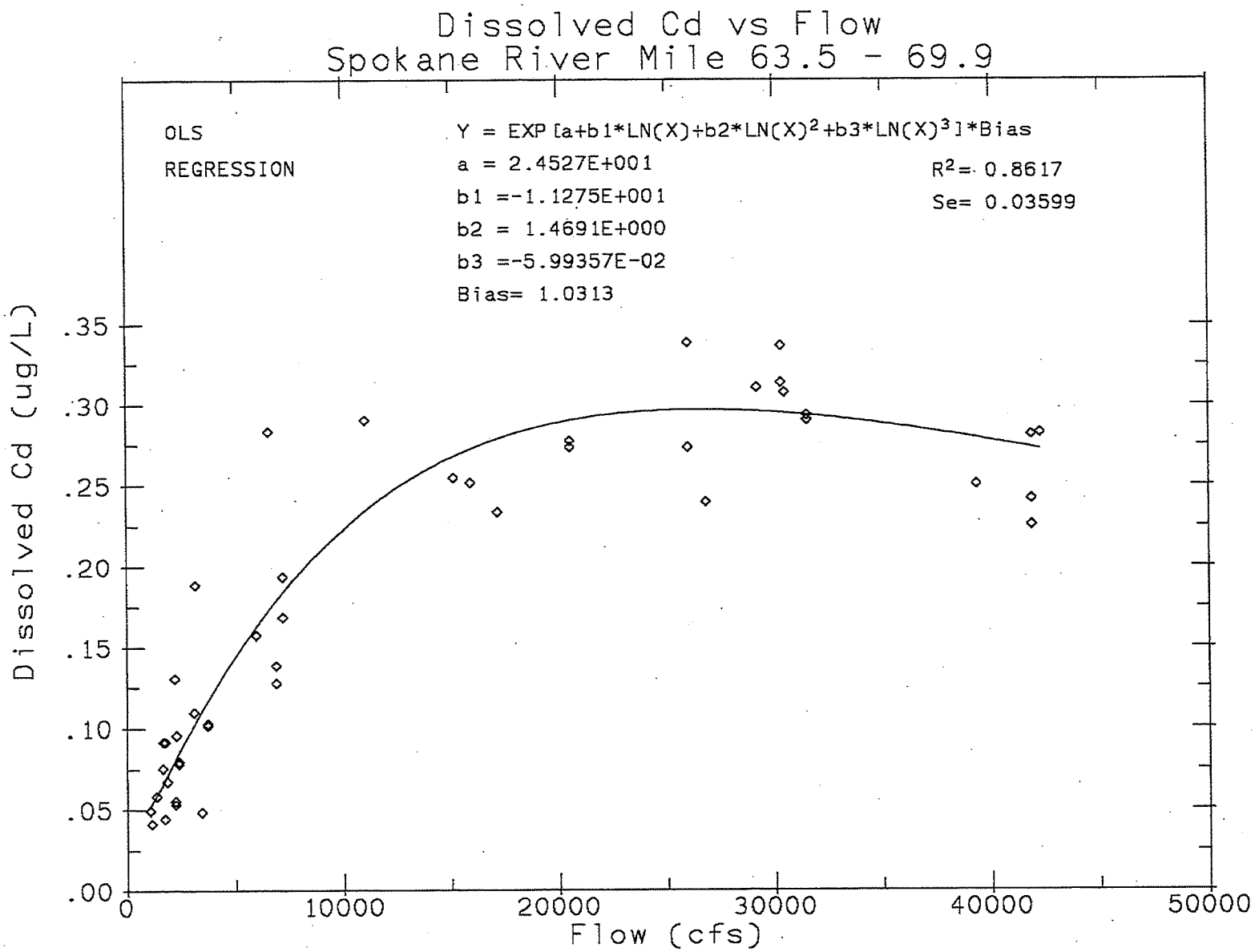
Station No.: 57A150 SPOKANE R @ STATELINE BR Water Class: A Latitude: 47 41 55.0
Water Body No.: WA-57-1010 River Mile: 96.00 Longitude: 117 02 37.0

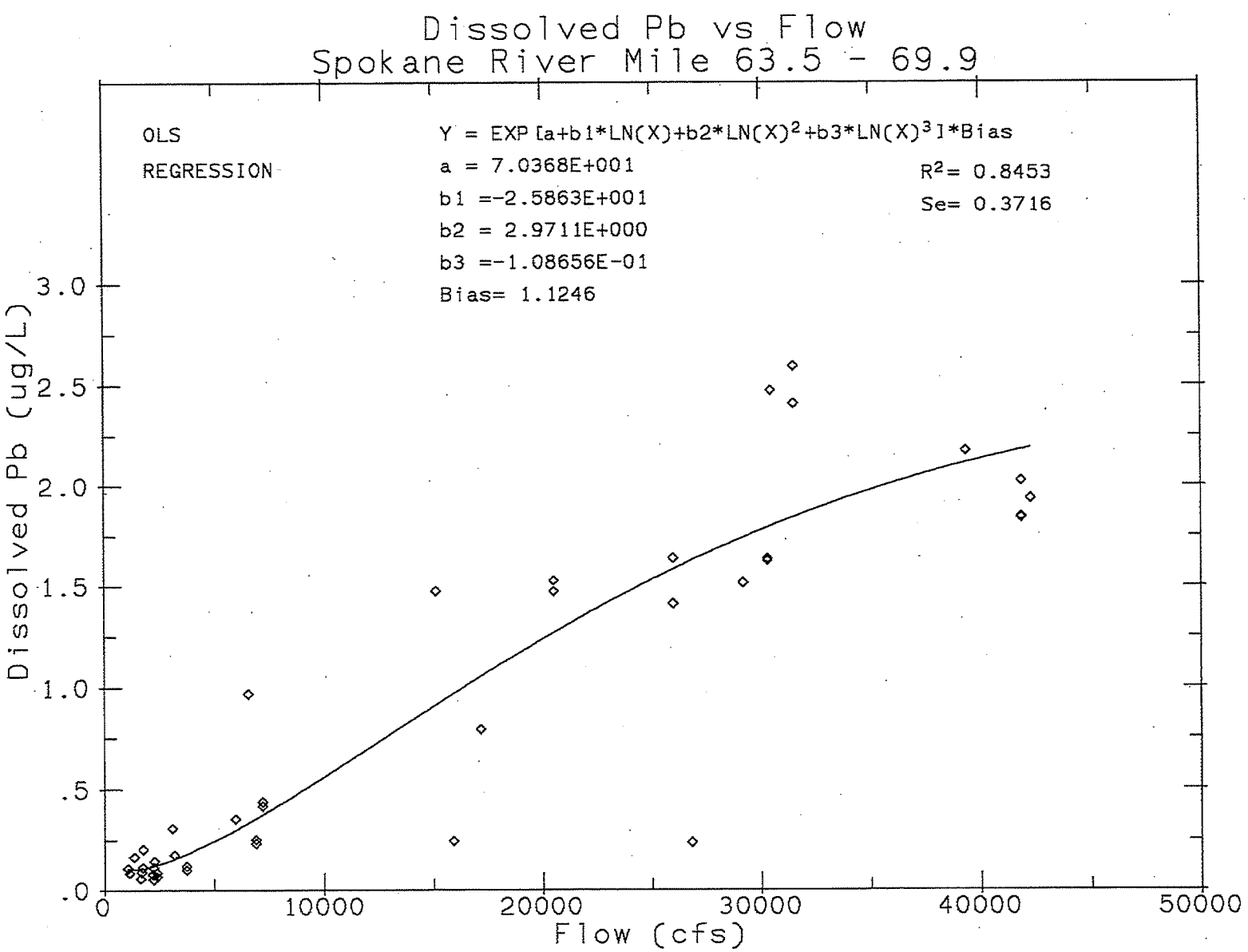
| Date | Time | Flow (CFS) | Copper (ug/L) | Lead (ug/L) | Zinc (ug/L) | Cadmium (ug/L) | Cadmium Dissol. (ug/L) | Copper Dissol. (ug/L) | Lead Dissol (ug/L) | Zinc Dissol. (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 94/04/05 | 1010 | 7090.0 | | | | | | | | |
| 94/05/03 | 0950 | 5380.0 | | | | | 0.298 P | 1.420 | 0.209 | 96.900 |
| 94/06/07 | 1010 | 3900.0 | | | | | | | | |
| 94/07/06 | 0955 | 697.0 | | | | | 0.150 P | 0.496 P | 0.180 P | 58.000 |
| 94/08/02 | 1020 | 366.0 | | | | | | | | |
| 94/09/06 | 1000 | 303.0 | | | | | 0.040 U | 0.400 P | 0.120 P | 22.300 |
| 94/10/10 | 1105 | 1450.0 | | | | | | | | |
| 94/11/07 | 1040 | 2630.0 | | | | | 0.130 P | 0.495 P | 0.143 P | 59.700 |
| 94/12/05 | 1135 | 1460.0 | | | | | | | | |
| 95/01/09 | 1015 | 4490.0 | 14.0 P | 20.0 U | 79.5 | 3.00 U | 0.180 P | 0.440 P | 0.064 P | 79.700 |
| 95/02/06 | 1100 | 14400.0 | | | | | | | | |
| 95/03/06 | 1115 | 16700.0 | | | | | 0.406 | 0.706 | 0.818 | 104.000 |
| 95/04/03 | 1125 | 12700.0 | | | | | | | | |
| 95/05/02 | 1120 | 9020.0 | | | | | | | | |
| 95/06/05 | 0930 | 5800.0 | | | | | | | | |
| 95/07/10 | 0820 | 3080.0 | | | | | | | | |
| 95/08/07 | 1050 | 746.0 | | | | | | | | |
| 95/09/05 | 0820 | 424.0 | | | | | | | | |
| 95/10/02 | 1010 | 1570.0 | 0.4 | 1.4 | 48.4 N | 0.16 | 0.110 | 0.410 | 0.172 | 51.200 |
| 95/11/06 | 0940 | 3680.0 | | | | | | | | |
| 95/12/04 | 0945 | 29800.0 | 0.6 | 3.7 | 102.0 B | 0.47 | 0.289 | 0.345 | 0.212 | 92.100 |
| 96/01/08 | 1010 | 8370.0 | | | | | | | | |
| 96/02/05 | 0920 | 6100.0 | 0.9 | 5.4 | 89.6 | 0.46 | 0.377 | 0.841 | 1.150 | 94.500 |
| 96/03/04 | 1010 | 16000.0 | | | | | | | | |
| 96/04/09 | 0945 | 11100.0 | 1.1 | 14.8 | 82.3 | 0.40 | 0.370 | 0.931 | 3.870 | 86.100 |
| 96/05/06 | 0955 | 19800.0 | | | | | | | | |
| 96/06/03 | 1100 | 15500.0 | 0.9 | 5.6 | 67.1 J | 0.34 | 0.282 | 0.547 | 1.640 | 66.500 |
| 96/07/08 | 1205 | 3070.0 | | | | | | | | |
| 96/08/05 | 1010 | 1200.0 | 1.1 | 1.4 | 45.7 | 0.45 | 0.281 | 0.450 | 0.206 | 46.100 |
| 96/09/03 | 1105 | 615.0 | | | | | | | | |
| 96/10/08 | 0945 | 1750.0 | 0.8 J | 1.2 | 46.9 J | 0.18 | 0.219 | 0.500 | 0.227 | 50.200 J |
| 96/11/05 | 0940 | 2780.0 | | | | | | | | |
| 96/12/03 | 0930 | 4550.0 | 0.6 | 1.5 | 78.6 | 0.30 | 0.249 | 0.450 | 0.340 | 81.600 |
| 97/01/14 | 0945 | 13300.0 | | | | | | | | |
| 97/02/04 | 0945 | 8210.0 | 0.7 | 3.1 | 110.0 J | 0.34 | 0.342 | 0.593 | 0.914 | 105.000 |

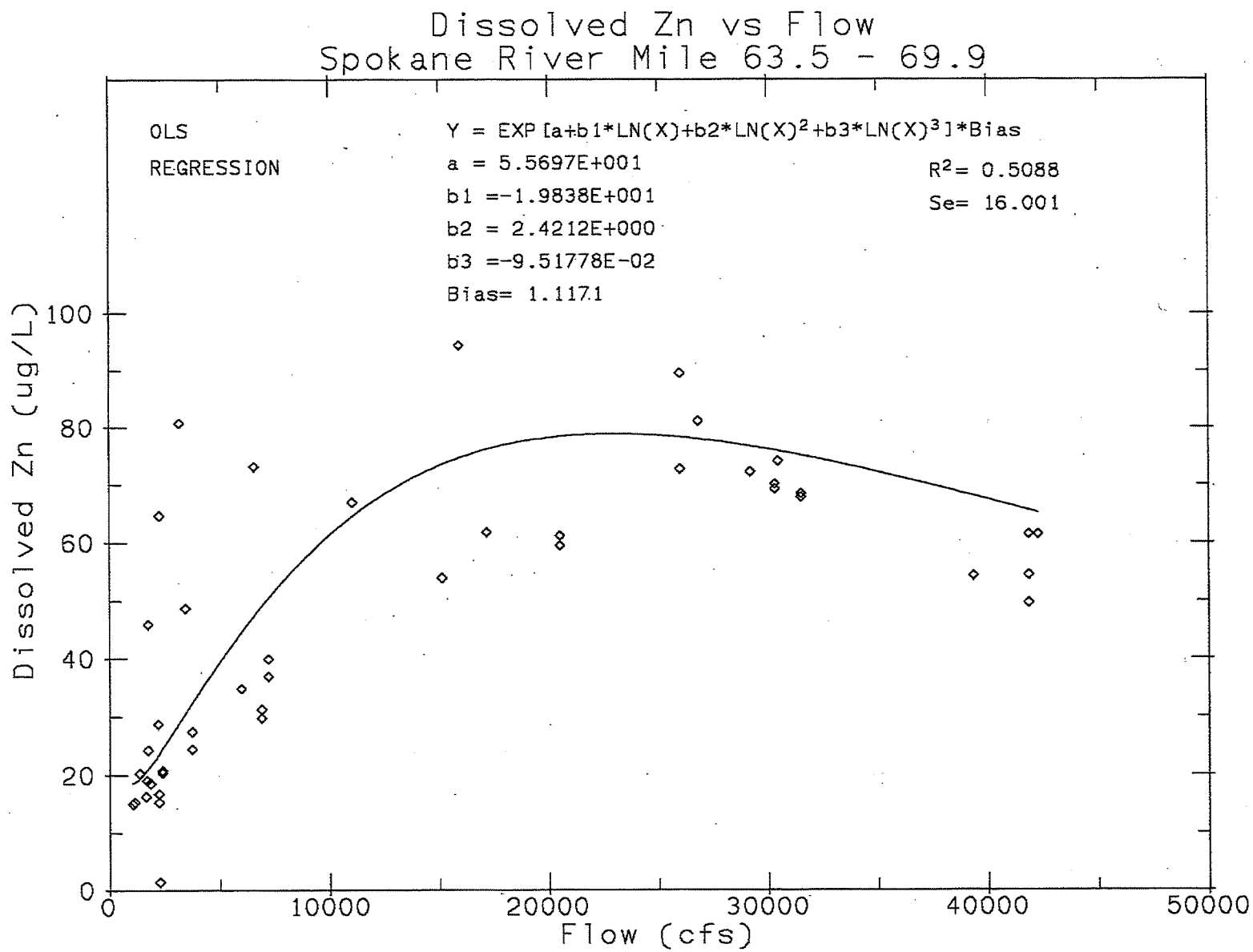
Remarks: U,K - Below reporting limit; B - analyte in blank; X - background organisms; J - Estimate; S - Spreader colonies, P - below quantitation limit.

