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DEPARTMENT OF
ECOLOGY

A Total Maximum Daily Load Evaluation for Arsenic in the Similkameen River

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WASHINGTON STATE
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ECOLOGY

A Total Maximum Daily Load Evaluation for Arsenic in the Similkameen River

by
Art Johnson

Environmental Assessment Program
Olympia, Washington 98504-7710

November 2002

Section 303(d) listings addressed in this report:
Similkameen River, Waterbody No. WA-49-1030, arsenic.

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Abstract

Under Section 303(d) of the federal Clean Water Act, the Similkameen River has been listed by Washington State for non-attainment of the EPA human health criteria for arsenic. A Total Maximum Daily Load evaluation was therefore conducted for the river, as required by EPA.

The major source of arsenic appears to be tailings from historical mining activity in British Columbia between Hedley and the U.S. border. The only significant sources identified in Washington were: 1) Palmer Lake, likely arising from periodic flooding by the Similkameen River and perhaps inputs from Sinlahekin Creek, and 2) resuspension of contaminated sediments.

It was determined that the Similkameen River naturally exceeds the EPA arsenic criteria upstream of Hedley. Under these circumstances, natural conditions constitute the water quality criteria. Because the criteria are naturally exceeded, the loading capacity for the river is equal to the natural background.

Water quality targets of 0.4 – 0.6 ug/L total recoverable arsenic are proposed, and estimates are provided of the load reductions needed in British Columbia and Washington State to meet the targets. The proposed targets make no allowance for the downstream increase in arsenic concentrations that might occur naturally as the Similkameen flows through British Columbia. If new data or analysis can provide a reliable estimate of what that increase would be, the numerical targets should be revised upward accordingly. In the interim, the proposed targets appear reasonable, given the concentrations typical of other Washington rivers and streams.

An arsenic monitoring plan is suggested for the Similkameen River. The plan recommends: 1) periodical review of Canadian federal/provincial water quality monitoring data for the Similkameen, 2) renewing arsenic monitoring of the river in Washington if and when cleanups are undertaken, 3) analyzing inorganic arsenic in Similkameen River and Palmer Lake fish to assess human health risk, and 4) conducting a study of arsenic sources and cycling in Palmer Lake.

Acknowledgements

Data and other information used in preparing this report were provided by Larry Pommen, Tom Webber, Nellie Peppin, Jay Adams, and Vic Jensen of B.C. Ministry of Water, Land and Air Protection, as well as Andrea Ryan, Tania Tuominen, and Lynne Campo of Environment Canada. Their help is very much appreciated.

Department of Ecology personnel assisting with the field work included Dave Hallock, Chuck Springer, Mark Peterschmidt, Keith Seiders, Bernie Strong, and Brandee Era.

The good work of the Ecology Manchester Environmental Laboratory staff in analyzing samples for this project is gratefully acknowledged, especially Jim Ross, Sally Cull, Randy Knox, Denis Erickson, Dean Momohara, and Meredith Jones.

This report benefited from review by Lorraine Edmond of EPA Region 10 and Mark Peterschmidt, Dale Norton, and Joe Joy of Ecology. Lorraine and Mark provided welcome guidance and advice throughout the study. Lorraine provided recent information on mine tailings in B.C. in the Hedley and Cahill Creek areas and notes on historical mining practices. Mark contributed the discussion on lead-arsenate residues in orchards.

Introduction

The Similkameen River has been listed by the state of Washington under Section 303(d) of the federal Clean Water Act for non-attainment of the U.S. Environmental Protection Agency (EPA) human health criteria for arsenic. The listing is based on water sampling done by the Washington State Department of Ecology (Ecology) in 1995-96.

EPA requires the states to set priorities for cleaning up 303(d) listed waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards.

The present report reviews data on arsenic concentrations in the Similkameen River. A TMDL is proposed and loading reductions recommended to meet numeric water quality targets. This report addresses the following TMDL elements required by EPA Region 10: scope of the TMDL, applicable water quality standards, numerical targets, loading capacity, wasteload and load allocations, margin of safety, seasonal variation, and monitoring plan.

Drainage Basin Description

The 72-mile long Similkameen River originates in the Cascade Mountains along the international border between British Columbia and Washington State. It flows north out of Manning Provincial Park, then turns south to cross the border and meet the Okanogan River at Oroville, the last 27 miles being in Washington (Figure 1). The climate is semi-arid over much of the basin. Mining, forestry, agriculture, and recreation are the major land-use activities.

The Similkameen drains 9,308 square miles, over 90% of which is in British Columbia. Peak flows normally occur in April to July as a result of snowmelt (Figure 2). Stream flow during the winter generally stays low due to freezing weather that maintains or contributes to the snowpack; exceptions occur when mild weather and heavy rain combine to cause flooding. The annual average discharge is 2,300 cubic feet per second (cfs); the average for September is 609 cfs (at Nighthawk, WA).

Shaw and Taylor (1994) have a detailed description of the British Columbia portion of the basin. The largest towns are Princeton in the upper drainage (pop. 3,050) and Keremeos (pop. 830) and Cawston (pop. 800) along the lower river (1980 data). Agriculture is found throughout the area and depends heavily on irrigation water drawn from the Similkameen and other tributaries. Forestry is concentrated in the west.

Mining occurs at a number of locations in British Columbia, although a detailed accounting of the mining activity was not obtained for the present report. Pommen (2001a) summarized the early gold mining as follows: *"Placer gold mining took place in the 1860s and 1870s, and hard rock mining began in the late 1890s, with 1905-55 being the most productive period. There have been 77 past producers in the basin."*

Shaw and Taylor (1994) mention the following mines in British Columbia: Similco Mines copper mine between the Similkameen River and Wolfe Creek, below Princeton; eleven placer mines along the Similkameen and Tulameen rivers, including the Dankoe silver/gold mine near the U.S. border; and the large Corona Nickel Plate Mine and Candorado Mines Ltd. near Hedley which mine or process tailings for gold. As of 1994 other mines were proposed near Hedley. Similco is currently in caretaking status. The Nickel Plate and Candorado mines have been closed and under reclamation since about 1997.

Downstream of the border, the Similkameen flows though arid sagebrush typical of north-central Washington. Approximately six miles below the border the river meets Palmer Lake outlet, sometimes called Palmer Creek. A unique hydrologic feature of their juncture is that, during the spring, high flows in the Similkameen can cause Palmer Creek to reverse direction and the river flows into the lake. Based on observations during the present study, this appears to occur at flows greater than 5,000 cfs. Other than Palmer Lake, Washington tributaries to the Similkameen are dry most of the year, except at higher elevations.

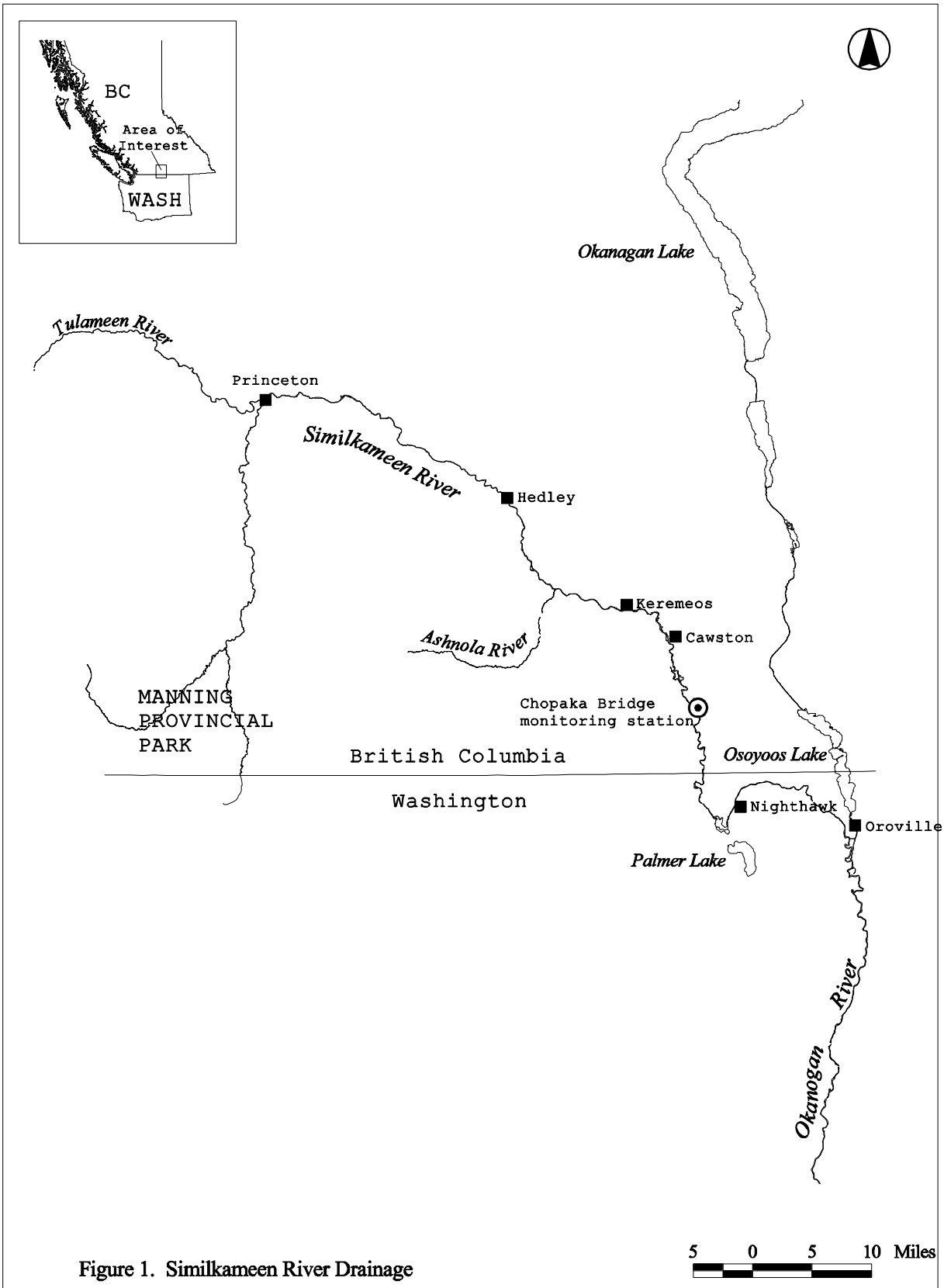

Figure 1. Similkameen River Drainage

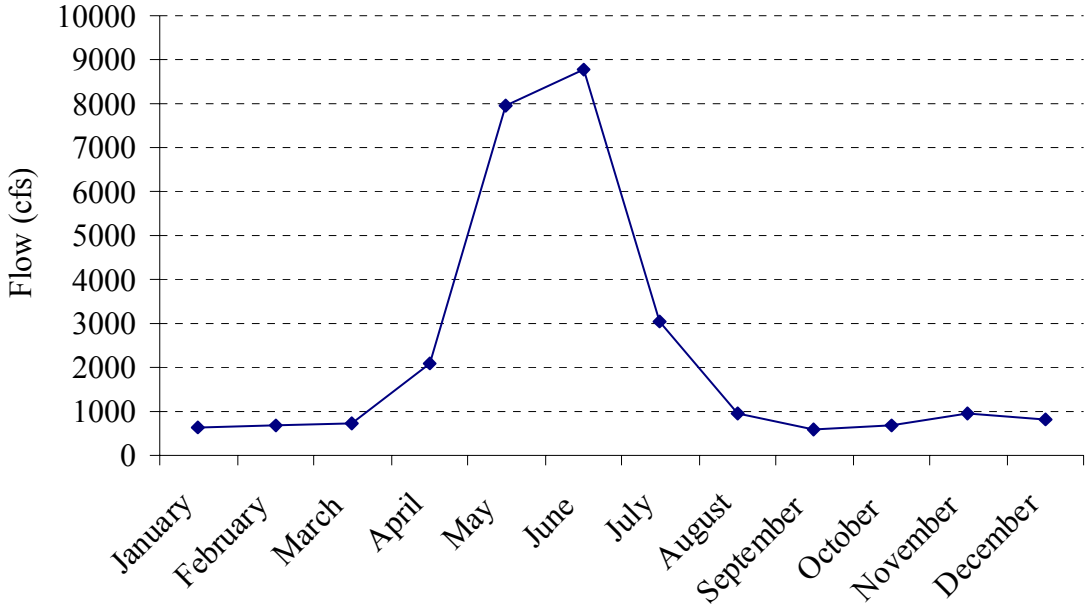

Figure 2. Mean Monthly Flow for the Similkameen River near Nighthawk, WA, 1928 - 2000 (USGS station 12442500)

The watershed is sparsely populated in Washington. Nighthawk, just downstream of Palmer Lake, is the largest community, with approximately 26 people. There is some hay and cattle farming in the Nighthawk/Palmer Lake area; most of the land downstream is undeveloped range land. Enloe Dam, about nine miles below Nighthawk, was built in 1920 to generate electricity, but has not been used for power since 1958. The dam blocks fish passage. The town of Oroville at the mouth of the river has a population of 1,590. There are several fruit orchards along the Similkameen River near Oroville, as well as on the east shore of Palmer Lake. The river flows through allotments of the Colville Confederated Tribes near the U.S. border and in the vicinity of Palmer Lake outlet.

Okanogan County has a long history of prospecting and mining activities. In the Similkameen the major mining area is concentrated around Nighthawk, particularly near Little Chopaka Mountain. By 1967 none of the mines were operating. The only large mine was the Kabba-Texas near Nighthawk. The Washington mines are discussed later in this report.

Scope of the TMDL

Geographic

This TMDL covers the portion of the Similkameen River from the international border between Washington State and British Columbia (river mile 27.1) to the river's mouth near Oroville, Washington, including Palmer Lake outlet and other tributaries to the river within Washington.

Pollutant Parameters

This TMDL is for total recoverable arsenic in the water column.

The data that resulted in 303(d) listing the Similkameen are shown in Table 1. In sampling done by Ecology during 1995-96, total recoverable arsenic concentrations substantially exceeded EPA National Toxics Rule criteria of 0.018 and 0.14 ug/L (see *Applicable Water Quality Standards*) at each of three locations, for both low-flow and high-flow conditions. Concentrations ranged from 2.1 to 7.0 ug/L (parts per billion).

Table 1. Ecology 1995-96 Similkameen River Data (from Johnson, 1997)
[arsenic concentrations are mean +/- half the range of two field replicates)

Location	Flow (cfs)	Temp. (^oC)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	Tot. Rec. Arsenic (ug/L)
	August 29, 1995						
Chopaka Bridge, B.C.	- -	18.3	7.6	184	2	0.6	2.0 +/- 0.5
Nighthawk, WA	556	na	8.2	192	2	1.2	3.6 +/- 0.5
Oroville, WA	- -	17.5	8.2	195	1	1.0	4.0 +/- 0.5
	April 24, 1996						
Chopaka Bridge, B.C.	- -	5.9	7.6	133	111	38	6.5 +/- 0.6
Nighthawk, WA	6,720	6.6	7.3	140	41	21	3.1 +/- 0.2
Oroville, WA	- -	7.3	7.7	144	73	20	4.6 +/- 0.2

na = not analyzed

Applicable Water Quality Standards

Washington State

Water quality standards for surface waters of the state of Washington are codified in Chapter 173-201 of the Washington Administrative Code (WAC). The Similkameen is a Class A river.

Characteristic Uses

Characteristic uses for Class A waters shall include, but not be limited to the following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Stock watering.

(iii) Fish and shellfish:
Salmonid migration, rearing, spawning, and harvesting.
Other fish migration, rearing, spawning, and harvesting.
Clam, oyster, and mussel rearing, spawning, and harvesting.
Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning, and harvesting.

(iv) Wildlife habitat.

(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).

(vi) Commerce and navigation.

Water Quality Criteria

Water quality criteria that apply to arsenic in Washington State are listed in Table 2.

For protection of freshwater aquatic life, dissolved arsenic concentrations shall not exceed 360 ug/L for acute exposure and 190 ug/L for chronic exposure (WAC 173-201A). Since these EPA criteria were adopted in Washington, EPA revised their national criteria to 340 ug/L and 150 ug/L dissolved arsenic (EPA, 1999).

For 303(d) listing purposes, Washington follows the EPA National Toxics Rule (40 CFR Part 131). The listing criteria for arsenic are 0.018 ug/L for consumption of water and organisms, and 0.14 ug/L for consumption of organisms only. These criteria are for a 10^{-6} (1 in 1 million) cancer risk. Although the criteria are for total inorganic arsenic, the arsenic listings for the Similkameen and other state waterbodies have been based on total recoverable data. In order for a waterbody to be placed on the 303(d) list for toxic pollutants in the water column, Ecology requires a minimum of two samples within a three-year period exceed the criteria (Water Quality Program Policy 1-11, Sept. 2002).