# Appendix C.3

## Metals data from Spokane River between river miles 63.5–69.9 (compiled by CH2M Hill, 1997)


Dissolved Cd vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP [a+b1*LN(X)+b2*LN(X)2+b3*LN(X)3]*Bias
a = 2.4527E+001
b1 =-1.1275E+001
b2 = 1.4691E+000
b3 =-5.99357E-02
Bias= 1.0313
R2= 0.8617
Se= 0.03599
Dissolved Cd (ug/L)
.00
.05
.10
.15
.20
.25
.30
.35
0
10000
20000
30000
40000
50000
Flow (cfs)


Dissolved Pb vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP [a+b1*LN(X)+b2*LN(X)2+b3*LN(X)3]*Bias
a = 7.0368E+001
b1 =-2.5863E+001
b2 = 2.9711E+000
b3 =-1.08656E-01
Bias= 1.1246
R2= 0.8453
Se= 0.3716
Dissolved Pb (ug/L)
3.0
2.5
2.0
1.5
1.0
.5
.0
0
10000
20000
30000
40000
50000
Flow (cfs)


Dissolved Zn vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP[a+b1*LN(X)+b2*LN(X)²+b3*LN(X)³]*Bias
a = 5.5697E+001
b1 =-1.9838E+001
b2 = 2.4212E+000
b3 =-9.51778E-02
Bias= 1.1171
R²= 0.5088
Se= 16.001
Dissolved Zn (ug/L)
0
20
40
60
80
100
0
10000
20000
30000
40000
50000
Flow (cfs)

Appendix C3. Metals daa from Spokane River Mile 63.5-69.9 (compiled by CH2M-Hill, 1997).

**DATA FOR GRAPHING - Undetected Values not included. All Concentrations in ug/L.**

| SOURCE | STA | Name | River Mile | Date | Flow (cfs) | TR Ag | Dis Ag | TR Cd | Dis Cd | TR Cu | Dis Cu | TR Hg | TR Pb | Dis Pb | TR Zn | Dis Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 6/27/96 | 5944 | | | 0.2325 | 0.1575 | 0.399 | 0.1915 | 0.000382 | 1.99 | 0.351 | 45.7 | 34.7 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 7/12/96 | 3072 | | | 0.225 | 0.109 | 0.25 | 0.15 | 0.00144 | 1.32 | 0.306 | 45.2 | |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 7/19/96 | 2174 | | 0.001285 | 0.163 | 0.13 | 0.258 | 0.151 | 0.000863 | 0.92 | 0.0752 | 35.4 | 28.6 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 7/26/96 | 1827 | 0.12 | | 0.129 | 0.0667 | 0.414 | 0.0886 | 0.0001995 | 1.01 | | 127 | 18.5 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 8/12/96 | 1624 | 0.0181 | | 0.1 | 0.07535 | 0.462 | 0.324 | 0.000359 | 0.894 | 0.05535 | 23 | 16.25 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 8/19/96 | 1036 | | | 0.0688 | 0.0488 | 0.535 | 0.306 | 0.000281 | 0.751 | 0.105 | 20.7 | 14.9 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 9/5/96 | 1115 | 0.0506 | 0.0199 | 0.0747 | 0.04115 | 0.505 | 0.438 | 0.000557 | 1.83 | 0.0824 | 18.6 | 15.2 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 9/12/96 | 2250 | | | 0.0956 | | 0.576 | 0.035 | 0.000363 | 1.76 | | 23.2 | 1.34 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 4/25/97 | 25970 | 0.0246 | 0.0673 | 0.559 | 0.338 | 1.23 | 0.752 | 0.00232 | 7.70 | 1.63 | 113 | 89.4 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 5/7/97 | 30552 | 0.0369 | 0.0134 | 0.401 | 0.290 | 0.978 | 0.5858 | 0.00305 | 11.6 | 2.40 | 88.2 | 67.7 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 5/19/97 | 41095 | 0.0475 | 0.0110 | 0.466 | 0.225 | 1.4347 | 0.5775 | 0.01463 | 18.4 | 1.83 | 84.5 | 49.5 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 6/2/97 | 30039 | 0.0119 | 0.0198 | 0.446 | 0.313 | 0.9725 | 0.5801 | 0.00093 | 9.9 | 1.63 | 89.2 | 69.1 |
| SAWTP | FW | Fort Wright (Meenach Bridge) | 69.9 | 6/16/97 | 21351 | 0.0164 | 0.0147 | 0.436 | 0.277 | 0.7026 | 0.5084 | 0.00138 | 7.4 | 1.52 | 78.9 | 61.0 |
| DOE | B&P | 54A120 | 66 | 10/2/95 | 1720 | | | | 0.044 | | 0.488 | 0.0010 | | 0.110 | | 24.1 |
| DOE | B&P | 54A120 | 66 | 8/5/96 | 1660 | | | | 0.091 | | 0.450 | 0.0010 | | 0.087 | | 19.0 |
| DOE | B&P | 54A120 | 66 | 12/4/95 | 26800 | | | | 0.239 | | 0.416 | 0.0010 | | 0.232 | | 80.9 |
| DOE | B&P | 54A120 | 66 | 6/3/96 | 15100 | | | | 0.254 | | 0.510 | 0.0010 | | 1.470 | | 53.8 |
| DOE | B&P | 54A120 | 66 | 2/5/96 | 6540 | | | | 0.283 | | 0.698 | 0.0010 | | 0.966 | | 73.0 |
| DOE | B&P | 54A120 | 66 | 4/9/96 | 11000 | | | | 0.290 | | 0.931 | 0.0010 | | 4.270 | | 66.8 |
| DOE | | Rifle Club | 63.5-64.5 | 7/28/92 | 1326 | | | 0.098 | 0.058 | 1.0900 | 0.184 | 0.00086 | 0.896 | 0.163 | 40.9 | 20.2 |
| DOE | | Rifle Club | 63.5-64.6 | 9/24/92 | 1836.3 | | | 0.137 | | 1.2500 | | | 1.5 | | 51.6 | |
| DOE | | Rifle Club | 63.5-64.7 | 11/25/92 | 3153 | | | 0.203 | 0.188 | 1.0500 | 0.974 | 0.00122 | 1.0 | 0.17 | 105.0 | 80.6 |
| DOE | | Rifle Club | 63.5-64.8 | 1/27/93 | 3415 | | | 0.133 | 0.048 | 3.3300 | | 0.00414 | 2.3 | | 91.1 | 48.6 |
| DOE | | Rifle Club | 63.5-64.9 | 3/31/93 | 15882 | | | 0.501 | 0.251 | 1.2300 | 0.86 | 0.00365 | 3.2 | 0.24 | 179.0 | 94.3 |
| DOE | | Rifle Club | 63.5-64.10 | 5/25/93 | 17134 | | | 0.344 | 0.233 | 0.0670 | 0.48 | 0.00166 | 5.4 | 0.79 | 73.9 | 61.6 |
| DOE | | Rifle Club | 63.5-64.11 | 8/11/93 | 2246 | | | 0.127 | 0.095 | 1.2600 | 1.18 | 0.00091 | 0.6 | 0.14 | 77.0 | 64.5 |
| DOE | | Rifle Club | 63.5-64.12 | 9/8/93 | 1735 | | | 0.164 | 0.091 | 0.7400 | 0.61 | 0.00150 | 0.9 | 0.20 | 55.8 | 45.8 |
| DOE | | Riverside State Park - right bank | 66.0 | 5/8/97 | | | | | 0.307 | | 0.659 | | | 2.47 | | 73.9 |
| DOE | | T.J. Meenach bridge - center | 66.0 | 5/19/97 | | | | | 0.282 | | 0.636 | | | 1.93 | | 61.3 |
| DOE | | Riverside State Park - right bank | 66.0 | 5/20/97 | | | | | 0.281 | | 0.628 | | | 1.84 | | 61.3 |
| DOE | | Riverside State Park- right bank | 66.0 | 5/22/97 | | | | | 0.250 | | 0.728 | | | 2.17 | | 54.2 |
| DOE | | Riverside State Park - right bank | 66.0 | 6/5/97 | | | | | 0.310 | | 0.608 | | | 1.51 | | 72.1 |

# Appendix C.4

## Model calibration for hardness, cadmium, lead, zinc (calibration location are shown in the shaded cells)

# Appendix C4a. Model calibration results for Cd (shaded cells show calibration checks for the mass balance).

| Spokane River Model Reaches | | | Effluent Characteristics | | | | | Aquifer/Tributary Inflow/Outflow | | | | Reach Mass Balance Calculations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River Model Reach Number | Up-stream River Mile | Down-stream River Mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total Recoverable Cd (ug/L) | | Inflow/ Outflow (cfs) | Inflow Hardness (mg/L as CaCO3) (2) | Inflow Dissolved Cd (ug/L) (1) (3) | Flow at Upstream End of Reach (cfs) | Flow at Downstream End of Reach (cfs) | Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3) | Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3) | Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of Dissolved/ Total Recoverable Cd | Mass Balance Dissolved Cd at Upstream End of Reach (ug/L) | Mass Balance Dissolved Cd at Down-stream End of Reach after complete mix (ug/L) | Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Cd at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3) |
| 0 | – | 111.7 | *Lake CDA Outlet* | | | | | *Lk CDA Outlet (1)* | 1,000 | 20.0 | 0.23 | – | 1,000 | – | 20 | | 0.976 | – | 0.23 | |
| 1 | 111.7 | 106.6 | *CDA STP* | 6 | 9.28 | 145 | 0.30 | | | | | 1,000 | 1,009 | 20 | 21 | | 0.974 | 0.23 | 0.23 | |
| 2 | 106.6 | 101.7 | *Hayden STP* | 1.3 | 2.01 | 145 | 0.30 | | | | | 1,009 | 1,011 | 21 | 21 | | 0.974 | 0.23 | 0.23 | |
| 3 | 101.7 | 96.0 | *Post Falls STP* | 3.1 | 4.80 | 145 | 0.30 | *Aquifer Inflow/Outflow* | 6.09 | 85.0 | 0.008 | 1,011 | 1,022 | 21 | 22 | 20 | 0.972 | 0.23 | 0.23 | 0.23 |
| 4 | 96.0 | 93.0 | | | | | | *Aquifer Inflow/Outflow* | 2.56 | 85.0 | 0.008 | 1,022 | 1,025 | 22 | 23 | | 0.971 | 0.23 | 0.23 | |
| 5 | 93.0 | 90.4 | *Liberty Lake STP* | 1 | 1.55 | 145 | 0.30 | | | | | 1,025 | 1,026 | 23 | 23 | | 0.971 | 0.23 | 0.23 | |
| 6 | 90.4 | 87.8 | | | | | | | | | | 1,026 | 1,026 | 23 | 23 | | 0.971 | 0.23 | 0.23 | |
| 7 | 87.8 | 85.3 | *Kaiser* | 23.3 | 36.05 | 120 | 0.30 | *Aquifer Inflow* | 337.14 | 85.0 | 0.008 | 990 | 1,363 | 23 | 41 | | 0.947 | 0.23 | 0.17 | |
| 8 | 85.3 | 82.6 | | | | | | | | | | 1,363 | 1,363 | 41 | 41 | 42 | 0.947 | 0.17 | 0.17 | |
| 9 | 82.6 | 79.8 | *IEPCo* | 4 | 6.19 | 145 | 0.30 | *Aquifer Inflow* | -256.20 | na | na | 1,363 | 1,113 | 41 | 41 | | 0.946 | 0.17 | 0.17 | |
| 10 | 79.8 | 78.0 | | | | | | *Aquifer Inflow* | 394.97 | 85.0 | 0.008 | 1,113 | 1,508 | 41 | 53 | | 0.936 | 0.17 | 0.13 | |
| 11 | 78.0 | 74.1 | | | | | | *Aquifer Outflow* | -179.70 | na | na | 1,508 | 1,329 | 53 | 53 | | 0.936 | 0.13 | 0.13 | |
| 12 | 74.1 | 69.8 | | | | | | *Hangman Cr + Aquifer* | 158.62 | 85.0 | 0.008 | 1,329 | 1,487 | 53 | 56 | | 0.933 | 0.13 | 0.12 | |
| 13 | 69.8 | 67.6 | | | | | | *Aquifer Inflow* | 42.75 | 85.0 | 0.008 | 1,487 | 1,530 | 56 | 57 | | 0.933 | 0.12 | 0.11 | |
| 14 | 67.6 | 64.6 | *Spokane AWTP* | 44 | 68.08 | 145 | 0.30 | *Aquifer Inflow* | 58.30 | 85.0 | 0.008 | 1,530 | 1,656 | 57 | 62 | 62 | 0.929 | 0.11 | 0.11 | 0.11 |

(1) dissolved Cd was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness asssumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Cd assumed to be a 90%tile of 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion.

# Appendix C4b. Model calibration results for Pb (shaded cells show calibration checks for the mass balance).

| Spokane River Model Reaches | | | Effluent Characteristics | | | | | Aquifer/Tributary Inflow/Outflow | | | | Reach Mass Balance Calculations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River Model Reach Number | Up-stream River Mile | Down-stream River Mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total Recoverable Pb (ug/L) | | Inflow/Outflow (cfs) | Inflow Hardness (mg/L as CaCO3) (2) | Inflow Dissolved Pb (ug/L) (1) (3) | Flow at Upstream End of Reach (cfs) | Flow at Downstream End of Reach (cfs) | Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3) | Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3) | Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of Dissolved/ Total Recoverable Pb | Mass Balance Dissolved Pb at Upstream End of Reach (ug/L) | Mass Balance Dissolved Pb at Down-stream End of Reach after complete mix (ug/L) | Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Pb at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3) |
| 0 | -- | 111.7 | *Lake CDA Outlet* | | | | | *Lk CDA Outlet (1)* | 1,000 | 20.0 | 1.2 | -- | 1,000 | -- | 20 | | 1.00 | -- | 1.2 | |
| 1 | 111.7 | 106.6 | *CDA STP* | 6 | 9.28 | 145 | 2.5 | | | | | 1,000 | 1,009 | 20 | 21 | | 1.00 | 1.2 | 1.3 | |
| 2 | 106.6 | 101.7 | *Hayden STP* | 1.3 | 2.01 | 145 | 2.5 | | | | | 1,009 | 1,011 | 21 | 21 | | 1.00 | 1.3 | 1.3 | |
| 3 | 101.7 | 96.0 | *Post Falls STP* | 3.1 | 4.80 | 145 | 2.5 | *Aquifer Inflow/Outflow* | 6.09 | 85.0 | 0.09 | 1,011 | 1,022 | 21 | 22 | 20 | 1.00 | 1.3 | 1.3 | 1.2 |
| 4 | 96.0 | 93.0 | | | | | | *Aquifer Inflow/Outflow* | 2.56 | 85.0 | 0.09 | 1,022 | 1,025 | 22 | 23 | | 1.00 | 1.3 | 1.3 | |
| 5 | 93.0 | 90.4 | *Liberty Lake STP* | 1 | 1.55 | 145 | 2.5 | | | | | 1,025 | 1,026 | 23 | 23 | | 1.00 | 1.3 | 1.3 | |
| 6 | 90.4 | 87.8 | | | | | | | | | | 1,026 | 1,026 | 23 | 23 | | 1.00 | 1.3 | 1.3 | |
| 7 | 87.8 | 85.3 | *Kaiser* | 23.3 | 36.05 | 120 | 2.5 | *Aquifer Inflow* | 337.14 | 85.0 | 0.09 | 990 | 1,363 | 23 | 41 | | 0.92 | 1.3 | 0.9 | |
| 8 | 85.3 | 82.6 | | | | | | | | | | 1,363 | 1,363 | 41 | 41 | 42 | 0.92 | 0.9 | 0.9 | |
| 9 | 82.6 | 79.8 | *IEPCo* | 4 | 6.19 | 145 | 2.5 | *Aquifer Inflow* | -256.20 | na | na | 1,363 | 1,113 | 41 | 41 | | 0.92 | 0.9 | 0.9 | |
| 10 | 79.8 | 78.0 | | | | | | *Aquifer Inflow* | 394.97 | 85.0 | 0.09 | 1,113 | 1,508 | 41 | 53 | | 0.88 | 0.9 | 0.7 | |
| 11 | 78.0 | 74.1 | | | | | | *Aquifer Outflow* | -179.70 | na | na | 1,508 | 1,329 | 53 | 53 | | 0.88 | 0.7 | 0.7 | |
| 12 | 74.1 | 69.8 | | | | | | *Hangman Cr + Aquifer* | 158.62 | 85.0 | 0.09 | 1,329 | 1,487 | 53 | 56 | | 0.88 | 0.7 | 0.6 | |
| 13 | 69.8 | 67.6 | | | | | | *Aquifer Inflow* | 42.75 | 85.0 | 0.09 | 1,487 | 1,530 | 56 | 57 | | 0.87 | 0.6 | 0.6 | |
| 14 | 67.6 | 64.6 | *Spokane AWTP* | 44 | 68.08 | 145 | 2.5 | *Aquifer Inflow* | 58.30 | 85.0 | 0.09 | 1,530 | 1,656 | 57 | 62 | 62 | 0.86 | 0.6 | 0.6 | 0.6 |

(1) dissolved Pb was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness asssumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (Jerry Bills data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion.