Table 2. Applicable Water Quality Criteria for Arsenic (ug/L)

Washington		
Aquatic Life (WAC 173-201A)		
acute criterion[a]	360	dissolved arsenic
chronic criterion[b]	190	dissolved arsenic
Human Health (EPA National Toxics Rule)		
consumption of water + organisms	0.018	inorganic arsenic
consumption of organisms only	0.14	inorganic arsenic
Ground Water Quality Standard (WAC 173-200)	0.05	total arsenic
Drinking Water (Safe Drinking Water Act)	50	total arsenic
British Columbia		
Aquatic Life[c] (CCME, 1998)	5	total arsenic
Drinking Water[c] (Health & Welfare Canada, 1996)	25	total arsenic

[a]A 1-hour average not to be exceeded more than once every three years on the average.

[b]A 4-day average not to be exceeded more than once every three years on the average.

[c]maximum

The state ground water standard of 0.05 ug/L is in the same region as the human health NTR criteria, it also being based on a 10^{-6} cancer risk. The much higher maximum contaminant level (MCL) of 50 ug/L arsenic in the Safe Drinking Water Act (SDWA) is set at a 10^{-4} cancer risk but also takes economic factors into account. EPA will be changing the MCL from 50 ug/L to 10 ug/L within the next few years.

In Washington State, the SDWA number is used by the Department of Health for public water supplies. The ground water standard applies to discharge permit limits set by Ecology. In practice, background concentrations are typically used in permits because the standard is lower than natural background.

States set their own water quality criteria under the federal Clean Water Act. For water quality standards protective of human health, EPA recommends that states adopt an excess cancer risk level between 1 in 100,000 and 1 in 10,000,000. Washington State has selected criteria for

carcinogens such that the upper-bound excess cancer risk is less than or equal to 1 in 1,000,000 (WAC 173-210A). Other states have adopted different human health criteria for arsenic and EPA subsequently approved those criteria. For example, Idaho's human health criteria of 0.02 ug/L and 6.2 ug/L differ from Washington's only in using a different bioconcentration factor.

Antidegradation

The antidegradation policy of the state of Washington, generally guided by Chapter 90.48 RCW, Water Pollution Control Act, and Chapter 90.54 RCW, Water Resources Act of 1971, is stated as follows:

(1) Existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurious to existing beneficial uses shall be allowed.

(2) Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

(3) Water quality shall be maintained and protected in waters designated as outstanding resource waters in WAC 173-201A-080.

(4) Whenever waters are of a higher quality than the criteria assigned for said waters, the existing water quality shall be protected and pollution of said waters which will reduce the existing quality shall not be allowed, except in those instances where:

   (a) It is clear, after satisfactory public participation and intergovernmental coordination, that overriding considerations of the public interest will be served;

   (b) All wastes and other materials and substances discharged into said waters shall be provided with all known, available, and reasonable methods of prevention, control, and treatment by new and existing point sources before discharge. All activities which result in the pollution of waters from nonpoint sources shall be provided with all known, available, and reasonable best management practices; and

   (c) When the lowering of water quality in high quality waters is authorized, the lower water quality shall still be of high enough quality to fully support all existing beneficial uses.

(5) Short-term modification of water quality may be permitted as conditioned by WAC 173-201A-110.

British Columbia

Aquatic life and drinking water guidelines that apply to the Similkameen River in British Columbia are 5 ug/L and 25 ug/L total arsenic, respectively (CCME, 1998; Health and Welfare Canada, 1996). British Columbia currently has no water quality criteria that correspond to the EPA human health criteria.

Water Quality Data

Data Sources

Table 3 lists the sources of arsenic data on the Similkameen River used in the present assessment.

Table 3. Sources of Data on Arsenic Concentrations in the Similkameen River

Type of Study Location	Sampling Period Agency	Reference
Routine monitoring Princeton, Hedley, Chopaka Bridge, and Princeton BC	1984 to present Environment Canada / B.C. Ministry of Water, Land and Air Protection	database, Webber and Stewart (2001), Shaw and Taylor (1994)
Routine monitoring Oroville WA	Dec 1995 - August 1997 Wash. St. Dept. Ecology	database
Intensive sampling Chopaka Bridge BC to Oroville WA	August 1995, April 1996 Wash. St. Dept. Ecology	Johnson (1997)
Routine monitoring Chopaka Bridge BC and Oroville WA	May 2000 - June 2001 Wash. St. Dept. Ecology	present study
Intensive and source sampling Chopaka Bridge BC to Oroville WA	Sept. 2000, April 2001, May 2001, Nov. 2001, Feb. 2002 Wash. St. Dept. Ecology	present study

Canada and British Columbia have monitored arsenic and other water quality parameters at three stations on the Similkameen main stem since 1984 (see Figure 1): in the upper river at Princeton Highway 3 Bridge (river mile (r.m.) 98.3, federal site no. BC08NL0001, provincial station no. 0500629); near Hedley (r.m. 72.0, federal site no. BC08NL008); and at Chopaka Road Bridge near the U.S. border (r.m. 36.1, federal site no. BC08NL0005; provincial station no. 0500073).

Between 1995 and 1997 Ecology did routine monitoring for arsenic and other parameters near the mouth of the Similkameen River at the town of Oroville (r.m. 5.0, station no. 49B070).

During the same period Ecology analyzed arsenic in a small set of samples collected from Chopaka Bridge, Nighthawk, and Oroville during low flow conditions in August 1995 and again during high flow in April 1996 (Johnson, 1997).

Ecology collected recent additional data as a result of the 303(d) listing. Total recoverable and dissolved[1] arsenic were analyzed in monthly samples collected at Chopaka Bridge and Oroville between May 2000 and June 2001. Total recoverable and dissolved arsenic were also analyzed in downstream transects of seven sites between Chopaka Bridge and Oroville during September 2000, April 2001, and May 2001. Tributaries and other potential arsenic inputs to the river within Washington were sampled during one or more of these periods. Arsenic speciation data was obtained for a subset of these sampling sites. Effluent samples from the Oroville wastewater treatment plant were collected for arsenic analysis in February 2002.

Figure 3 shows the location of Ecology's samples. Appendix A has a description of the sampling sites. Sampling methods are described in Appendix B. Supporting QA/QC for these data can be found in Appendix C and D.

Canada monitors flow at Princeton (flow station no. BC08NL007) and at Hedley (flow station no. BC08NL038). The U.S. Geological Survey (USGS) has operated a stream gaging station at Nighthawk since 1928 (station no. 12442500). Ecology has made periodic flow measurements at Oroville since 1996.

Total vs. Total Recoverable Arsenic

The Canadian federal/provincial arsenic data on whole water samples from the Similkameen River are reported as total arsenic. Their total arsenic analysis has generally employed a digestion with potassium persulphate and concentrated hydrochloric acid. Ecology reports their whole water data as total recoverable arsenic and uses a nitric acid digestion. The Canadian and Ecology methods should produce similar results on most surface water samples.

In response to concerns about the comparability of the arsenic data being used in the TMDL evaluation for the Similkameen River, expressed at a meeting of Canadian and U.S. agency representatives on April 18-19, 2002, it was agreed that an intercomparison study should be conducted. The design of the study included analysis of split samples and side-by-side samples of the river at Chopaka Bridge, field blanks, and standard reference materials. The sample exchange was conducted by Ecology and the B.C. Ministry of Water, Land and Air Protection on May 23, 2002.

Preliminary data from the intercomparison study are summarized in Appendix E. The results showed good agreement except for the analysis of whole water samples from the Similkameen, where the Canadian laboratory (National Laboratory for Environmental Testing (NLET) Burlington, Ontario) and Ecology laboratory (Manchester Environmental Laboratory, Manchester, WA) differed by a factor of about 6. While Ecology's total recoverable results are