# Appendix C4c. Model calibration results for Zn (shaded cells show calibration checks for the mass balance).

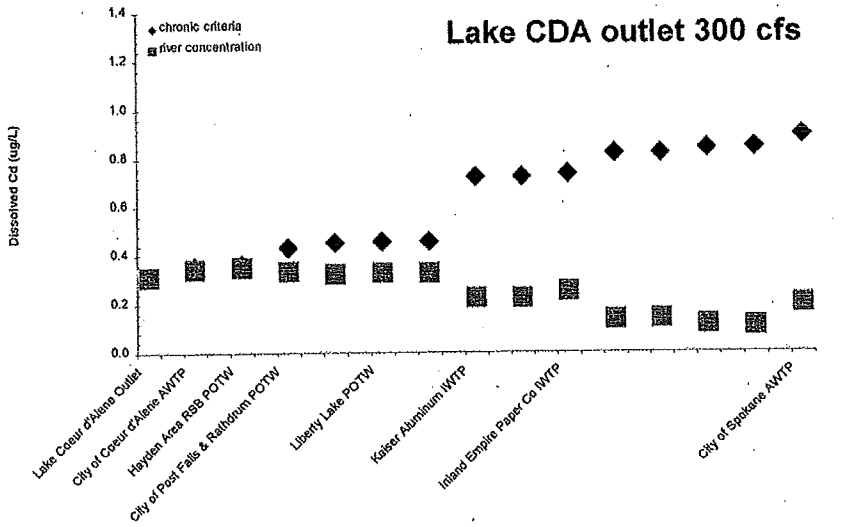
| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | Aquifer/Tributary Inflow/Outflow | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River Model Reach Number | Up-stream River Mile | Down-stream River Mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total Recoverable Zn (ug/L) | | Inflow/Outflow (cfs) | Inflow Hardness (mg/L as CaCO3) (2) | Inflow Dissolved Zn (ug/L) (1) (3) | Flow at Upstream End of Reach (cfs) | Flow at Downstream End of Reach (cfs) | Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3) | Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3) | Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of Dissolved/ Total Recoverable Zn | Mass Balance Dissolved Zinc at Upstream End of Reach (ug/L) | Mass Balance Dissolved Zn at Down-stream End of Reach after complete mix (ug/L) | Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Zn at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3) |
| 0 | -- | 111.7 | *Lake CDA Outlet* | | | | | *Lk CDA Outlet (1)* | 1,000 | 20.0 | 63.5 | -- | 1,000 | -- | 20 | | 0.986 | -- | 63.5 | |
| 1 | 111.7 | 106.6 | *CDA STP* | 6 | 9.28 | 145 | 100 | | | | | 1,000 | 1,009 | 20 | 21 | | 0.986 | 63.5 | 63.8 | |
| 2 | 106.6 | 101.7 | *Hayden STP* | 1.3 | 2.01 | 145 | 100 | | | | | 1,009 | 1,011 | 21 | 21 | | 0.986 | 63.8 | 63.9 | |
| 3 | 101.7 | 96.0 | *Post Falls STP* | 3.1 | 4.80 | 145 | 100 | *Aquifer Inflow/Outflow* | 6.09 | 85.0 | 18 | 1,011 | 1,022 | 21 | 22 | 20 | 0.986 | 63.9 | 63.8 | 63.5 |
| 4 | 96.0 | 93.0 | | | | | | *Aquifer Inflow/Outflow* | 2.56 | 85.0 | 18 | 1,022 | 1,025 | 22 | 23 | | 0.986 | 63.8 | 63.7 | |
| 5 | 93.0 | 90.4 | *Liberty Lake STP* | 1 | 1.55 | 145 | 100 | | | | | 1,025 | 1,026 | 23 | 23 | | 0.986 | 63.7 | 63.7 | |
| 6 | 90.4 | 87.8 | | | | | | | | | | 1,026 | 1,026 | 23 | 23 | | 0.986 | 63.7 | 63.7 | |
| 7 | 87.8 | 85.3 | *Kaiser* | 23.3 | 36.05 | 120 | 100 | *Aquifer Inflow* | 337.14 | 85.0 | 18 | 990 | 1,363 | 23 | 41 | | 0.986 | 63.7 | 53.3 | |
| 8 | 85.3 | 82.6 | | | | | | | | | | 1,363 | 1,363 | 41 | 41 | 42 | 0.986 | 53.3 | 53.3 | |
| 9 | 82.6 | 79.8 | *IEPCo* | 4 | 6.19 | 145 | 85 | *Aquifer Inflow* | -256.20 | na | na | 1,363 | 1,113 | 41 | 41 | | 0.986 | 53.3 | 53.6 | |
| 10 | 79.8 | 78.0 | | | | | | *Aquifer Inflow* | 394.97 | 85.0 | 18 | 1,113 | 1,508 | 41 | 53 | | 0.986 | 53.6 | 44.2 | |
| 11 | 78.0 | 74.1 | | | | | | *Aquifer Outflow* | -179.70 | na | na | 1,508 | 1,329 | 53 | 53 | | 0.986 | 44.2 | 44.3 | |
| 12 | 74.1 | 69.8 | | | | | | *Hangman Cr + Aquifer* | 158.62 | 85.0 | 18 | 1,329 | 1,487 | 53 | 56 | | 0.986 | 44.3 | 41.5 | |
| 13 | 69.8 | 67.6 | | | | | | *Aquifer Inflow* | 42.75 | 85.0 | 18 | 1,487 | 1,530 | 56 | 57 | | 0.986 | 41.5 | 40.8 | |
| 14 | 67.6 | 64.6 | *Spokane AWTP* | 44 | 68.08 | 145 | 100 | *Aquifer Inflow* | 58.30 | 85.0 | 18 | 1,530 | 1,656 | 57 | 62 | 62 | 0.986 | 40.8 | 42.4 | 42.4 |

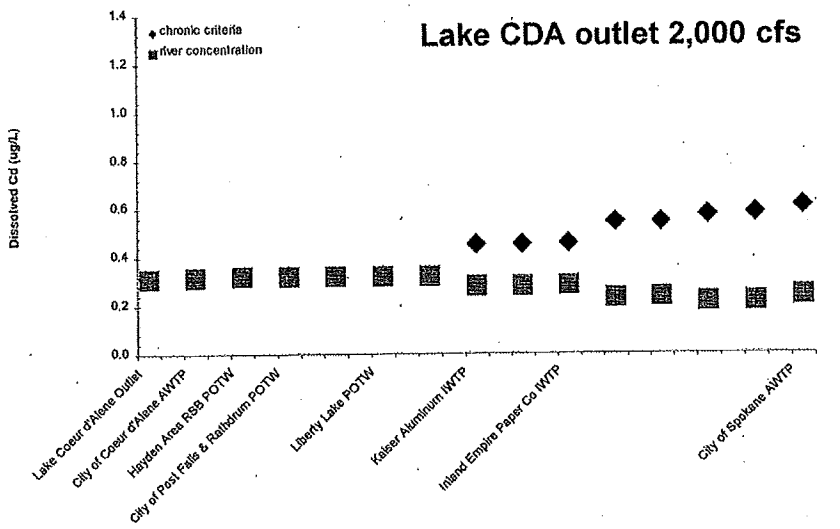
(1) dissolved Zn was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness asssumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Zn assumed to be a 90%tile of 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (Jerry Bills data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion is documented in wqhydro.regfile.di.zn.rm.66.doc

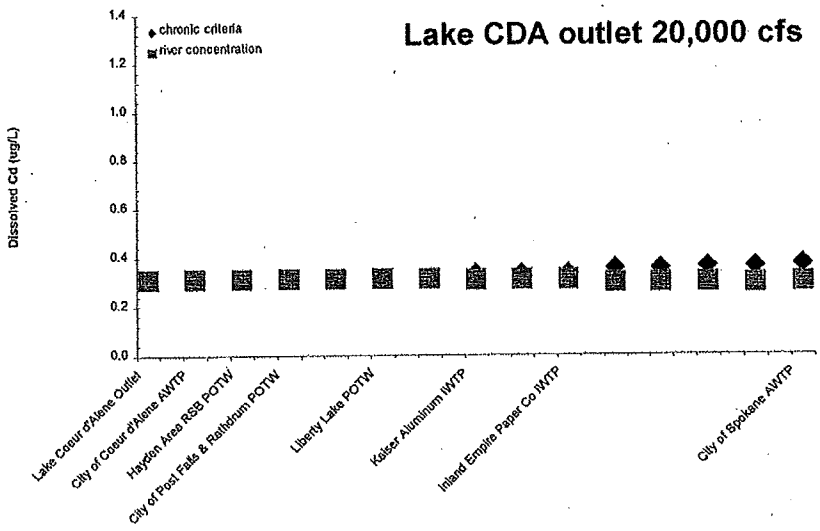
# Appendix D.1

# Results for Cadmium

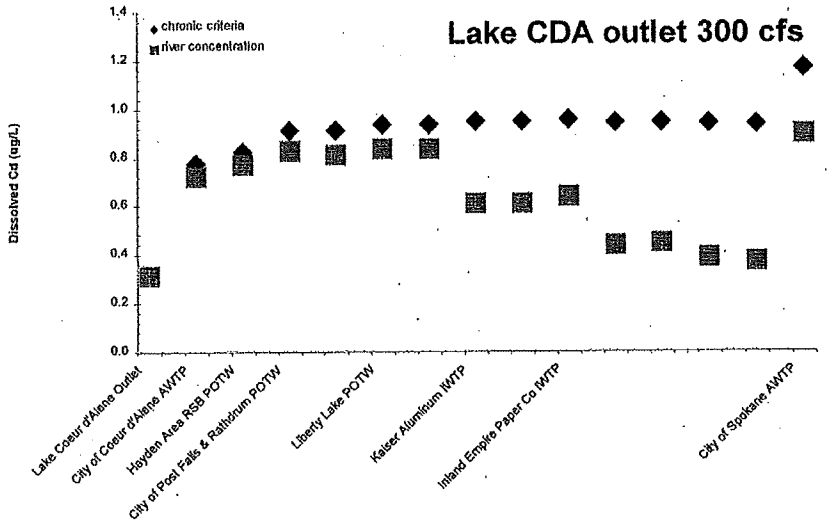
Dissolved Cd after complete mix at current effluent design flows.

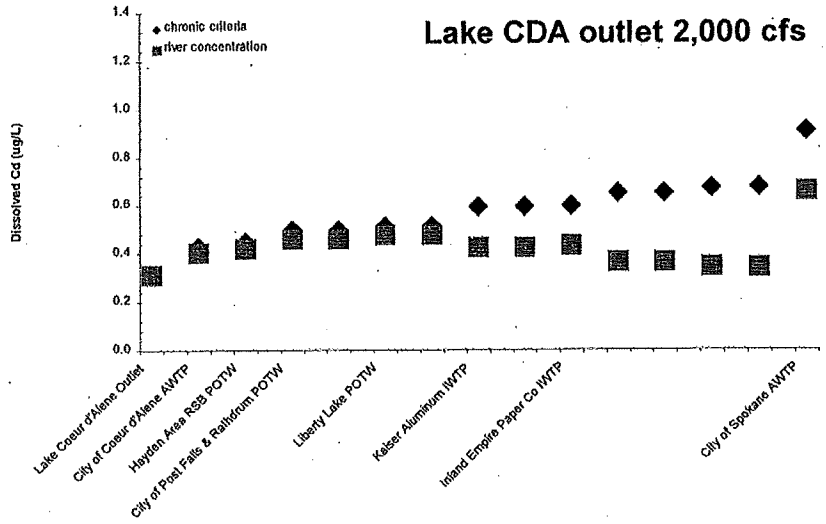


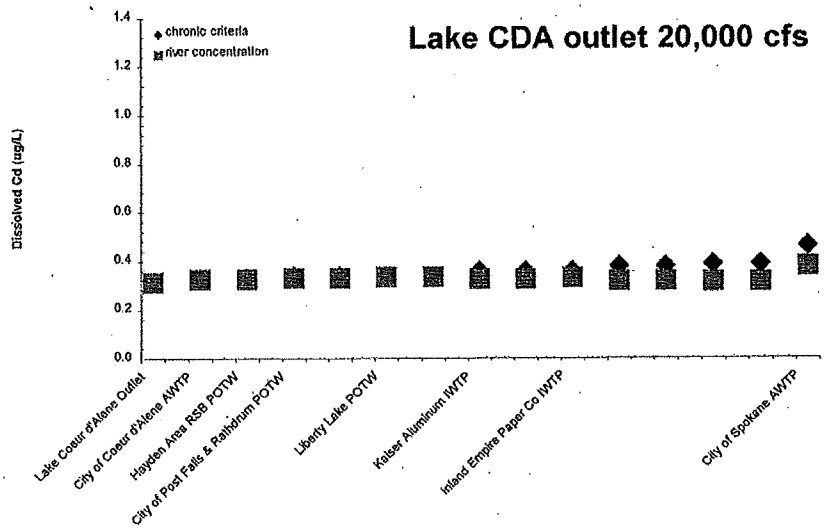



Dissolved Cd after complete mix at 20X current effluent design flows.



# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Cd (ug/L) | Effluent ratio of dissolved/total rec. Cd | Dissolved Cd (ug/L) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | – | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 1.31 | 0.901 | 1.18 | 4.51. | 1.18 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Cd (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Cd at down-stream end of reach | Mass balance dissolved Cd at upstream end of reach (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | -- | 111.7 | *Lk CDA Outlet (1)* | 300 | 20 | 0.31 | -- | 300 | -- | 20.0 | na | 0.976 | -- | 0.31 | |
| 1 | 111.7 | 106.6 | | | | | 300 | 309 | 20.0 | 23.8 | na | 0.969 | 0.31 | 0.35 | |
| 2 | 106.6 | 101.7 | | | | | 309 | 311 | 23.8 | 24.5 | na | 0.968 | 0.35 | 0.35 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | 28.05 | 85.0 | 0.008 | 311 | 344 | 24.5 | 31.1 | na | 0.958 | 0.35 | 0.34 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | 11.81 | 85.0 | 0.008 | 344 | 356 | 31.1 | 32.9 | na | 0.955 | 0.34 | 0.32 | |
| 5 | 93.0 | 90.4 | | | | | 356 | 357 | 32.9 | 33.4 | na | 0.955 | 0.32 | 0.33 | |
| 6 | 90.4 | 87.8 | | | | | 357 | 357 | 33.4 | 33.4 | na | 0.955 | 0.33 | 0.33 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 303.42 | 85.0 | 0.008 | 321 | 661 | 33.4 | 61.8 | na | 0.929 | 0.33 | 0.23 | |
| 8 | 85.3 | 82.6 | | | | | 661 | 661 | 61.8 | 61.8 | na | 0.929 | 0.23 | 0.23 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 661 | 411 | 61.8 | 63.1 | na | 0.928 | 0.23 | 0.25 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 355.47 | 85.0 | 0.008 | 411 | 766 | 63.1 | 73.2 | na | 0.922 | 0.25 | 0.14 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 766 | 587 | 73.2 | 73.2 | na | 0.922 | 0.14 | 0.14 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 144.77 | 85.0 | 0.008 | 587 | 731 | 73.2 | 75.6 | na | 0.921 | 0.14 | 0.11 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.008 | 731 | 774 | 75.6 | 76.1 | na | 0.920 | 0.11 | 0.11 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.008 | 774 | 901 | 76.1 | 81.9 | na | 0.917 | 0.11 | 0.20 | na |

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet

(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.