[1] 0.45 micron filtered

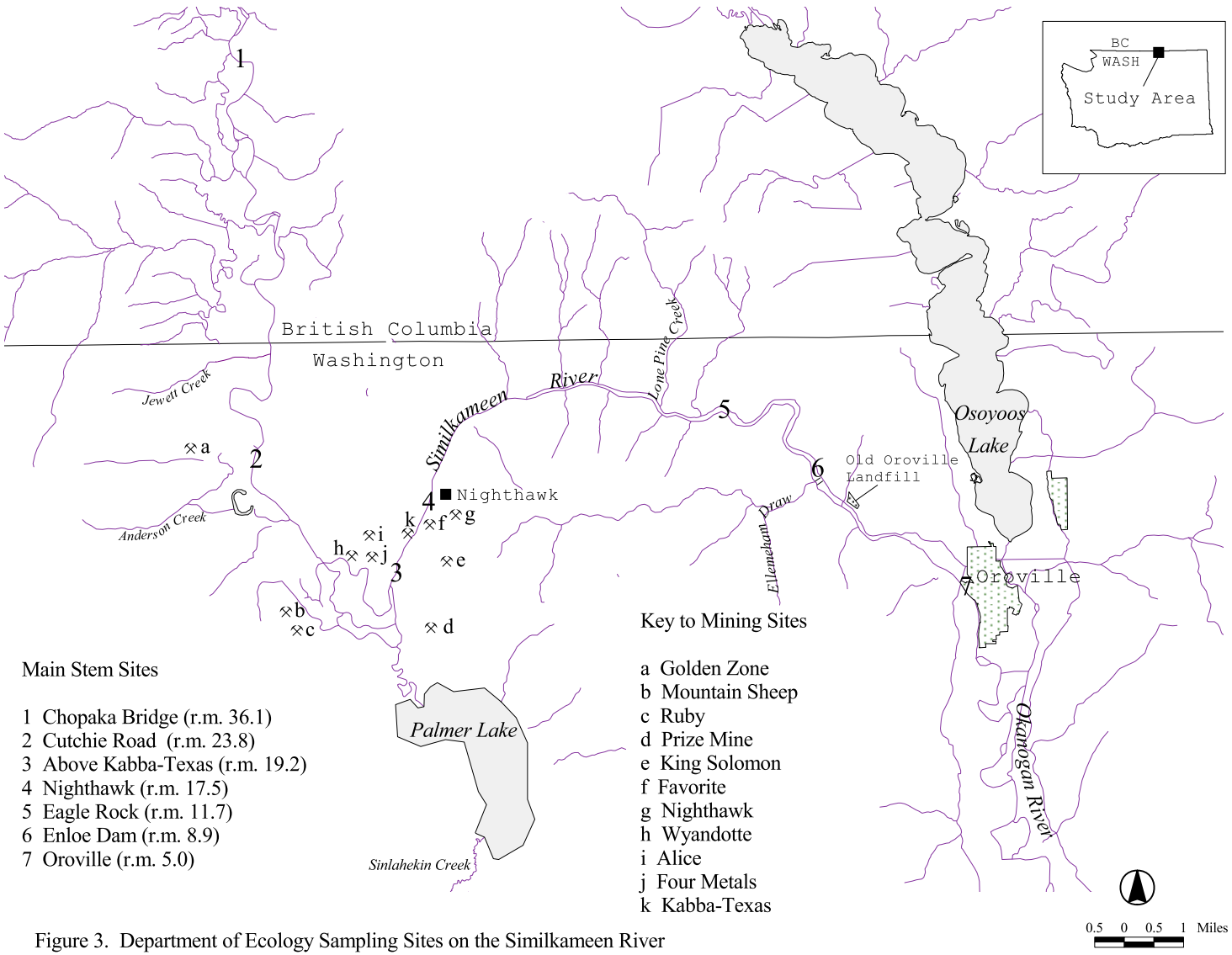

Figure 3. Department of Ecology Sampling Sites on the Similkameen River

more consistent with historical data for this time period (both Canadian and Ecology historical data), the reason for this discrepancy has not been determined. NLET is currently investigating the problem.

The B.C. Ministry of Water, Land and Air Protection recently provided preliminary data from a reanalysis of two of the intercomparison samples, conducted by the provincial laboratory, Philip Analytical Services (Jensen, 2002). Philip reported 4.6 ug/L and 7.5 ug/L total arsenic in water samples collected from the Similkameen River @ Nighthawk and @ Oroville, respectively. NLET had reported 1.5 ug/L in the Oroville sample (Nighthawk sample not analyzed). Ecology had not analyzed these samples, but the Philip results are consistent with Ecology results for total recoverable arsenic at Chopaka Bridge, which averaged 4 ug/L (Appendix E).

Review of British Columbia Data

Webber and Stewart (2001) assessed the state of water quality in the Canadian portion of the Similkameen River based on data collected up to 1997. They demonstrate that a seasonal peak in total arsenic concentrations occurs near the U.S. border at Chopaka Bridge during the spring. Between 1984 and 1997, the British Columbia aquatic life guideline of 5 ug/L "*was exceeded on 19 occasions (5% of values) and almost all of these occurred during spring freshet when turbidity was elevated*." The drinking water guideline, 25 ug/L, was exceeded three times, all prior to 1992. Figure 4 illustrates this pattern, plotting the most recent data currently available (through November 1999). The correlation with turbidity caused Webber and Stewart to conclude that the arsenic was associated with particulate matter and may not be bioavailable.

Figure 5 compares the arsenic concentrations measured at Chopaka with river flow for the corresponding dates (USGS gage at Nighthawk). Close examination of these data shows the arsenic spikes occur on a rising flow. During periods of relatively high but dropping water levels, arsenic concentrations are sometimes comparable to the lower flow regimes of summer and fall. This phenomenon is known as hysteresis and is interpreted as the result of initial transport of stored materials within the stream channel, or the initial flush of mobile materials from riparian or terrestrial sources (Chang, 1998).

Through visual inspection of the historical record, Webber and Stewart (2001) noted a declining trend in the arsenic concentrations at Chopaka Bridge. This apparent trend can be more easily seen when the data are examined by month of collection. The May and September data are shown in Figure 6 as an example; a similar trend is seen for other months. According to Webber and Stewart, "*specific causes of this improvement have not been identified*". It does not appear to be related to flow. Although not mentioned by Webber and Stewart, the steps taken to reduce erosion of tailings piles along Hedley Creek (see *Arsenic Sources*) would seem a possible cause of the decline. The fact that a decreasing trend is also evident at Princeton, which is above the region suspected as being the arsenic source, suggests that bias in the early data could also be a contributing factor.

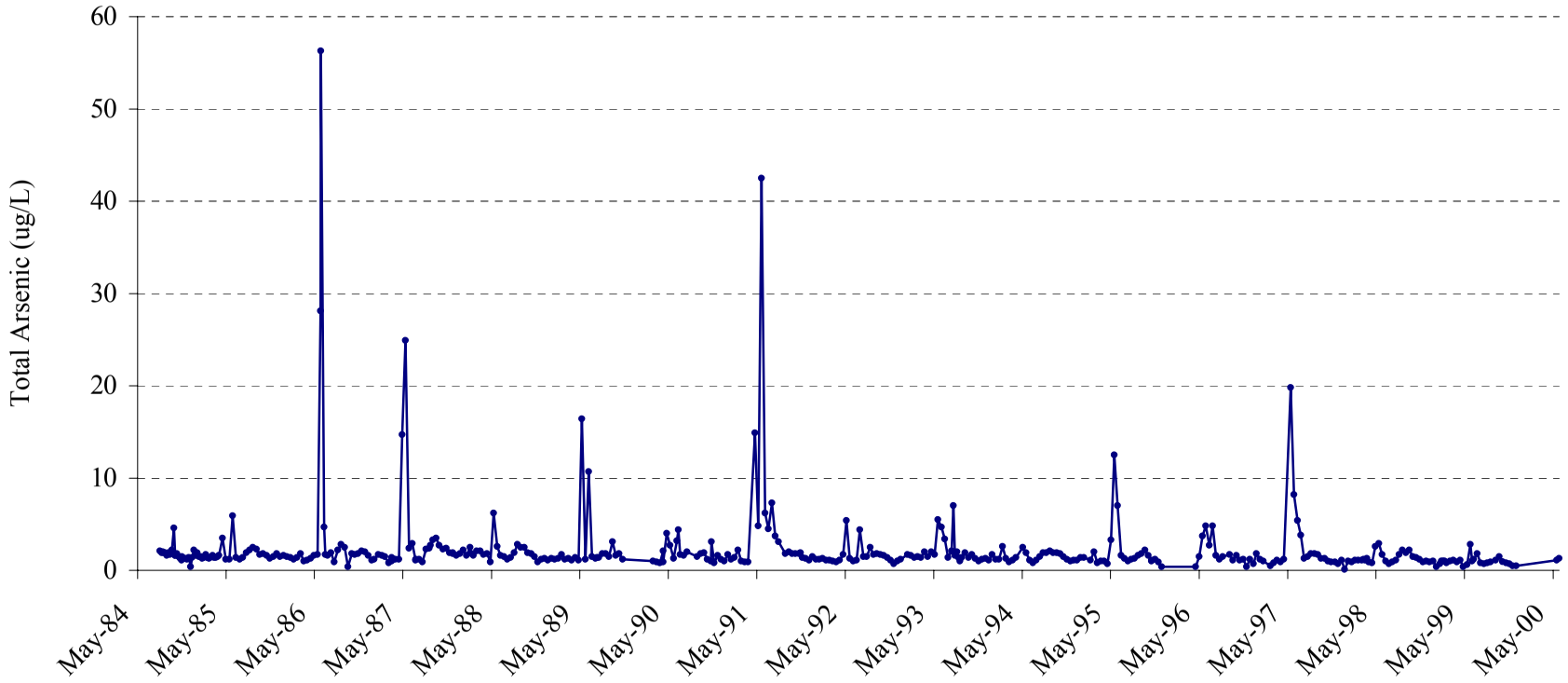

Figure 4. Historical Data on Total Arsenic Concentrations in the Similkameen River at Chopaka Bridge, B.C. (Canadian federal/provincial data)