(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| Spokane River Model Reaches | | | NPDES Dischargers | Acute Mixing Zone Boundary | | | | | | Chronic Mixing Zone Boundary | | | | | | Complete Mix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | – | 111.7 | | | | | | | | | | | | | | 20.0 | 0.65 | 0.31 | 0.31 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 1.81 | 89.1 | 3.27 | 0.949 | 0.93 | Yes | 9.08 | 33.8 | 0.46 | 0.954 | 0.43 | Yes | 23.8 | 0.78 | 0.36 | 0.35 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 4.84 | 48.8 | 1.70 | 0.974 | 0.58 | Yes | 39.44 | 26.8 | 0.39 | 0.964 | 0.37 | Yes | 24.5 | 0.81 | 0.36 | 0.35 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 2.62 | 70.5 | 2.53 | 0.959 | 0.77 | Yes | 17.23 | 31.5 | 0.44 | 0.957 | 0.41 | Yes | 31.1 | 1.04 | 0.43 | 0.34 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 32.9 | 1.11 | 0.45 | 0.32 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 6.75 | 49.5 | 1.73 | 0.973 | 0.50 | Yes | 58.51 | 34.8 | 0.47 | 0.953 | 0.34 | Yes | 33.4 | 1.13 | 0.46 | 0.33 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 33.4 | 1.13 | 0.46 | 0.33 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 1.22 | 104.2 | 3.87 | 0.942 | 1.07 | Yes | 3.23 | 60.2 | 0.71 | 0.930 | 0.60 | Yes | 61.8 | 2.20 | 0.72 | 0.23 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 61.8 | 2.20 | 0.72 | 0.23 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 3.67 | 84.5 | 3.08 | 0.951 | 0.56 | Yes | 27.70 | 64.8 | 0.75 | 0.927 | 0.27 | Yes | 63.1 | 2.25 | 0.73 | 0.25 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 73.2 | 2.64 | 0.82 | 0.14 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 73.2 | 2.64 | 0.82 | 0.14 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 75.6 | 2.73 | 0.84 | 0.11 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 76.1 | 2.75 | 0.84 | 0.11 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.28 | 129.7 | 4.91 | 0.933 | 1.13 | Yes | 3.84 | 94.0 | 0.99 | 0.912 | 0.44 | Yes | 81.9 | 2.98 | 0.89 | 0.20 | Yes |

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Cd (ug/L) | Effluent ratio of dissolved/total rec. Cd | Dissolved Cd (ug/L) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 1.31 | 0.901 | 1.18 | 4.51 | 1.18 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Cd (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Cd at down-stream end of reach | Mass balance dissolved Cd at upstream end of reach (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | -- | 111.7 | *Lk CDA Outlet (1)* | 2,000 | 20 | 0.31 | -- | 2,000 | -- | 20.0 | na | 0.976 | -- | 0.31 | |
| 1 | 111.7 | 106.6 | | | | | 2,000 | 2,009 | 20.0 | 20.6 | na | 0.975 | 0.31 | 0.32 | |
| 2 | 106.6 | 101.7 | | | | | 2,009 | 2,011 | 20.6 | 20.7 | na | 0.975 | 0.32 | 0.32 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -25.27 | na | na | 2,011 | 1,991 | 20.7 | 21.0 | na | 0.974 | 0.32 | 0.32 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -10.64 | na | na | 1,991 | 1,980 | 21.0 | 21.0 | na | 0.974 | 0.32 | 0.32 | |
| 5 | 93.0 | 90.4 | | | | | 1,980 | 1,982 | 21.0 | 21.1 | na | 0.974 | 0.32 | 0.32 | |
| 6 | 90.4 | 87.8 | | | | | 1,982 | 1,982 | 21.1 | 21.1 | na | 0.974 | 0.32 | 0.32 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 385.30 | 85.0 | 0.008 | 1,946 | 2,367 | 21.1 | 33.0 | na | 0.955 | 0.32 | 0.28 | |
| 8 | 85.3 | 82.6 | | | | | 2,367 | 2,367 | 33.0 | 33.0 | na | 0.955 | 0.28 | 0.28 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 2,367 | 2,117 | 33.0 | 33.3 | na | 0.955 | 0.28 | 0.29 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 451.40 | 85.0 | 0.008 | 2,117 | 2,568 | 33.3 | 42.4 | na | 0.945 | 0.29 | 0.23 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -178.70 | na | na | 2,568 | 2,389 | 42.4 | 42.4 | na | 0.945 | 0.23 | 0.23 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 178.40 | 85.0 | 0.008 | 2,389 | 2,567 | 42.4 | 45.4 | na | 0.942 | 0.23 | 0.22 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.008 | 2,567 | 2,610 | 45.4 | 46.0 | na | 0.941 | 0.22 | 0.21 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.008 | 2,610 | 2,736 | 46.0 | 49.3 | na | 0.939 | 0.21 | 0.24 | na |

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *NPDES Dischargers* | *Acute Mixing Zone Boundary* | | | | | | *Chronic Mixing Zone Boundary* | | | | | | *Complete Mix* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | – | 111.7 | | | | | | | | | | | | | | 20.0 | 0.65 | 0.31 | 0.31 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6.39 | 39.6 | 1.35 | 0.983 | 0.50 | Yes | 54.86 | 22.3 | 0.34 | 0.972 | 0.33 | Yes | 20.6 | 0.67 | 0.32 | 0.32 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 25.97 | 25.4 | 0.84 | 1.001 | 0.37 | Yes | 250.74 | 21.1 | 0.33 | 0.974 | 0.32 | Yes | 20.7 | 0.67 | 0.32 | 0.32 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 11.48 | 31.5 | 1.06 | 0.992 | 0.43 | Yes | 105.84 | 21.9 | 0.33 | 0.973 | 0.33 | Yes | 21.0 | 0.68 | 0.32 | 0.32 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 21.0 | 0.68 | 0.32 | 0.32 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 33.00 | 24.8 | 0.81 | 1.002 | 0.37 | Yes | 320.96 | 21.4 | 0.33 | 0.974 | 0.33 | Yes | 21.1 | 0.68 | 0.33 | 0.32 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 21.1 | 0.68 | 0.33 | 0.32 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 2.35 | 63.2 | 2.25 | 0.963 | 0.72 | Yes | 14.49 | 27.9 | 0.40 | 0.962 | 0.38 | Yes | 33.0 | 1.11 | 0.45 | 0.28 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 33.0 | 1.11 | 0.45 | 0.28 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 10.56 | 43.6 | 1.51 | 0.979 | 0.40 | Yes | 96.62 | 34.2 | 0.47 | 0.954 | 0.29 | Yes | 33.3 | 1.12 | 0.46 | 0.29 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 42.4 | 1.46 | 0.55 | 0.23 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 42.4 | 1.46 | 0.55 | 0.23 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 45.4 | 1.57 | 0.57 | 0.22 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 46.0 | 1.60 | 0.58 | 0.21 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.96 | 96.6 | 3.56 | 0.945 | 0.84 | Yes | 10.58 | 55.4 | 0.67 | 0.934 | 0.33 | Yes | 49.3 | 1.72 | 0.61 | 0.24 | Yes |

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Cd (ug/L) | Effluent ratio of dissolved/total rec. Cd | Dissolved Cd (ug/L) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 1.31 | 0.901 | 1.18 | 4.51 | 1.18 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 1.52 | 0.893 | 1.36 | 5.54 | 1.36 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Cd (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Cd at down-stream end of reach | Mass balance dissolved Cd at upstream end of reach (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | – | 111.7 | *Lk CDA Outlet (1)* | 20,000 | 20 | 0.31 | – | 20,000 | – | 20.0 | na | 0.976 | – | 0.31 | |
| 1 | 111.7 | 106.6 | | | | | 20,000 | 20,009 | 20.0 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 2 | 106.6 | 101.7 | | | | | 20,009 | 20,011 | 20.1 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -88.01 | na | na | 20,011 | 19,928 | 20.1 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -37.06 | na | na | 19,928 | 19,891 | 20.1 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 5 | 93.0 | 90.4 | | | | | 19,891 | 19,893 | 20.1 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 6 | 90.4 | 87.8 | | | | | 19,893 | 19,893 | 20.1 | 20.1 | na | 0.976 | 0.31 | 0.31 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 481.64 | 85.0 | 0.008 | 19,857 | 20,374 | 20.1 | 21.8 | na | 0.973 | 0.31 | 0.31 | |
| 8 | 85.3 | 82.6 | | | | | 20,374 | 20,374 | 21.8 | 21.8 | na | 0.973 | 0.31 | 0.31 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 20,374 | 20,124 | 21.8 | 21.9 | na | 0.973 | 0.31 | 0.31 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 564.25 | 85.0 | 0.008 | 20,124 | 20,688 | 21.9 | 23.6 | na | 0.969 | 0.31 | 0.30 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 20,688 | 20,509 | 23.6 | 23.6 | na | 0.969 | 0.30 | 0.30 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 217.97 | 85.0 | 0.008 | 20,509 | 20,727 | 23.6 | 24.2 | na | 0.968 | 0.30 | 0.30 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.008 | 20,727 | 20,769 | 24.2 | 24.4 | na | 0.968 | 0.30 | 0.29 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.008 | 20,769 | 20,896 | 24.4 | 24.9 | na | 0.967 | 0.29 | 0.30 | na |

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Cadmium

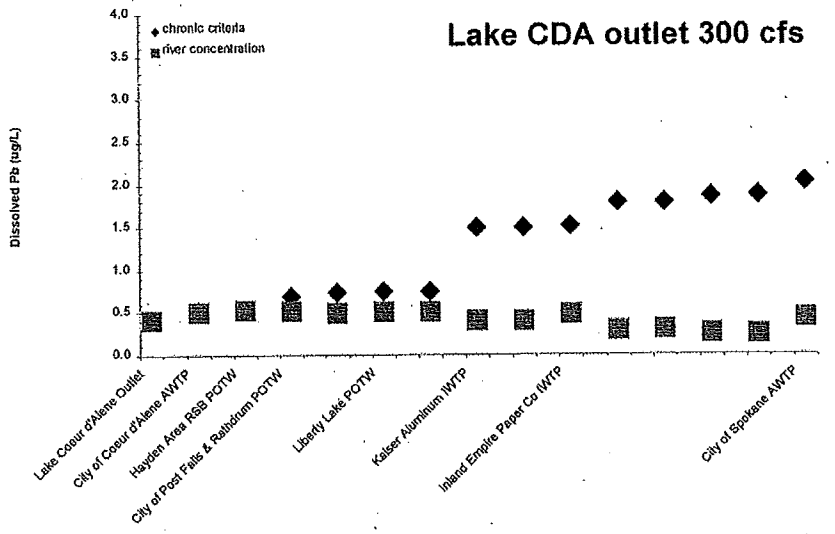
Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

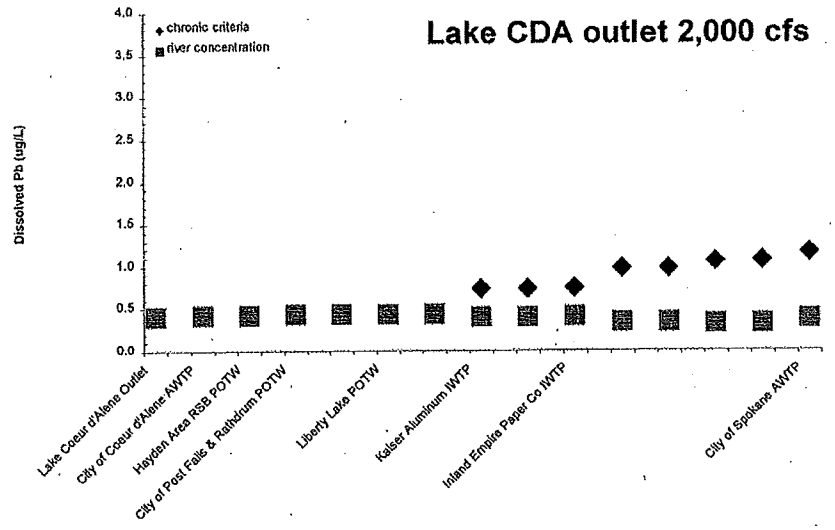
| Spokane River Model Reaches | | | NPDES Dischargers | Acute Mixing Zone Boundary | | | | | | Chronic Mixing Zone Boundary | | | | | | Complete Mix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Cd criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Cd conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Cd criteria (ug/L) | Chronic dissolved Cd criteria (ug/L) | Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | -- | 111.7 | | | | | | | | | | | | | | 20.0 | 0.65 | 0.31 | 0.31 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 54.86 | 22.3 | 0.73 | 1.007 | 0.34 | Yes | 539.61 | 20.2 | 0.32 | 0.976 | 0.31 | Yes | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 249.70 | 20.6 | 0.67 | 1.010 | 0.33 | Yes | 2488.03 | 20.1 | 0.31 | 0.976 | 0.31 | Yes | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 105.31 | 21.3 | 0.69 | 1.009 | 0.34 | Yes | 1044.05 | 20.2 | 0.32 | 0.976 | 0.31 | Yes | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 322.40 | 20.5 | 0.66 | 1.010 | 0.33 | Yes | 3215.04 | 20.1 | 0.31 | 0.976 | 0.31 | Yes | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 20.1 | 0.65 | 0.31 | 0.31 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 14.77 | 26.9 | 0.89 | 0.999 | 0.39 | Yes | 138.70 | 20.8 | 0.32 | 0.975 | 0.32 | Yes | 21.8 | 0.71 | 0.33 | 0.31 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 21.8 | 0.71 | 0.33 | 0.31 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 83.30 | 23.3 | 0.76 | 1.005 | 0.33 | Yes | 824.03 | 22.0 | 0.34 | 0.972 | 0.31 | Yes | 21.9 | 0.71 | 0.33 | 0.31 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 23.6 | 0.77 | 0.35 | 0.30 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 23.6 | 0.77 | 0.35 | 0.30 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 24.2 | 0.80 | 0.36 | 0.30 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 24.4 | 0.80 | 0.36 | 0.29 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 8.63 | 38.3 | 1.31 | 0.984 | 0.44 | Yes | 77.27 | 25.9 | 0.38 | 0.965 | 0.31 | Yes | 24.9 | 0.82 | 0.37 | 0.30 | Yes |

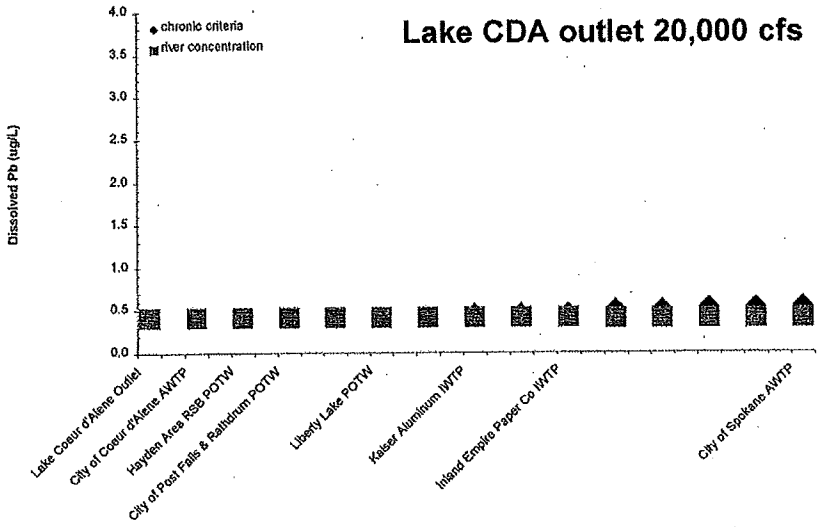
# Appendix D.2

# Results for Lead

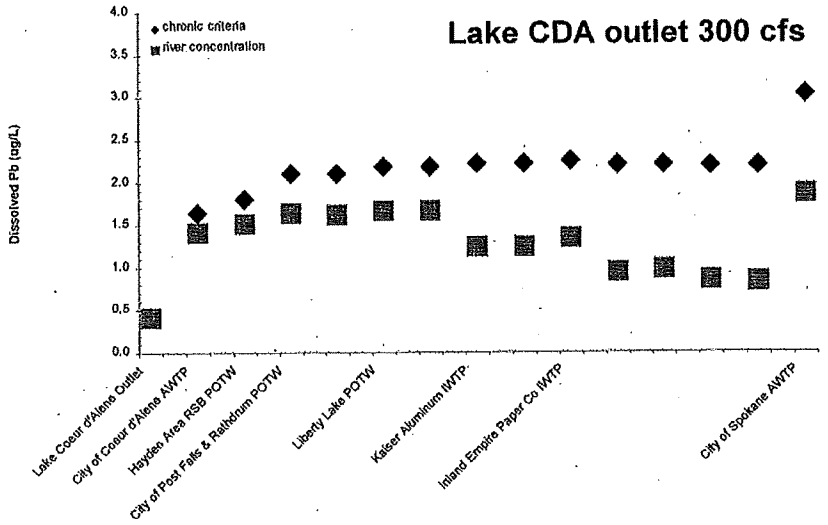
Dissolved Pb after complete mix at current effluent design flows.

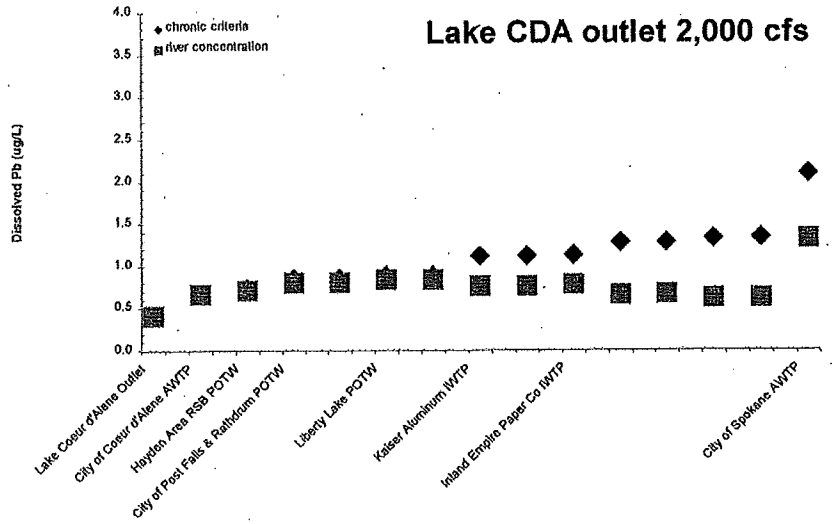


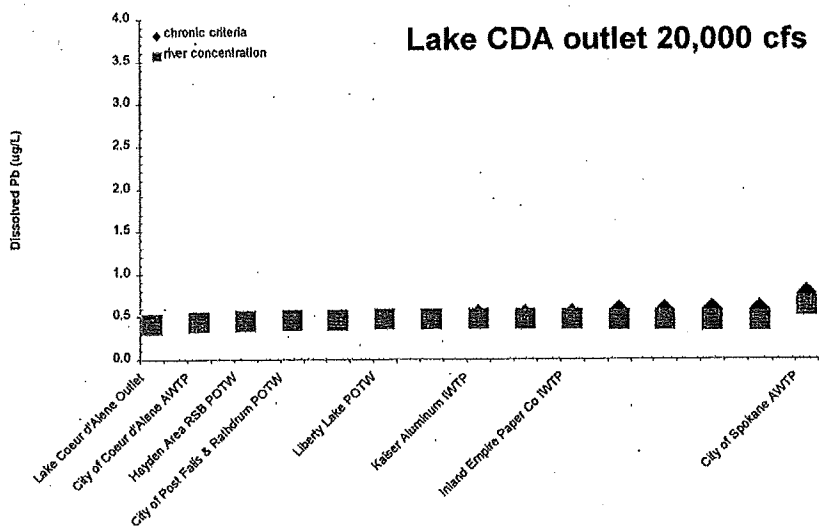



Dissolved Pb after complete mix at 20X current design flows.



# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Pb from total rec. tangent equation (ug/L) | Effluent ratio of dis-solved/ total rec. Pb | Dissolved Pb (ug/L) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Effluent meets end-of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 3.0 | 0.764 | 2.3 | 78.7 | 3.1 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Pb (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regres sion 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Pb at down stream end of reach | Mass balance dissolved Pb at upstream end of reach (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Check of mass balance with regres sion estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data comp-ilation and log-log cubic regres-sion (ug/L) (3) |
| 0 | -- | 111.7 | *Lk CDA Outlet (1)* | 300 | 20 | 0.41 | -- | 300 | -- | 20.0 | na | 1.000 | -- | 0.41 | |
| 1 | 111.7 | 106.6 | | | | | 300 | 309 | 20.0 | 23.8 | na | 1.000 | 0.41 | 0.51 | |
| 2 | 106.6 | 101.7 | | | | | 309 | 311 | 23.8 | 24.5 | na | 0.996 | 0.51 | 0.53 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | 28.05 | 85.0 | 0.09 | 311 | 344 | 24.5 | 31.1 | na | 0.961 | 0.53 | 0.52 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | 11.81 | 85.0 | 0.09 | 344 | 356 | 31.1 | 32.9 | na | 0.953 | 0.52 | 0.50 | |
| 5 | 93.0 | 90.4 | | | | | 356 | 357 | 32.9 | 33.4 | na | 0.951 | 0.50 | 0.51 | |
| 6 | 90.4 | 87.8 | | | | | 357 | 357 | 33.4 | 33.4 | na | 0.951 | 0.51 | 0.51 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 303.42 | 85.0 | 0.09 | 321 | 661 | 33.4 | 61.8 | na | 0.861 | 0.51 | 0.40 | |
| 8 | 85.3 | 82.6 | | | | | 661 | 661 | 61.8 | 61.8 | na | 0.861 | 0.40 | 0.40 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 661 | 411 | 61.8 | 63.1 | na | 0.858 | 0.40 | 0.48 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 355.47 | 85.0 | 0.09 | 411 | 766 | 63.1 | 73.2 | na | 0.836 | 0.48 | 0.28 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 766 | 587 | 73.2 | 73.2 | na | 0.836 | 0.28 | 0.30 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 144.77 | 85.0 | 0.09 | 587 | 731 | 73.2 | 75.6 | na | 0.832 | 0.30 | 0.25 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.09 | 731 | 774 | 75.6 | 76.1 | na | 0.831 | 0.25 | 0.24 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.09 | 774 | 901 | 76.1 | 81.9 | na | 0.820 | 0.24 | 0.44 | na |

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet

(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.

(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| Spokane River Model Reaches | | | NPDES Dischargers | Acute Mixing Zone Boundary | | | | | | Chronic Mixing Zone Boundary | | | | | | Complete Mix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | – | 111.7 | | | | | | | | | | | | | | 20.0 | 10.5 | 0.41 | 0.41 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 1.81 | 89.1 | 57.0 | 0.808 | 1.8 | Yes | 9.08 | 33.8 | 0.76 | 0.949 | 0.73 | Yes | 23.8 | 13.1 | 0.51 | 0.51 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 4.84 | 48.8 | 29.3 | 0.896 | 1.0 | Yes | 39.44 | 26.8 | 0.59 | 0.983 | 0.58 | Yes | 24.5 | 13.6 | 0.53 | 0.53 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 2.62 | 70.5 | 44.0 | 0.842 | 1.5 | Yes | 17.23 | 31.5 | 0.70 | 0.959 | 0.68 | Yes | 31.1 | 17.8 | 0.69 | 0.52 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 32.9 | 18.9 | 0.74 | 0.50 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 6.75 | 49.5 | 29.8 | 0.893 | 0.9 | Yes | 58.51 | 34.8 | 0.79 | 0.945 | 0.54 | Yes | 33.4 | 19.2 | 0.75 | 0.51 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 33.4 | 19.2 | 0.75 | 0.51 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 1.22 | 104.2 | 67.5 | 0.785 | 2.0 | Yes | 3.23 | 60.2 | 1.44 | 0.865 | 1.13 | Yes | 61.8 | 38.1 | 1.49 | 0.40 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 61.8 | 38.1 | 1.49 | 0.40 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 3.67 | 84.5 | 53.7 | 0.816 | 1.1 | Yes | 27.70 | 64.8 | 1.57 | 0.854 | 0.50 | Yes | 63.1 | 39.0 | 1.52 | 0.48 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 73.2 | 45.9 | 1.79 | 0.28 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 73.2 | 45.9 | 1.79 | 0.30 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 75.6 | 47.5 | 1.85 | 0.25 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 76.1 | 47.9 | 1.87 | 0.24 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.28 | 129.7 | 85.6 | 0.753 | 2.2 | Yes | 3.84 | 94.0 | 2.35 | 0.800 | 0.94 | Yes | 81.9 | 51.9 | 2.02 | 0.44 | Yes |

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Pb from total rec. tangent equation (ug/L) | Effluent ratio of dis-solved/ total rec. Pb | Dissolved Pb (ug/L) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Effluent meets end-of-pipe criteria? |
| 0 | – | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 3.0 | 0.764 | 2.3 | 78.7 | 3.1 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Pb (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regres sion 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Pb at down stream end of reach | Mass balance dissolved Pb at upstream end of reach (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Check of mass balance with regres sion estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data comp-ilation and log-log cubic regres-sion (ug/L) (3) |
| 0 | -- | 111.7 | *Lk CDA Outlet (1)* | 2,000 | 20 | 0.41 | -- | 2,000 | -- | 20.0 | na | 1.000 | -- | 0.41 | |
| 1 | 111.7 | 106.6 | | | | | 2,000 | 2,009 | 20.0 | 20.6 | na | 1.000 | 0.41 | 0.43 | |
| 2 | 106.6 | 101.7 | | | | | 2,009 | 2,011 | 20.6 | 20.7 | na | 1.000 | 0.43 | 0.43 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -25.27 | na | na | 2,011 | 1,991 | 20.7 | 21.0 | na | 1.000 | 0.43 | 0.44 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -10.64 | na | na | 1,991 | 1,980 | 21.0 | 21.0 | na | 1.000 | 0.44 | 0.44 | |
| 5 | 93.0 | 90.4 | | | | | 1,980 | 1,982 | 21.0 | 21.1 | na | 1.000 | 0.44 | 0.44 | |
| 6 | 90.4 | 87.8 | | | | | 1,982 | 1,982 | 21.1 | 21.1 | na | 1.000 | 0.44 | 0.44 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 385.30 | 85.0 | 0.09 | 1,946 | 2,367 | 21.1 | 33.0 | na | 0.953 | 0.44 | 0.40 | |
| 8 | 85.3 | 82.6 | | | | | 2,367 | 2,367 | 33.0 | 33.0 | na | 0.953 | 0.40 | 0.40 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 2,367 | 2,117 | 33.0 | 33.3 | na | 0.951 | 0.40 | 0.41 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 451.40 | 85.0 | 0.09 | 2,117 | 2,568 | 33.3 | 42.4 | na | 0.916 | 0.41 | 0.34 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 2,568 | 2,389 | 42.4 | 42.4 | na | 0.916 | 0.34 | 0.34 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 178.40 | 85.0 | 0.09 | 2,389 | 2,567 | 42.4 | 45.4 | na | 0.906 | 0.34 | 0.32 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.09 | 2,567 | 2,610 | 45.4 | 46.0 | na | 0.904 | 0.32 | 0.32 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.09 | 2,610 | 2,736 | 46.0 | 49.3 | na | 0.894 | 0.32 | 0.38 | na |

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *NPDES Dischargers* | *Acute Mixing Zone Boundary* | | | | | | *Chronic Mixing Zone Boundary* | | | | | | *Complete Mix* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | -- | 111.7 | | | | | | | | | | | | | | 20.0 | 10.5 | 0.41 | 0.41 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6.39 | 39.6 | 23.2 | 0.926 | 0.9 | Yes | 54.86 | 22.3 | 0.47 | 1.000 | 0.47 | Yes | 20.6 | 10.9 | 0.43 | 0.43 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 25.97 | 25.4 | 14.1 | 0.991 | 0.5 | Yes | 250.74 | 21.1 | 0.44 | 1.000 | 0.44 | Yes | 20.7 | 11.0 | 0.43 | 0.43 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 11.48 | 31.5 | 18.0 | 0.959 | 0.7 | Yes | 105.84 | 21.9 | 0.46 | 1.000 | 0.46 | Yes | 21.0 | 11.2 | 0.44 | 0.44 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 21.0 | 11.2 | 0.44 | 0.44 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 33.00 | 24.8 | 13.7 | 0.994 | 0.5 | Yes | 320.96 | 21.4 | 0.45 | 1.000 | 0.45 | Yes | 21.1 | 11.3 | 0.44 | 0.44 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 21.1 | 11.3 | 0.44 | 0.44 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 2.35 | 63.2 | 39.1 | 0.858 | 1.3 | Yes | 14.49 | 27.9 | 0.61 | 0.977 | 0.60 | Yes | 33.0 | 19.0 | 0.74 | 0.40 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 33.0 | 19.0 | 0.74 | 0.40 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 10.56 | 43.6 | 25.9 | 0.912 | 0.7 | Yes | 96.62 | 34.2 | 0.77 | 0.947 | 0.43 | Yes | 33.3 | 19.2 | 0.75 | 0.41 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 42.4 | 25.1 | 0.98 | 0.34 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 42.4 | 25.1 | 0.98 | 0.34 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 45.4 | 27.1 | 1.05 | 0.32 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 46.0 | 27.5 | 1.07 | 0.32 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.96 | 96.6 | 62.2 | 0.796 | 1.6 | Yes | 10.58 | 55.4 | 1.32 | 0.877 | 0.58 | Yes | 49.3 | 29.7 | 1.16 | 0.38 | Yes |

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 20,000 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Pb from total rec. tangent equation (ug/L) | Effluent ratio of dis-solved/ total rec. Pb | Dissolved Pb (ug/L) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Effluent meets end-of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 3.0 | 0.764 | 2.3 | 78.7 | 3.1 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.06 | 145 | 3.7 | 0.737 | 2.7 | 96.5 | 3.8 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Pb (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regres sion 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Pb at down stream end of reach | Mass balance dissolved Pb at upstream end of reach (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Check of mass balance with regres sion estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data comp-ilation and log-log cubic regres-sion (ug/L) (3) |
| 0 | – | 111.7 | *Lk CDA Outlet (1)* | 20,000 | 20 | 0.41 | – | 20,000 | – | 20.0 | na | 1.000 | – | 0.41 | |
| 1 | 111.7 | 106.6 | | | | | 20,000 | 20,009 | 20.0 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 2 | 106.6 | 101.7 | | | | | 20,009 | 20,011 | 20.1 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -88.01 | na | na | 20,011 | 19,928 | 20.1 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -37.06 | na | na | 19,928 | 19,891 | 20.1 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 5 | 93.0 | 90.4 | | | | | 19,891 | 19,893 | 20.1 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 6 | 90.4 | 87.8 | | | | | 19,893 | 19,893 | 20.1 | 20.1 | na | 1.000 | 0.41 | 0.41 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 481.64 | 85.0 | 0.09 | 19,857 | 20,374 | 20.1 | 21.8 | na | 1.000 | 0.41 | 0.41 | |
| 8 | 85.3 | 82.6 | | | | | 20,374 | 20,374 | 21.8 | 21.8 | na | 1.000 | 0.41 | 0.41 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 20,374 | 20,124 | 21.8 | 21.9 | na | 1.000 | 0.41 | 0.41 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 564.25 | 85.0 | 0.09 | 20,124 | 20,688 | 21.9 | 23.6 | na | 1.000 | 0.41 | 0.40 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 20,688 | 20,509 | 23.6 | 23.6 | na | 1.000 | 0.40 | 0.40 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 217.97 | 85.0 | 0.09 | 20,509 | 20,727 | 23.6 | 24.2 | na | 0.998 | 0.40 | 0.40 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 0.09 | 20,727 | 20,769 | 24.2 | 24.4 | na | 0.997 | 0.40 | 0.40 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 0.09 | 20,769 | 20,896 | 24.4 | 24.9 | na | 0.994 | 0.40 | 0.41 | na |