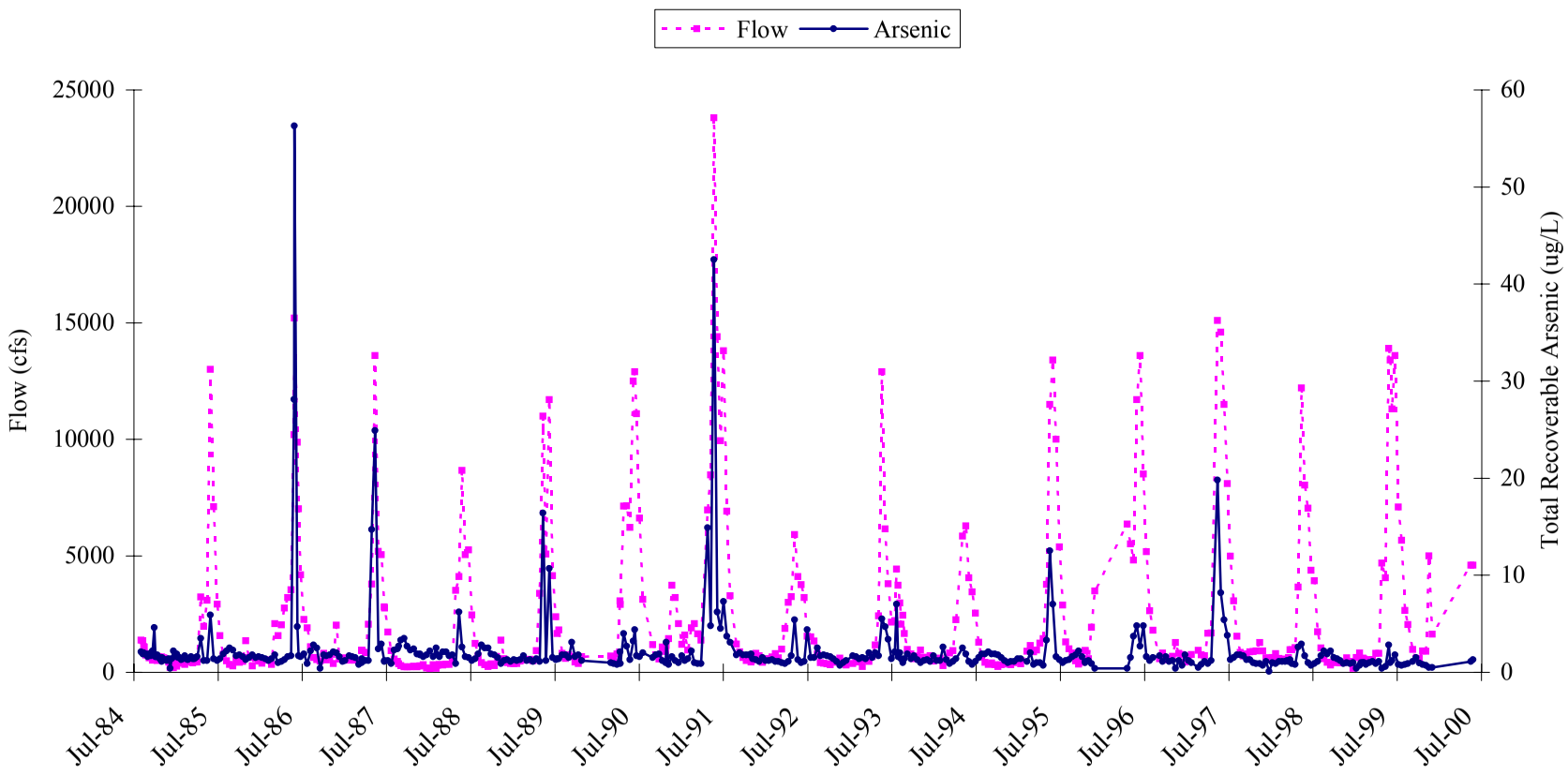

Figure 5. Total Arsenic Concentrations in the Similkameen River at Chopaka Bridge, B.C. Compared to Flow on Same Dates (Canadian federal/provincial data; USGS gage at Nighthawk, WA)

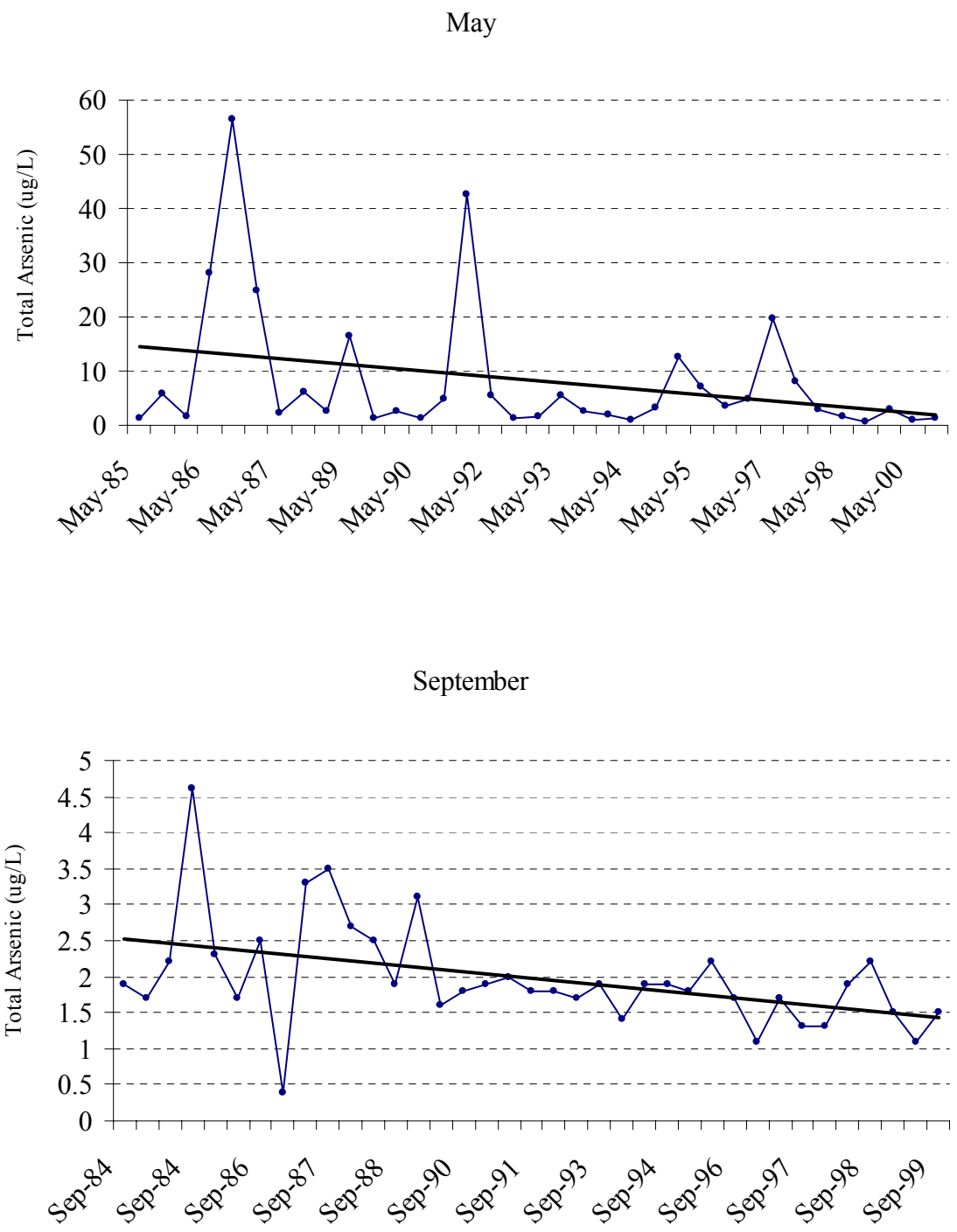

Figure 6. May and September Total Arsenic Data for Chopaka Bridge, B.C., with linear regression (Canadian federal/provincial data)

When data older than 1990 are excluded from consideration, there is less evidence of decreasing arsenic levels. Therefore, in an effort to represent current conditions, the present assessment relies on data collected since 1990.