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Lead

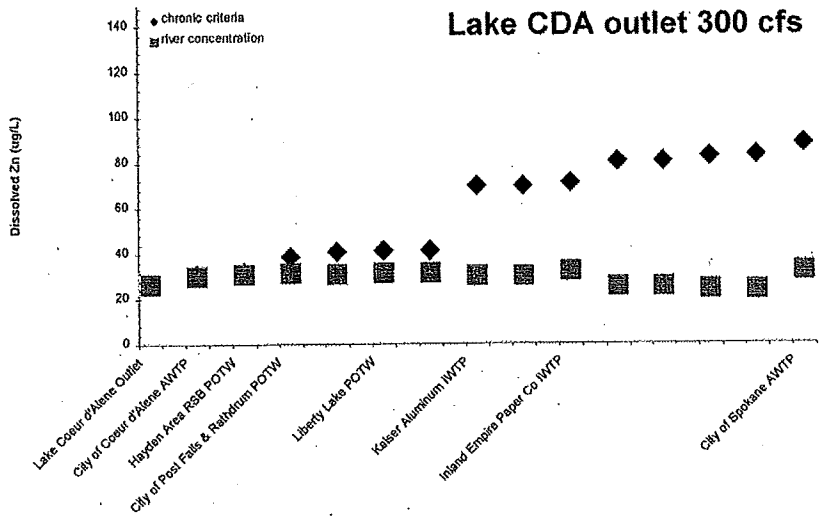
Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

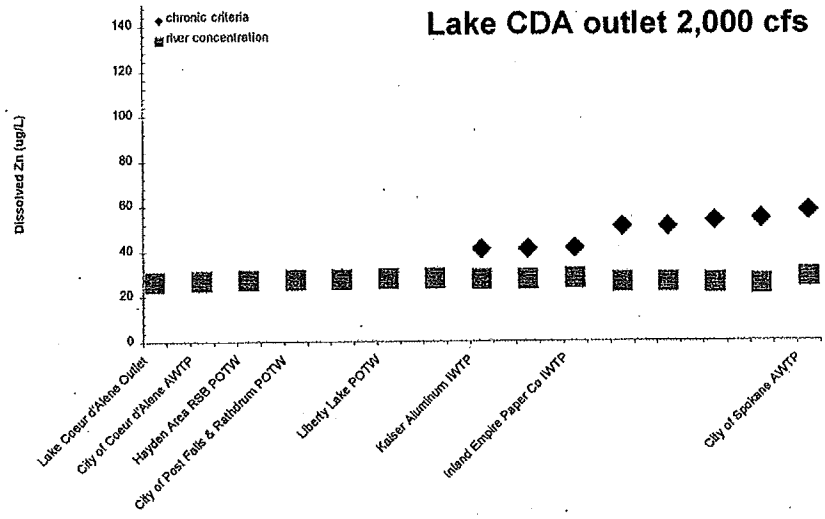
| *Spokane River Model Reaches* | | | *NPDES Dischargers* | *Acute Mixing Zone Boundary* | | | | | | *Chronic Mixing Zone Boundary* | | | | | | *Complete Mix* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Pb criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Pb conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Pb criteria (ug/L) | Chronic dissolved Pb criteria (ug/L) | Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | -- | 111.7 | | | | | | | | | | | | | | 20.0 | 10.5 | 0.41 | 0.41 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 54.86 | 22.3 | 12.2 | 1.000 | 0.5 | Yes | 539.61 | 20.2 | 0.42 | 1.000 | 0.42 | Yes | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 249.70 | 20.6 | 11.1 | 1.000 | 0.4 | Yes | 2488.03 | 20.1 | 0.41 | 1.000 | 0.41 | Yes | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 105.31 | 21.3 | 11.6 | 1.000 | 0.4 | Yes | 1044.05 | 20.2 | 0.42 | 1.000 | 0.42 | Yes | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 322.40 | 20.5 | 11.1 | 1.000 | 0.4 | Yes | 3215.04 | 20.1 | 0.41 | 1.000 | 0.41 | Yes | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 20.1 | 10.6 | 0.41 | 0.41 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 14.77 | 26.9 | 15.1 | 0.982 | 0.6 | Yes | 138.70 | 20.8 | 0.43 | 1.000 | 0.43 | Yes | 21.8 | 11.8 | 0.46 | 0.41 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 21.8 | 11.8 | 0.46 | 0.41 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 83.30 | 23.3 | 12.8 | 1.000 | 0.4 | Yes | 824.03 | 22.0 | 0.46 | 1.000 | 0.41 | Yes | 21.9 | 11.8 | 0.46 | 0.41 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 23.6 | 13.0 | 0.51 | 0.40 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 23.6 | 13.0 | 0.51 | 0.40 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 24.2 | 13.4 | 0.52 | 0.40 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 24.4 | 13.5 | 0.53 | 0.40 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 8.63 | 38.3 | 22.4 | 0.931 | 0.7 | Yes | 77.27 | 25.9 | 0.56 | 0.988 | 0.44 | Yes | 24.9 | 13.8 | 0.54 | 0.41 | Yes |

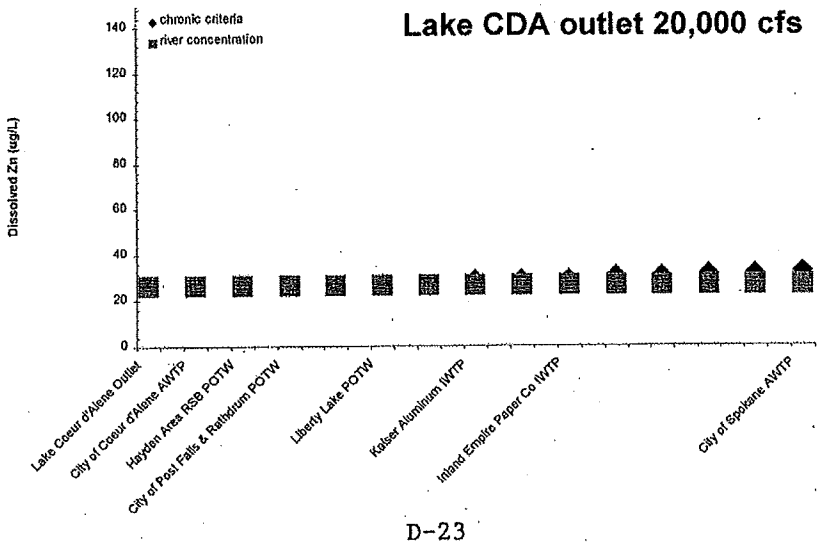
# Appendix D.3

# Results for Zinc

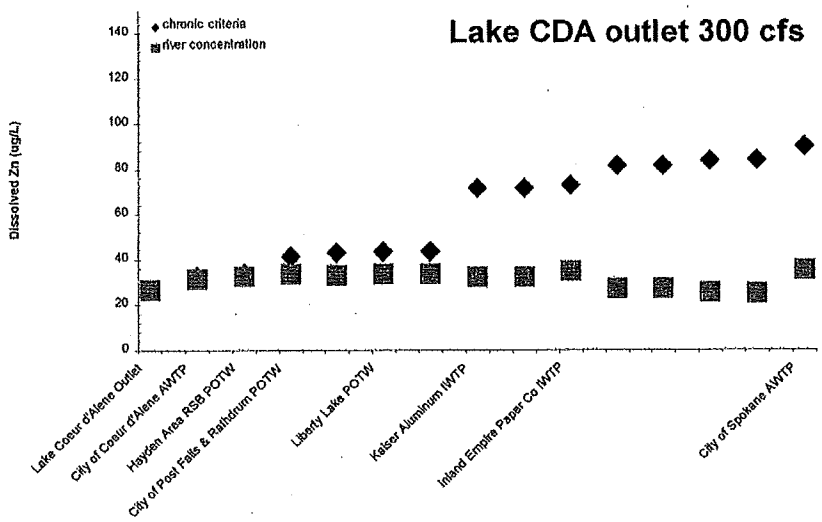
Dissolved Zn after complete mix at current effluent design flows.

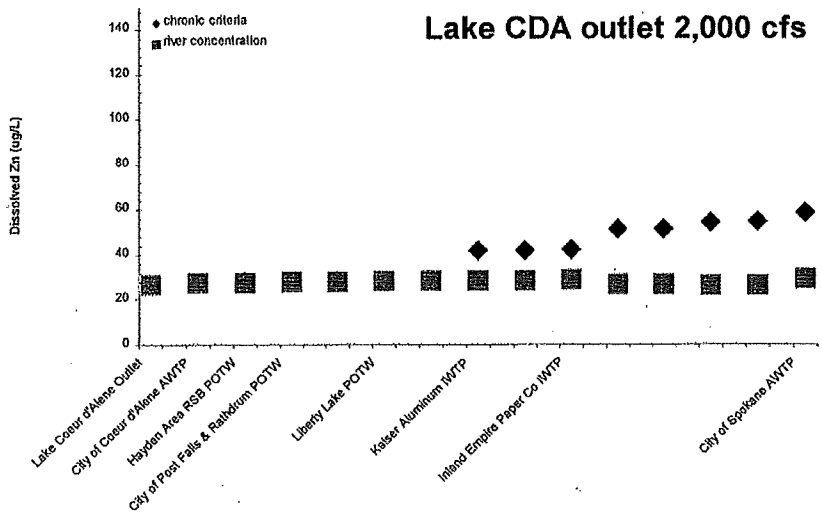


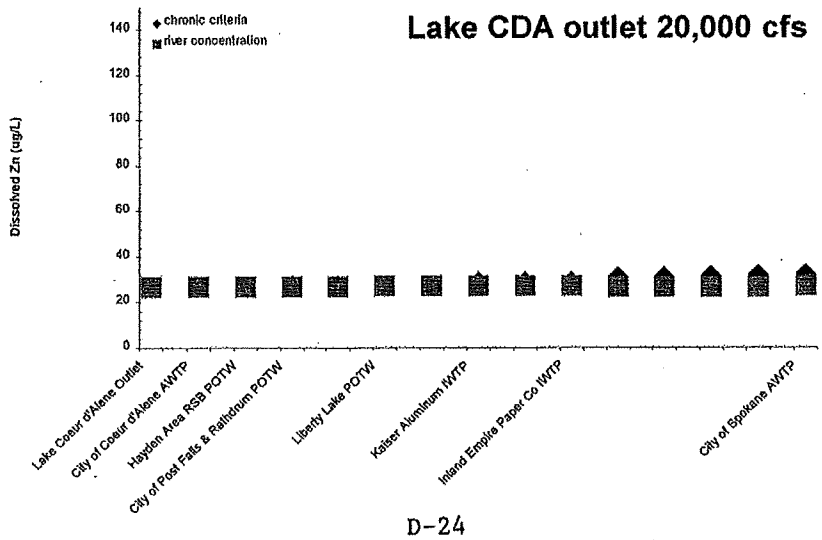



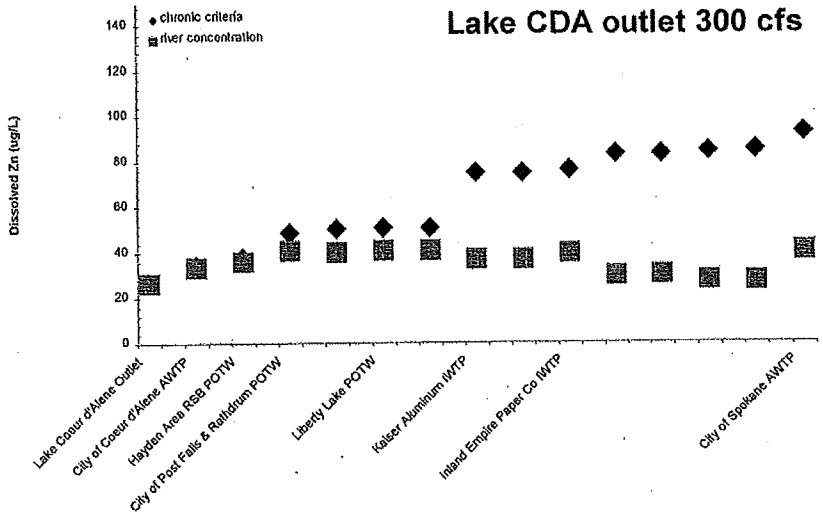
Dissolved Zn after complete mix at 20-year projected design flows.

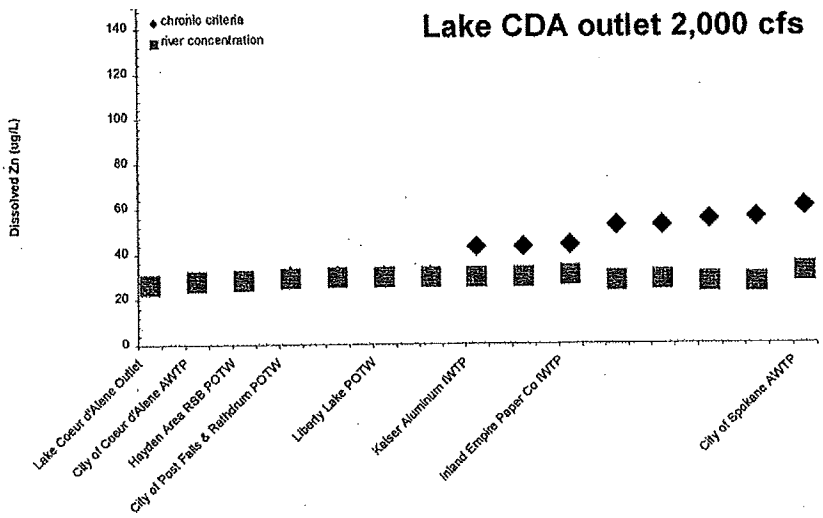


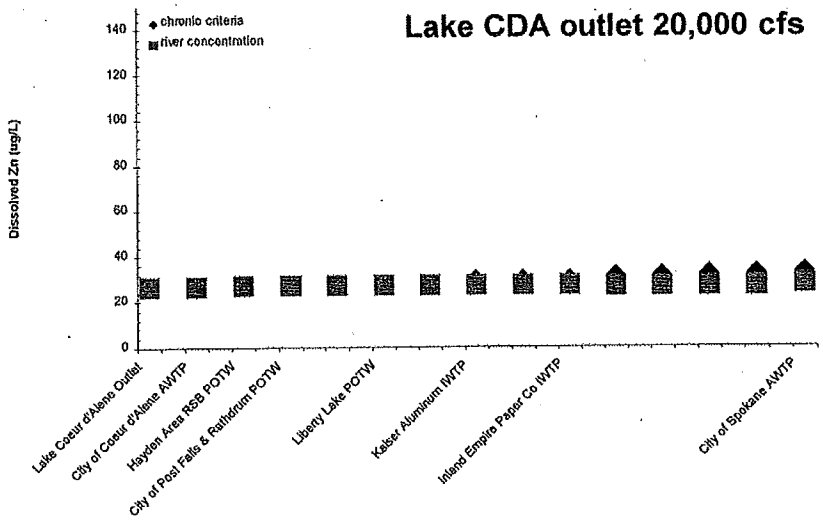



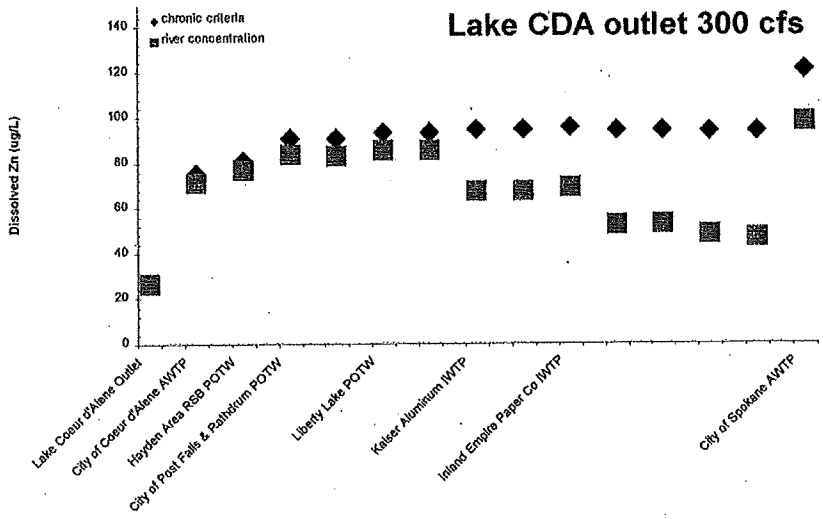
Dissolved Zn after complete mix at 50-year projected design flows.