There are 12 pairs of total and dissolved arsenic values in the Canadian federal/provincial data set for Chopaka Bridge (Table 4). For flows at or above 11,300 cfs, more than half the arsenic was in particulate form. At lower flows most of the arsenic appeared to be dissolved. These results suggest a greater potential for biological uptake than suggested by Webber and Stewart (2001).

Table 4. Canadian Federal/Provincial Data on Total and Dissolved Arsenic in the Similkameen River at Chopaka Bridge, B.C.

		Arsenic		
Date	Flow* (cfs)	Total (ug/L)	Dissolved (ug/L)	Turbidity (NTU)
29-Apr-97	7,190	na	1.0	20
1-Jun-99	13,400	1.1	0.4	41
8-Jun-99	11,300	1.2	0.5	15
22-Jun-99	13,600	1.8	0.5	27
6-Jul-99	7,090	0.8	0.5	9
16-May-00	4,600	0.4	0.3	5.6
30-May-00	6,540	0.4	0.4	4.5
13-Jun-00	6,630	0.4	0.4	5.1
27-Jun-00	4,670	0.5	0.5	2.3
26-Jul-00	1,650	0.8	0.8	0.66
8-Aug-00	825	1.0	4.9**	0.53
22-Aug-00	568	1.1	1.1	0.33
5-Sep-00	585	0.9	0.9	0.39

na = not analyzed
*USGS gage at Nighthawk, WA
**appears to be an error

Review of Washington Data

Table 5 shows Ecology's historical data for the mouth of the river, collected between December 1995 and August 1997. Total recoverable arsenic concentrations increased from winter to spring in both 1996 and 1997, and were correlated with total suspended solids (TSS) and turbidity. A high arsenic concentration of 22 ug/L was recorded in December 1995. This occurred in association with a flow of 3,950 cfs, abnormally high for that time of year.

Table 5. Historical Ecology Data for the Similkameen River at Oroville, WA

Date	Flow (cfs)	Temp. (^oC)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	Tot. Rec. Arsenic (ug/L)
11-Dec-95	3,950	0.0	7.3	171	68	29	22
12-Feb-96	2,380	0.0	7.6	173	8	2.7	1.9
15-Apr-96	5,850	6.6	8.1	138	63	25	3.6
11-Jun-96	16,500	9.8	8.3	91	99	40	6.3
13-Aug-96	1,100	18.9	8.3	175	2	2.0	3.8
15-Oct-96	750	9.5	8.4	203	1	1.1	2.8
10-Dec-96	900	na	na	na	na	na	1.9
15-Apr-97	1,650	7.6	7.4	197	9	5.4	2.0
10-Jun-97	14,000	13	7.2	89	82	36	8.3
12-Aug-97	1,200	19.7	8.1	183	4	1.7	4.2

na = not analyzed

Figure 7 compares the Canadian federal/provincial data and Ecology data for five occasions where samples were collected at Chopaka Bridge and Oroville on or about the same day. These results show a consistent downstream increase of 0.8 – 3.6 ug/L between the U.S. border and the mouth of the river, typically a factor of about 2.

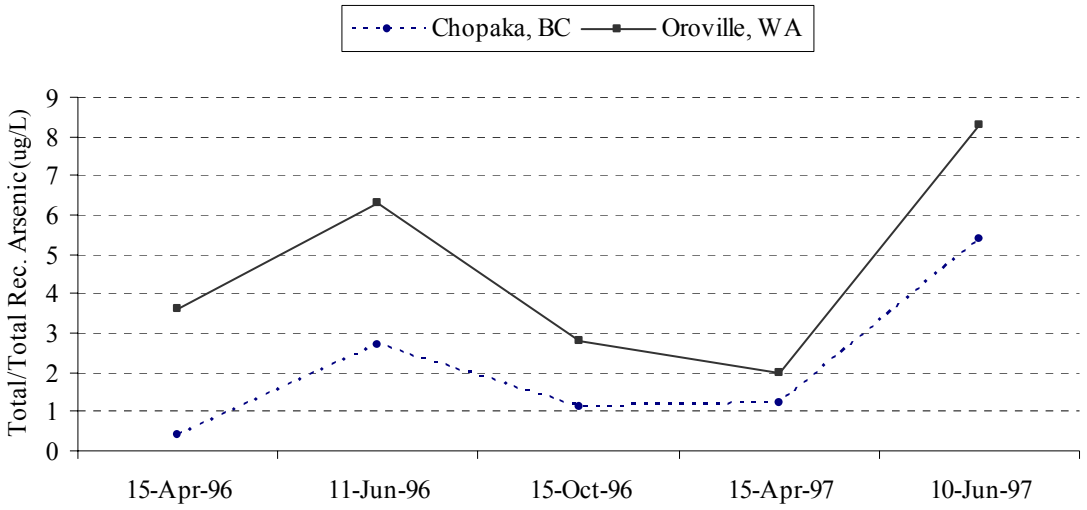

Figure 7. Comparison of Historical Arsenic Data for Chopaka Bridge, B.C. (Canadian federal/provincial total arsenic data) and Oroville, WA (Ecology total recoverable arsenic data). [The Chopaka Bridge April 1996 sample was collected on the 16th.]

Ecology's 1995-96 data for Chopaka Bridge, Nighthawk, and Oroville were previously presented in Table 1. The April data represent the only instance where higher arsenic concentrations have been measured near the border than at the mouth, possibly due to the high TSS concentration in the Chopaka Bridge sample.

Results from the monthly monitoring Ecology did between May 2000 and June 2001 are shown in Table 6. The objective of this effort was to obtain a consistent, comparable data set for Chopaka Bridge and Oroville that covered both low-flow and high-flow conditions.

The total recoverable data from the recent monitoring are plotted in Figure 8. These results are consistent with the historical data in showing a two-fold arsenic increase (0.5 – 2.6 ug/L) on the Washington side of the border. The Pacific Northwest experienced record low precipitation during 2001, and flows in the Similkameen were approximately half the historical average (Figure 9). As a result there was only a modest arsenic peak in the river that spring.

Dissolved arsenic concentrations tracked total recoverable and increased downstream (Figure 10). Overall, the difference between dissolved and total recoverable arsenic was insignificant (paired t-test, $p < 0.05$).

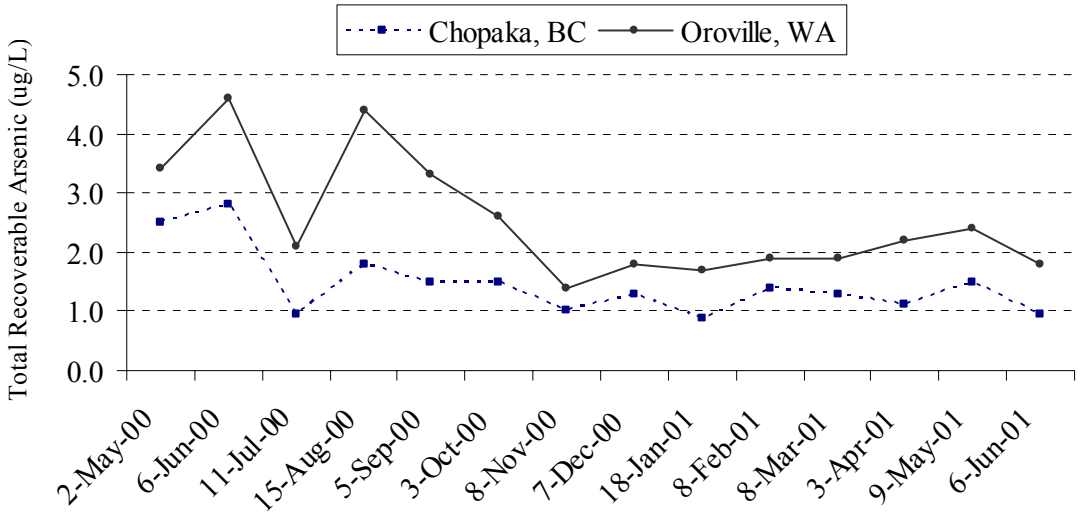

Figure 8. Total Recoverable Arsenic Concentrations Measured in Monthly Monitoring of Similkameen River from May 2000 to June 2001 (Ecology data)