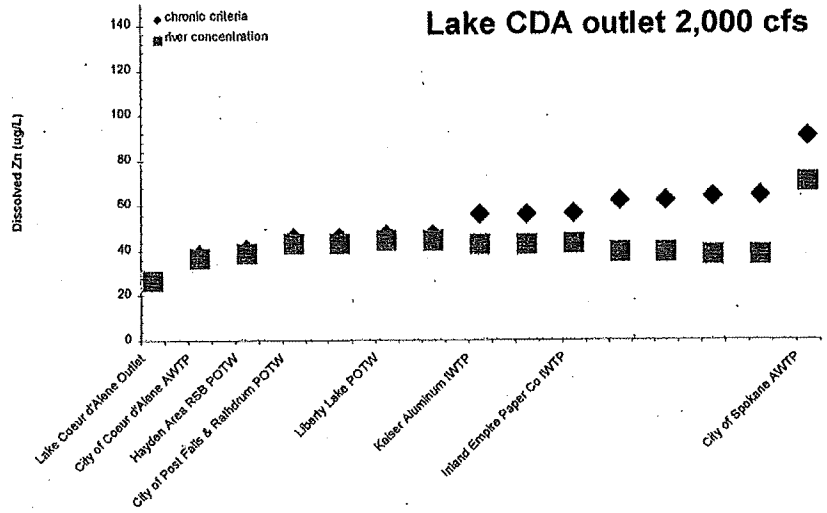


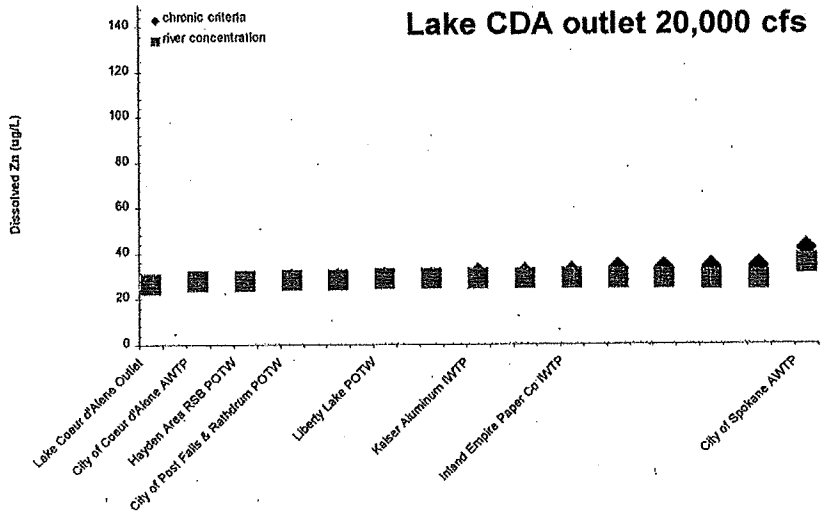



Dissolved Zn after complete mix at 20X current effluent design flows.



# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Zn (ug/L) | Effluent ratio of dissolved/total rec. Zn | Dissolved Zn (ug/L) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | – | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 123.7 | 0.986 | 122.0 | 133.6 | 122.0 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | Aquifer/Tributary Inflow/Outflow | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Zn (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Zn | Mass balance dissolved Zn at upstream end of reach (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | – | 111.7 | *Lk CDA Outlet (1)* | 300 | 20 | 26.7 | – | 300 | – | 20.0 | na | 0.986 | – | 26.7 | |
| 1 | 111.7 | 106.6 | | | | | 300 | 309 | 20.0 | 23.8 | na | 0.986 | 26.7 | 30.2 | |
| 2 | 106.6 | 101.7 | | | | | 309 | 311 | 23.8 | 24.5 | na | 0.986 | 30.2 | 30.9 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | 28.05 | 85.0 | 18 | 311 | 344 | 24.5 | 31.1 | na | 0.986 | 30.9 | 31.4 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | 11.81 | 85.0 | 18 | 344 | 356 | 31.1 | 32.9 | na | 0.986 | 31.4 | 31.0 | |
| 5 | 93.0 | 90.4 | | | | | 356 | 357 | 32.9 | 33.4 | na | 0.986 | 31.0 | 31.5 | |
| 6 | 90.4 | 87.8 | | | | | 357 | 357 | 33.4 | 33.4 | na | 0.986 | 31.5 | 31.5 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 303.42 | 85.0 | 18 | 321 | 661 | 33.4 | 61.8 | na | 0.986 | 31.5 | 30.1 | |
| 8 | 85.3 | 82.6 | | | | | 661 | 661 | 61.8 | 61.8 | na | 0.986 | 30.1 | 30.1 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 661 | 411 | 61.8 | 63.1 | na | 0.986 | 30.1 | 32.1 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 355.47 | 85.0 | 18 | 411 | 766 | 63.1 | 73.2 | na | 0.986 | 32.1 | 25.4 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 766 | 587 | 73.2 | 73.2 | na | 0.986 | 25.4 | 25.5 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 144.77 | 85.0 | 18 | 587 | 731 | 73.2 | 75.6 | na | 0.986 | 25.5 | 24.0 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 18 | 731 | 774 | 75.6 | 76.1 | na | 0.986 | 24.0 | 23.7 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 18 | 774 | 901 | 76.1 | 81.9 | na | 0.986 | 23.7 | 32.3 | na |

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

| Spokane River Model Reaches | | | NPDES Dischargers | Acute Mixing Zone Boundary | | | | | | Chronic Mixing Zone Boundary | | | | | | Complete Mix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | – | 111.7 | | | | | | | | | | | | | | 20.0 | 29.3 | 26.7 | 26.7 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 1.81 | 89.1 | 103.8 | 0.978 | 90.4 | Yes | 9.08 | 33.8 | 41.7 | 0.986 | 39.6 | Yes | 23.8 | 33.9 | 30.9 | 30.2 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 4.84 | 48.8 | 62.3 | 0.978 | 53.1 | Yes | 39.44 | 26.8 | 34.3 | 0.986 | 33.1 | Yes | 24.5 | 34.8 | 31.8 | 30.9 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 2.62 | 70.5 | 85.1 | 0.978 | 73.1 | Yes | 17.23 | 31.5 | 39.3 | 0.986 | 37.5 | Yes | 31.1 | 42.6 | 38.9 | 31.4 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 32.9 | 44.7 | 40.8 | 31.0 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 6.75 | 49.5 | 63.1 | 0.978 | 47.2 | Yes | 58.51 | 34.8 | 42.8 | 0.986 | 32.9 | Yes | 33.4 | 45.2 | 41.3 | 31.5 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 33.4 | 45.2 | 41.3 | 31.5 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 1.22 | 104.2 | 118.5 | 0.978 | 104.6 | Yes | 3.23 | 60.2 | 68.0 | 0.986 | 59.5 | Yes | 61.8 | 76.1 | 69.5 | 30.1 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 61.8 | 76.1 | 69.5 | 30.1 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 3.67 | 84.5 | 99.2 | 0.978 | 60.4 | Yes | 27.70 | 64.8 | 72.4 | 0.986 | 34.2 | Yes | 63.1 | 77.4 | 70.7 | 32.1 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 73.2 | 87.9 | 80.3 | 25.4 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 73.2 | 87.9 | 80.3 | 25.5 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 75.6 | 90.3 | 82.4 | 24.0 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 76.1 | 90.8 | 82.9 | 23.7 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.28 | 129.7 | 142.7 | 0.978 | 115.8 | Yes | 3.84 | 94.0 | 99.2 | 0.986 | 54.8 | Yes | 81.9 | 96.6 | 88.2 | 32.3 | Yes |

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Zn (ug/L) | Effluent ratio of dissolved/total rec. Zn | Dissolved Zn (ug/L) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 123.7 | 0.986 | 122.0 | 133.6 | 122.0 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Zn (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Zn | Mass balance dissolved Zn at upstream end of reach (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | -- | 111.7 | *Lk CDA Outlet (1)* | 2,000 | 20 | 26.7 | -- | 2,000 | -- | 20.0 | na | 0.986 | -- | 26.7 | |
| 1 | 111.7 | 105.6 | | | | | 2,000 | 2,009 | 20.0 | 20.6 | na | 0.986 | 26.7 | 27.3 | |
| 2 | 105.6 | 101.7 | | | | | 2,009 | 2,011 | 20.6 | 20.7 | na | 0.986 | 27.3 | 27.4 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -25.27 | na | na | 2,011 | 1,991 | 20.7 | 21.0 | na | 0.986 | 27.4 | 27.7 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -10.64 | na | na | 1,991 | 1,980 | 21.0 | 21.0 | na | 0.986 | 27.7 | 27.7 | |
| 5 | 93.0 | 90.4 | | | | | 1,980 | 1,982 | 21.0 | 21.1 | na | 0.986 | 27.7 | 27.8 | |
| 6 | 90.4 | 87.8 | | | | | 1,982 | 1,982 | 21.1 | 21.1 | na | 0.986 | 27.8 | 27.8 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 385.30 | 85.0 | 18 | 1,946 | 2,367 | 21.1 | 33.0 | na | 0.986 | 27.8 | 27.6 | |
| 8 | 85.3 | 82.6 | | | | | 2,367 | 2,367 | 33.0 | 33.0 | na | 0.986 | 27.6 | 27.6 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -255.20 | na | na | 2,367 | 2,117 | 33.0 | 33.3 | na | 0.986 | 27.6 | 27.9 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 451.40 | 85.0 | 18 | 2,117 | 2,568 | 33.3 | 42.4 | na | 0.986 | 27.9 | 26.2 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 2,568 | 2,389 | 42.4 | 42.4 | na | 0.986 | 26.2 | 26.2 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 178.40 | 85.0 | 18 | 2,389 | 2,567 | 42.4 | 45.4 | na | 0.986 | 26.2 | 25.6 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 18 | 2,567 | 2,610 | 45.4 | 46.0 | na | 0.986 | 25.6 | 25.5 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 18 | 2,610 | 2,736 | 46.0 | 49.3 | na | 0.986 | 25.5 | 28.2 | na |

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *NPDES Dischargers* | *Acute Mixing Zone Boundary* | | | | | | *Chronic Mixing Zone Boundary* | | | | | | *Complete Mix* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | -- | 111.7 | | | | | | | | | | | | | | 20.0 | 29.3 | 26.7 | 26.7 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6.39 | 39.6 | 52.2 | 0.978 | 44.6 | Yes | 54.86 | 22.3 | 29.3 | 0.986 | 28.8 | Yes | 20.6 | 30.0 | 27.4 | 27.3 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 25.97 | 25.4 | 35.8 | 0.978 | 31.5 | Yes | 250.74 | 21.1 | 27.9 | 0.986 | 27.7 | Yes | 20.7 | 30.1 | 27.5 | 27.4 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 11.48 | 31.5 | 43.0 | 0.978 | 37.2 | Yes | 105.84 | 21.9 | 28.8 | 0.986 | 28.5 | Yes | 21.0 | 30.5 | 27.9 | 27.7 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 21.0 | 30.5 | 27.9 | 27.7 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 33.00 | 24.8 | 35.1 | 0.978 | 30.9 | Yes | 320.96 | 21.4 | 28.3 | 0.986 | 28.0 | Yes | 21.1 | 30.6 | 28.0 | 27.8 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 21.1 | 30.6 | 28.0 | 27.8 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 2.35 | 63.2 | 77.6 | 0.978 | 67.3 | Yes | 14.49 | 27.9 | 35.5 | 0.986 | 34.3 | Yes | 33.0 | 44.7 | 40.9 | 27.6 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 33.0 | 44.7 | 40.9 | 27.6 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 10.56 | 43.6 | 56.7 | 0.978 | 38.2 | Yes | 96.62 | 34.2 | 42.1 | 0.986 | 28.8 | Yes | 33.3 | 45.1 | 41.2 | 27.9 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 42.4 | 55.3 | 50.5 | 26.2 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 42.4 | 55.3 | 50.5 | 26.2 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 45.4 | 58.6 | 53.5 | 25.6 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 46.0 | 59.3 | 54.1 | 25.5 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 1.96 | 96.6 | 111.1 | 0.978 | 84.9 | Yes | 10.58 | 55.4 | 63.3 | 0.986 | 36.6 | Yes | 49.3 | 62.9 | 57.4 | 28.2 | Yes |

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Effluent Characteristics* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Flow (mgd) | Flow (cfs) | Hardness (mg/L as CaCO3) | Total rec. Zn (ug/L) | Effluent ratio of dissolved/total rec. Zn | Dissolved Zn (ug/L) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Effluent meets end of-pipe criteria? |
| 0 | -- | 111.7 | *Lake Coeur d'Alene Outlet* | | | | | | | | | |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 6 | 9.28 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 1.3 | 2.01 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 3.1 | 4.80 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 1 | 1.55 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 23.3 | 36.05 | 120 | 123.7 | 0.986 | 122.0 | 133.6 | 122.0 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 4 | 6.19 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | |
| 11 | 78.0 | 74.1 | | | | | | | | | | |
| 12 | 74.1 | 69.8 | | | | | | | | | | |
| 13 | 69.8 | 67.6 | | | | | | | | | | |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 44 | 68.08 | 145 | 145.2 | 0.986 | 143.2 | 156.8 | 143.2 | Yes |

*multiplier for municipal effluent flow = 1*
*multiplier for industrial effluent flow = 1*

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| *Spokane River Model Reaches* | | | *Aquifer/Tributary Inflow/Outflow* | | | | *Reach Mass Balance Calculations* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Inflow or outflow (cfs) | Inflow hardness (mg/L as CaCO3) (2) | Inflow dissolved Zn (ug/L) (3) | Flow at upstream end of reach (cfs) | Flow at down-stream end of reach (cfs) | Mass balance hardness at up-stream end of reach (mg/L as CaCO3) | Mass balance hardness at down-stream end of reach (mg/L as CaCO3) | Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3) | Ratio of dissolved/ total rec. Zn | Mass balance dissolved Zn at upstream end of reach (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilatio n and log-log cubic regression (ug/L) (3) |
| 0 | – | 111.7 | *Lk CDA Outlet (1)* | 20,000 | 20 | 26.7 | – | 20,000 | – | 20.0 | na | 0.986 | – | 26.7 | |
| 1 | 111.7 | 106.6 | | | | | 20,000 | 20,009 | 20.0 | 20.1 | na | 0.986 | 26.7 | 26.8 | |
| 2 | 106.6 | 101.7 | | | | | 20,009 | 20,011 | 20.1 | 20.1 | na | 0.986 | 26.8 | 26.8 | |
| 3 | 101.7 | 96.0 | *Aquifer Inflow/Outflow* | -88.01 | na | na | 20,011 | 19,928 | 20.1 | 20.1 | na | 0.986 | 26.8 | 26.8 | |
| 4 | 96.0 | 93.0 | *Aquifer Inflow/Outflow* | -37.06 | na | na | 19,928 | 19,891 | 20.1 | 20.1 | na | 0.986 | 26.8 | 26.8 | |
| 5 | 93.0 | 90.4 | | | | | 19,891 | 19,893 | 20.1 | 20.1 | na | 0.986 | 26.8 | 26.8 | |
| 6 | 90.4 | 87.8 | | | | | 19,893 | 19,893 | 20.1 | 20.1 | na | 0.986 | 26.8 | 26.8 | |
| 7 | 87.8 | 85.3 | *Aquifer Inflow* | 481.64 | 85.0 | 18 | 19,857 | 20,374 | 20.1 | 21.8 | na | 0.986 | 26.8 | 26.8 | |
| 8 | 85.3 | 82.6 | | | | | 20,374 | 20,374 | 21.8 | 21.8 | na | 0.986 | 26.8 | 26.8 | |
| 9 | 82.6 | 79.8 | *Aquifer Outflow* | -256.20 | na | na | 20,374 | 20,124 | 21.8 | 21.9 | na | 0.986 | 26.8 | 26.8 | |
| 10 | 79.8 | 78.0 | *Aquifer Inflow* | 564.25 | 85.0 | 18 | 20,124 | 20,688 | 21.9 | 23.6 | na | 0.986 | 26.8 | 26.6 | |
| 11 | 78.0 | 74.1 | *Aquifer Outflow* | -179.70 | na | na | 20,688 | 20,509 | 23.6 | 23.6 | na | 0.986 | 26.6 | 26.6 | |
| 12 | 74.1 | 69.8 | *Hangman Cr + Aquifer* | 217.97 | 85.0 | 18 | 20,509 | 20,727 | 23.6 | 24.2 | na | 0.986 | 26.6 | 26.5 | |
| 13 | 69.8 | 67.6 | *Aquifer Inflow* | 42.75 | 85.0 | 18 | 20,727 | 20,769 | 24.2 | 24.4 | na | 0.986 | 26.5 | 26.5 | |
| 14 | 67.6 | 64.6 | *Aquifer Inflow* | 58.30 | 85.0 | 18 | 20,769 | 20,896 | 24.4 | 24.9 | na | 0.986 | 26.5 | 26.8 | na |

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

# Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

| Spokane River Model Reaches | | | NPDES Dischargers | Acute Mixing Zone Boundary | | | | | | Chronic Mixing Zone Boundary | | | | | | Complete Mix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spokane River model reach number | Up-stream river mile | Down-stream river mile | | Acute dilution factor (allowing 2.5% of river flow) | Hardness at acute boundary (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at acute boundary | Meets acute criteria at acute mixing zone boundary? | Chronic dilution factor (allowing 25% of river flow) | Hardness at chronic boundary (mg/L as CaCO3) | Chronic dissolved Zn criteria (ug/L) | Ratio of dissolved/ total rec. Pb at mixing zone boundary | Dissolved Zn conc. at chronic boundary (ug/L) | Meets chronic criteria at chronic mixing zone boundary? | Hardness at down-stream end of reach after complete mix (mg/L as CaCO3) | Acute dissolved Zn criteria (ug/L) | Chronic dissolved Zn criteria (ug/L) | Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L) | Meets chronic criteria after complete mix at down-stream end of reach? |
| 0 | -- | 111.7 | | | | | | | | | | | | | | 20.0 | 29.3 | 26.7 | 26.7 | Yes |
| 1 | 111.7 | 106.6 | *City of Coeur d'Alene AWTP* | 54.86 | 22.3 | 32.1 | 0.978 | 26.6 | Yes | 539.61 | 20.2 | 27.0 | 0.986 | 26.9 | Yes | 20.1 | 29.3 | 26.8 | 26.8 | Yes |
| 2 | 106.6 | 101.7 | *Hayden Area RSB POTW* | 249.70 | 20.6 | 30.0 | 0.978 | 27.0 | Yes | 2488.03 | 20.1 | 26.8 | 0.986 | 26.8 | Yes | 20.1 | 29.4 | 26.8 | 26.8 | Yes |
| 3 | 101.7 | 96.0 | *City of Post Falls & Rathdrum POTW* | 105.31 | 21.3 | 30.8 | 0.978 | 27.7 | Yes | 1044.05 | 20.2 | 26.9 | 0.986 | 26.9 | Yes | 20.1 | 29.4 | 26.8 | 26.8 | Yes |
| 4 | 96.0 | 93.0 | | | | | | | | | | | | | | 20.1 | 29.4 | 26.8 | 26.8 | Yes |
| 5 | 93.0 | 90.4 | *Liberty Lake POTW* | 322.40 | 20.5 | 29.9 | 0.978 | 27.0 | Yes | 3215.04 | 20.1 | 26.9 | 0.986 | 26.9 | Yes | 20.1 | 29.4 | 26.8 | 26.8 | Yes |
| 6 | 90.4 | 87.8 | | | | | | | | | | | | | | 20.1 | 29.4 | 26.8 | 26.8 | Yes |
| 7 | 87.8 | 85.3 | *Kaiser Aluminum IWTP* | 14.77 | 26.9 | 37.6 | 0.978 | 33.0 | Yes | 138.70 | 20.8 | 27.7 | 0.986 | 27.5 | Yes | 21.8 | 31.5 | 28.8 | 26.8 | Yes |
| 8 | 85.3 | 82.6 | | | | | | | | | | | | | | 21.8 | 31.5 | 28.8 | 26.8 | Yes |
| 9 | 82.6 | 79.8 | *Inland Empire Paper Co IWTP* | 83.30 | 23.3 | 33.3 | 0.978 | 28.0 | Yes | 824.03 | 22.0 | 28.9 | 0.986 | 26.9 | Yes | 21.9 | 31.6 | 28.8 | 26.8 | Yes |
| 10 | 79.8 | 78.0 | | | | | | | | | | | | | | 23.6 | 33.6 | 30.7 | 26.6 | Yes |
| 11 | 78.0 | 74.1 | | | | | | | | | | | | | | 23.6 | 33.6 | 30.7 | 26.6 | Yes |
| 12 | 74.1 | 69.8 | | | | | | | | | | | | | | 24.2 | 34.4 | 31.4 | 26.5 | Yes |
| 13 | 69.8 | 67.6 | | | | | | | | | | | | | | 24.4 | 34.6 | 31.6 | 26.5 | Yes |
| 14 | 67.6 | 64.6 | *City of Spokane AWTP* | 8.63 | 38.3 | 50.8 | 0.978 | 39.7 | Yes | 77.27 | 25.9 | 33.3 | 0.986 | 28.0 | Yes | 24.9 | 35.3 | 32.2 | 26.8 | Yes |

# Appendix E

Appendix E. Comparison of alternative formulas for calculating WLAs for total recoverable Pb.

## WLA for total recoverable Pb = dissolved tangent / conversion factor

| | Hardness | WLAs for total recoverable Pb: dissolved tangent / conversion factor WLA = (0.02378(hardness)-0.05505)/ (1.46203-((LN(hardness))*(0.145712))) | conversion factor =(1.46203- -((LN(hardness)) *(0.145712))) | dissolved Pb criteria equation | total rec Pb = WLA | dissolved Pb = WLA * conversion factor | dissolved Pb exceeds chronic criterion? |
|---|---|---|---|---|---|---|---|
| | (mg/L as CaCO3) | (ug/L) | | (ug/L) | (ug/L) | (ug/L) | |
| Effluent: | 150 | 4.798 | 0.732 | 3.902 | 4.80 | 3.51 | No |
| River: | 20 | | 1.000 | 0.410 | 0.41 | 0.41 | No |
| Hypothetical mixed concentration of river and effluent dilution= 2 | | <--- violates if DF>2 | | | | | |
| | 85 | | 0.815 | 2.108 | 2.60 | 2.12 | Yes |

## WLA for total recoverable Pb = total recoverable tangent

| | Hardness | WLAs for total recoverable Pb: total recoverable tangent WLA = (0.0261*(Hardness)-0.1119) | conversion factor =(1.46203- -((LN(hardness)) *(0.145712))) | dissolved Pb criteria equation | total rec Pb = WLA | dissolved Pb = WLA * conversion factor | dissolved Pb exceeds chronic criterion? |
|---|---|---|---|---|---|---|---|
| | (mg/L as CaCO3) | (ug/L) | | (ug/L) | (ug/L) | (ug/L) | |
| Effluent: | 150 | 3.803 | 0.732 | 3.902 | 3.80 | 2.78 | No |
| River: | 20 | | 1.000 | 0.410 | 0.41 | 0.41 | No |
| Hypothetical mixed concentration of river and effluent dilution= 2 | | <--- meets criteria at all dilution factors | | | | | |
| | 85 | | 0.815 | 2.108 | 2.11 | 1.72 | No |

## WLA for total recoverable Pb = dissolved tangent (effluent conversion factor = 1)

| | Hardness | WLAs for total recoverable Pb: dissolved tangent WLA = (0.02378(hardness)-0.05505) | conversion factor = 1 | dissolved Pb criteria equation | total rec Pb = WLA | dissolved Pb = WLA * conversion factor | dissolved Pb exceeds chronic criterion? |
|---|---|---|---|---|---|---|---|
| | (mg/L as CaCO3) | (ug/L) | | (ug/L) | (ug/L) | (ug/L) | |
| Effluent: | 150 | 3.512 | 1.000 | 3.902 | 3.51 | 3.51 | No |
| River: | 20 | | 1.000 | 0.410 | 0.41 | 0.41 | No |
| Hypothetical mixed concentration of river and effluent dilution= 2 | | <--- meets criteria at all dilution factors | | | | | |
| | 85 | | 0.815 | 2.108 | 1.96 | 1.60 | No |

# Appendix F

Appendix F. Spreadsheet for calculation of WLAs and permit limits for total recoverable Cd, Pb, and Zn for NPDES dischargers to the Spokane River. The input values are for the example described in the text for the Spokane AWTP.

| | *Cd* | *Pb* | *Zn* |
|---|---|---|---|
| **Potential limits based on meeting the aquatic life criteria at effluent hardness** | | | |
| 1. Effluent hardness 5th percentile (mg/L as CaCO3): | 138 | 138 | 138 |
| 2. Chronic aquatic life criteria for dissolved metals (ug/L) | 1.31 | 3.23 | 137 |
| 3. Ratio of total recoverable / dissolved metals | 1.12 | -- | 1.01 |
| 4. Chronic aquatic life criteria for total recoverable metals (ug/L) | 1.46 | 3.49 | 139 |
| 5. Number of samples (n2) required per month for compliance monitoring: | 2 | 2 | 2 |
| 6. Coefficient of variation for effluent total recoverable metals: | 0.431 | 0.335 | 0.283 |
| 7. Calculated limits using the equations in Box 5-2 of the 1991 TSD | | | |
| Z statistic for water quality-based LTA derivation (99%tile): | 2.3263 | 2.3263 | 2.3263 |
| Z-statistic for water quality-based daily maximum permit limit (99%tile): | 2.3263 | 2.3263 | 2.3263 |
| Z statistic for water quality-based monthly average permit limit (95%tile): | 1.6449 | 1.6449 | 1.6449 |
| number of days (n1) for averageing of chronic aquatic life criteria: | 4 | 4 | 4 |
| σ^2: | 0.170385 | 0.106363 | 0.077043 |
| σ^2-n1: | 0.045394 | 0.027670 | 0.019824 |
| LTA for chronic (n1-day) aquatic life criteria: | 0.91 | 2.4 | 101 |
| σ^2-n2: | 0.088817 | 0.054595 | 0.039264 |
| Maximum Daily Limit (ug/L): | 2.2 | 4.9 | 186 |
| Average Monthly Limit (ug/L): | 1.4 | 3.4 | 138 |

# Appendix G

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Appendix G. Formulas for the Microsoft Excel spreadsheet for calculation of WLAs and permit limits for total recoverable Cd, Pb, and Zn for NPDES dischargers to the Spokane River. The input values are for the example described in the text for the Spokane AWTP. | | | |
| 2 | | | | |
| 3 | | *Cd* | *Pb* | *Zn* |
| 4 | | | | |
| 5 | **1. Potential limits based on meeting the aquatic life criteria at effluent hardness** | | | |
| 6 | | | | |
| 7 | 1. Effluent hardness 5th percentile (mg/L as CaCO3): | 138 | 138 | 138 |
| 8 | | | | |
| 9 | 2. Chronic aquatic life criteria for dissolved metals (ug/L) | =(1.101672-((LN(B7))*(0.041838)))*EXP(0.7852*(LN(B7))-3.49) | =0.02378*C7-0.05505 | =0.986*EXP(0.8473*(LN(D7))+0.7614) |
| 10 | | | | |
| 11 | 3. Ratio of total recoverable / dissolved metals | =1/(1.101672-((LN(B7))*(0.041838))) | -- | =1/0.986 |
| 12 | | | | |
| 13 | 4. Chronic aquatic life criteria for total recoverable metals (ug/L) | =B9*B11 | =0.0261*C7-0.1119 | =D9*D11 |
| 14 | | | | |
| 15 | 5. Number of samples (n2) required per month for compliance monitoring: | 2 | 2 | 2 |
| 16 | | | | |
| 17 | 6. Coefficient of variation for effluent metals (use 0.6 if data are not available): | 0.431 | 0.335 | 0.253 |
| 18 | | | | |
| 19 | 7. Calculated limits using the equations in Box 5-2 of the 1991 TSD | | | |
| 20 | Z statistic for water quality-based LTA derivation (99%tile): | 2.3263 | 2.3263 | 2.3263 |
| 21 | Z-statistic for water quality-based daily maximum permit limit (99%tile): | 2.3263 | 2.3263 | 2.3263 |
| 22 | Z statistic for water quality-based monthly average permit limit (95%tile): | 1.6449 | 1.6449 | 1.6449 |
| 23 | number of days (n1) for averageing of chronic aquatic life criteria: | 4 | 4 | 4 |
| 24 | σ^2: | =LN(B17^2+1) | =LN(C17^2+1) | =LN(D17^2+1) |
| 25 | σ^2-n1: | =LN((B17^2/B23)+1) | =LN((C17^2/C23)+1) | =LN((D17^2/D23)+1) |
| 26 | LTA for chronic (n1-day) aquatic life criteria: | =B13*EXP(0.5*B25-B20*SQRT(B25)) | =C13*EXP(0.5*C25-C20*SQRT(C25)) | =D13*EXP(0.5*D25-D20*SQRT(D25)) |
| 27 | σ^2-n2: | =LN((B17^2/B15)+1) | =LN((C17^2/C15)+1) | =LN((D17^2/D15)+1) |
| 28 | Maximum Daily Limit (ug/L): | =B26*EXP(B21*SQRT(B24)-0.5*B24) | =C26*EXP(C21*SQRT(C24)-0.5*C24) | =D26*EXP(D21*SQRT(D24)-0.5*D24) |
| 29 | Average Monthly Limit (ug/L): | =B26*EXP(B22*SQRT(B27)-0.5*B27) | =C26*EXP(C22*SQRT(C27)-0.5*C27) | =D26*EXP(D22*SQRT(D27)-0.5*D27) |
| 30 | | | | |
| 31 | | | | |