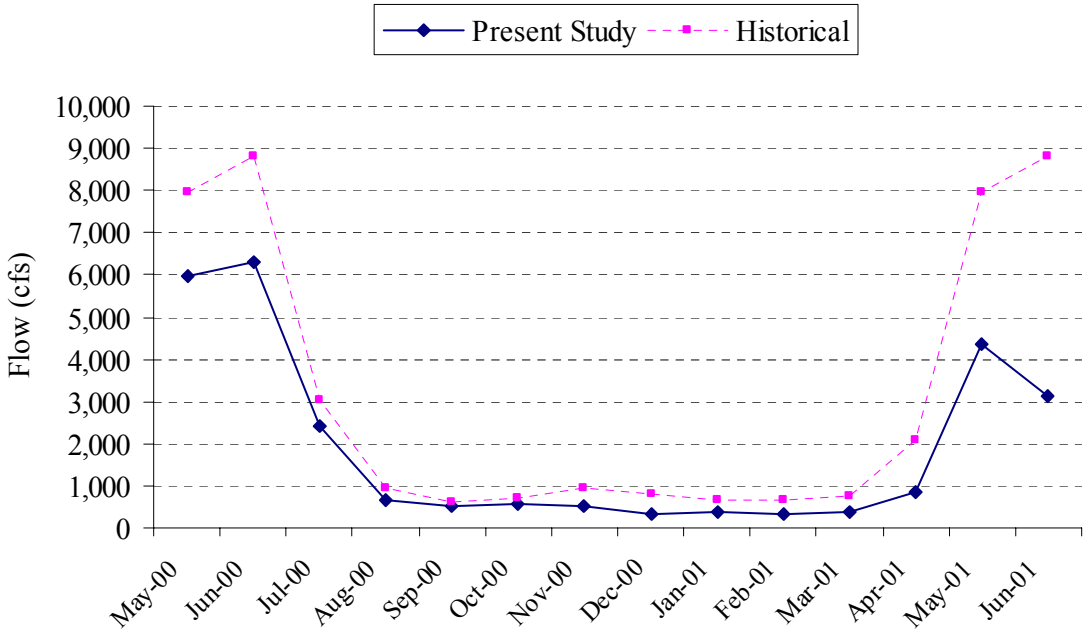

Figure 9. Similkameen River Flow during 2000 - 2001 Compared to Historical Averages (USGS gage at Nighthawk, WA)

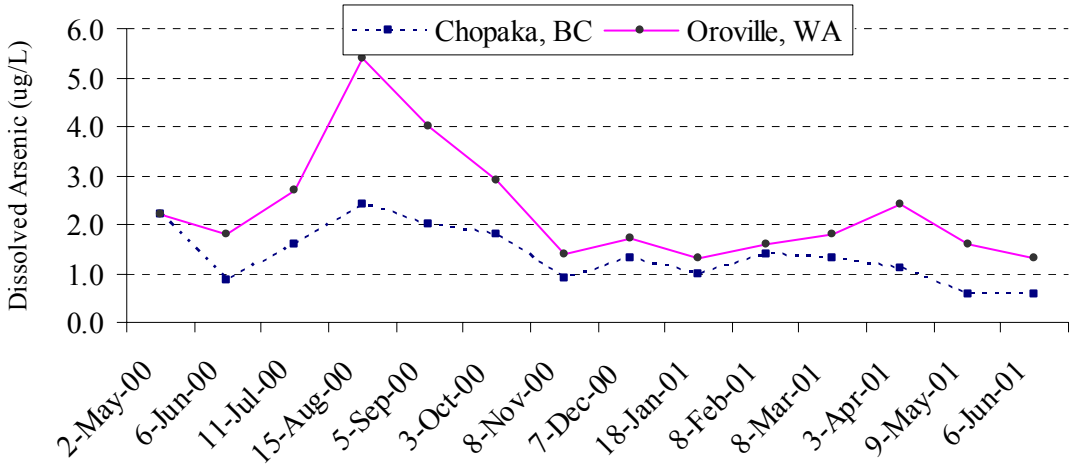

Figure 10. Dissolved Arsenic Concentrations Measured in Monthly Monitoring of the Similkameen River from May 2000 to June 2001 (Ecology data)

For flows at or below 5,550 cfs (Nighthawk), the dissolved and total recoverable concentrations were similar (Table 6), indicating that, under these flow regimes, most of the arsenic is transported in dissolved form. In the one set of samples collected at higher flow, 8,360 cfs, most of the arsenic was in particulate form.

Table 7 summarizes Ecology's data from the downstream transects between Chopaka Bridge and Oroville. The purpose here was to identify reaches that were sinks or sources of arsenic. The arsenic samples were collected in replicate and, with few exceptions, showed a low level of within-site variability

Table 6. Results of Recent Ecology Monitoring of the Similkameen River

Date	Flow* (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Arsenic Tot. Rec. (ug/L)	Arsenic Dissolved (ug/L)
Chopaka, B.C.							
2-May-00	5,550	8.5	7.8	93	35	2.5	2.2
6-Jun-00	8,360	9.0	na	54	69	2.8	0.86
11-Jul-00	2,910	14.2	8.2	107	5	0.93	1.6
15-Aug-00	583	17.9	8.4	162	2	1.8	2.4
5-Sep-00	585	14.3	8.2	163	10	1.5	2.0
3-Oct-00	560	9.0	8.3	194	2	1.5	1.8
8-Nov-00	653	3.2	8.1	177	1	1.0	0.88
7-Dec-00	353	1.9	7.8	160	1	1.3	1.3
18-Jan-01	299	0.0	7.9	213	2	0.89	0.98
8-Feb-01	220	0.0	7.8	217	1	1.4	1.4
8-Mar-01	313	4.7	8.1	224	4	1.3	1.3
3-Apr-01	446	7.5	8.1	216	2	1.1	1.1
9-May-01	2,750	13.0	8.1	126	13	1.5	0.58
6-Jun-01	4,040	11.7	8.0	94	9	0.94	0.57
Oroville, WA							
2-May-00	6,120	6.6	6.3	88	38	3.4	2.2
6-Jun-00	10,000	7.7	na	51	79	4.6	1.8
11-Jul-00	3,090	12.4	7.8	99	4	2.1	2.7
15-Aug-00	680	13.5	8.2	146	2	4.4	5.4
5-Sep-00	680	10.3	7.8	140	5	3.3	4.0
3-Oct-00	634	6.4	7.7	172	2	2.6	2.9
8-Nov-00	744	2.5	8.2	165	1	1.4	1.4
7-Dec-00	560	1.4	7.6	155	1	1.8	1.7
18-Jan-01	870	0.0	7.6	210	1	1.7	1.3
8-Feb-01	544	-0.5	7.5	220	2	1.9	1.6
8-Mar-01	536	4.6	8.1	214	3	1.9	1.8
3-Apr-01	610	4.7	8.1	203	2	2.2	2.4
9-May-01	2,712	9.0	7.8	108	16	2.4	1.6
6-Jun-01	4,434	10.1	7.8	78	8	1.8	1.3

*Chopaka Bridge flow data from USGS gage at Nighthawk, WA
na = not analyzed

Table 7. Ecology Data from Downstream Transects in the Similkameen River
(arsenic concentrations are mean +/- half the range of two field replicates)

Location	River Mile	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Arsenic Tot. Rec. (ug/L)	Arsenic Dissolved (ug/L)
					September 26, 2000			
Chopaka Bridge	36.1	- -	9.3	na	190	3	1.8 +/- 0.0	1.8 +/- 0.1
Cutchie Road	23.8	- -	10.6	na	193	1	2.2 +/- 0.1	2.0 +/- 0.1
Above Kabba-Texas	19.2	- -	9.9	na	194	2	2.7 +/- 0.3	2.6 +/- 0.2
Nighthawk	17.5	471	10.5	na	195	1	2.9 +/- 0.2	2.5 +/- 0.1
Eagle Rock	11.7	- -	12.4	na	194	2	3.3 +/- 0.1	3.0 +/- 0.0
Enloe Dam	8.9	- -	11.5	na	194	2	3.2 +/- 0.1	2.9 +/- 0.1
Oroville	5.0	- -	14.6	na	195	2	3.6 +/- 0.0	3.4 +/- 0.2
					April 19, 2001			
Chopaka Bridge	36.1	- -	9.6	8.28	210	8	1.7 +/-0.1	0.9 +/- 0.2
Cutchie Road	23.8	- -	9.6	8.04	218	6	2.0 +/- 0.0	1.2 +/- 0.1
Above Kabba-Texas	19.2	- -	12.7	8.07	222	4	2.9 +/- 0.1	1.8 +/- 0.0
Nighthawk	17.5	544	11.3	8.11	222	6	3.0 +/- 0.2	2.3 +/- 0.1
Eagle Rock	11.7	- -	13.8	8.33	224	4	3.0 +/- 0.1	2.4 +/- 0.1
Enloe Dam	8.9	- -	12.2	8.01	227	2	3.0 +/- 0.1	2.5 +/- 0.1
Oroville	5.0	- -	13.4	8.50	228	3	3.2 +/- 0.0	2.9 +/- 0.1
					May 21, 2001			
Chopaka Bridge	36.1	- -	10	na	103	4	0.85 +/- 0.01	0.57 +/- 0.02
Cutchie Road	23.8	- -	9.3	na	103	5	0.88*	0.78 +/- 0.01
Above Kabba-Texas	19.2	- -	10.1	na	115	10	1.9 +/- 0.0	1.2 +/- 0.0
Nighthawk	17.5	3,530	10.2	na	110	11	1.9*	1.2 +/- 0.1
Eagle Rock	11.7	- -	11.2	na	110	10	1.8 +/- 0.1	1.2 +/- 0.1
Enloe Dam	8.9	- -	11.9	na	110	8	1.8 +/- 0.1	1.4 +/- 0.1
Oroville	5.0	- -	12.2	na	110	10	2.0 +/- 0.1	1.4 +/- 0.0

na = not analyzed

*These data are for total inorganic arsenic (Table 8 and Appendix D). The total recoverable data for these two locations were rejected as being inconsistent with the dissolved data and with results for adjacent sites.

Over flows ranging from 471 cfs in September to 3,530 cfs in May, the downstream increase in total recoverable arsenic levels was gradual, with concentrations increasing by 1.2 – 1.8 ug/L, respectively, again about a factor of 2 (Figure 11). The largest increase, 0.5 – 1.0 ug/L, consistently occurred between Cutchie Road and Nighthawk (r.m. 23.8 – 17.5). Palmer Lake outlet (r.m. 19.5) was found to be a significant arsenic source to this reach (see *Arsenic Sources*).

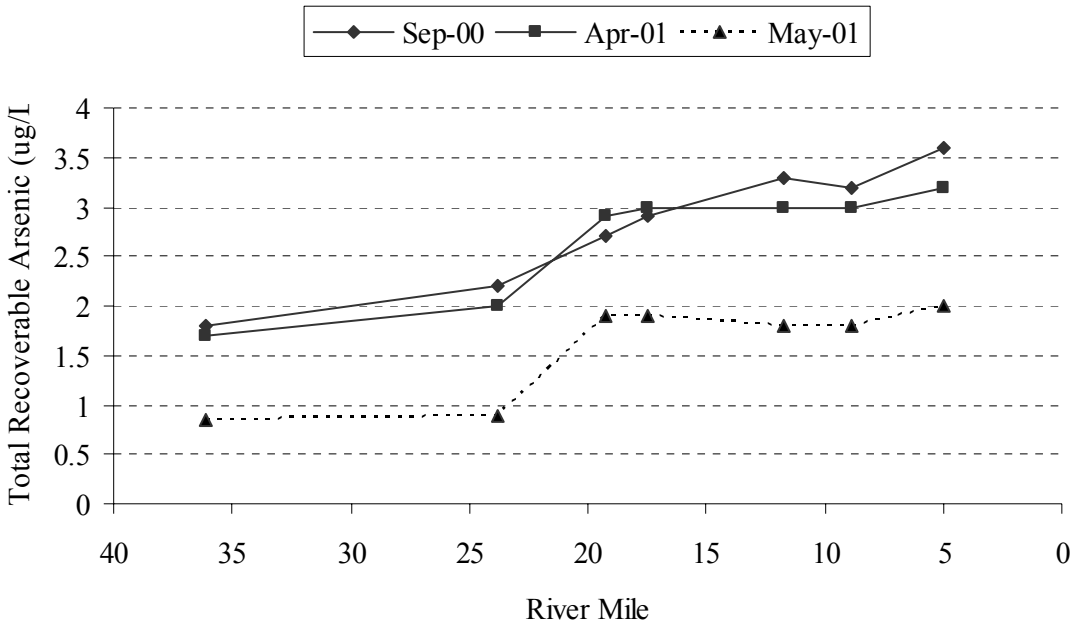

Figure 11. Summary of Ecology Results from Downstream Transects in the Similkameen River: Chopaka Bridge, B.C. (r.m. 36.1) to Oroville, WA (r.m. 5.0)

Arsenic speciation data (total inorganic, As^{+3}, and As^{+5}) were obtained for selected sites from the downstream transects. Table 8 compares the inorganic arsenic data with results from the total recoverable analyses (separately collected samples analyzed by different laboratories). The complete speciation data are in Appendix D.

Table 8. Total Inorganic vs. Total Recoverable Arsenic in the Similkameen River (ug/L)
[mean +/- half the range of two field replicates; Ecology data]

Location	River Mile	September 26, 2000		April 19, 2001		May 21, 2001	
		Total Inorganic Arsenic	Total Recov. Arsenic	Total Inorganic Arsenic	Total Recov. Arsenic	Total Inorganic Arsenic	Total Recov. Arsenic
Chopaka Bridge	36.1	1.4+/-0.04	1.8 +/- 0.0	1.2	1.7 +/-0.1	0.56	0.85 +/- 0.01
Palmer Lake outlet	19.5	7.0+/-0.08	9.7+/-0.2	8.1	7.8	5.6	5.2+/-1.1
Nighthawk	17.5	2.5+/-0.04	2.9 +/- 0.2	na	3.0 +/- 0.2	1.9	4.3 +/- 0.8
Oroville	5.0	2.7+/-0.1	3.6 +/- 0.0	2.7+/-0.02	3.2 +/- 0.0	2.0	2.0 +/- 0.1

na = not analyzed

These results show that most of the arsenic in the Similkameen River is present in inorganic form. Therefore, 303(d) listing the river based on total recoverable data appears appropriate. The concentration of organic arsenic in these samples was estimated to be less than 10% but was not quantified.

The available arsenic data show that the Similkameen River is well within the Washington State aquatic life criterion of 190 ug/L for chronic exposure. There is no record of Washington's drinking water standard, 50 ug/L, being exceeded. (It was exceeded in one British Columbia sample back in the 1980s). The EPA human health criteria of 0.018 and 0.14 ug/L are, however, consistently exceeded by an order of magnitude or more.

Arsenic Sources

British Columbia

As described earlier in this report, there have been 77 past producers of gold in the British Columbia portion of the Similkameen drainage basin. Pommen (2001a) described the relationship between arsenic and gold as follows:

"Gold is associated with arsenic in this area, and arsenic is one of the 'pathfinder elements' in prospecting for gold. Anomalous (high) levels of arsenic in soils, rocks, and stream sediments are used to look for gold. The arsenic is present as arsenopyrite, and to a lesser extent, gersdorffite (NiAsS). Levels are highly variable, but range up to as high as 1-19% (10,000-190,000 ppm) arsenic in some localized rock samples. ... There have been 77 past producers in the basin, and thus many potential sources of accelerated release of arsenic-bearing sediments."

Webber and Stewart (2001) assessed the probable location of arsenic sources to the Similkameen River as follows:

"*Total arsenic values at the upstream sites (Princeton and Hedley) were lower than those at the downstream site near the US Border and always met the drinking water (25 ug/L) and aquatic life (5 ug/L) guidelines. This indicates that the source of the elevated arsenic was between Hedley and the site near the US Border. The source of the arsenic is not clear. Monitoring to check the attainment of water quality objectives in the Similkameen River and Hedley, Red Top Gulch, and Cahill creeks, which drain abandoned and active mines, indicate that arsenic levels were low and objectives were met during 1987-95 (BC Environment, 1987-95). However, this monitoring did not coincide with spring freshets when the elevated arsenic levels in the Similkameen River near the US Border were measured. It may be that the abandoned or active mines were sources of particulate arsenic due to erosion and sediment generation during spring freshets. We recommend that monitoring be done to identify sources of arsenic in the Similkameen River, and that both total and dissolved forms be measured to assess its bio-availability*."

Geochemical stream sediment mapping by the Geological Survey Branch of B.C. Ministry of Energy and Mines confirms that most but not all of the highest arsenic concentrations are downstream of Hedley (map on file at Ecology headquarters; also see http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/default.htm).

A source not specifically mentioned in Webber and Stewart (2001) is tailings piles along Hedley Creek. According to the B.C. Ministry of Water, Land and Air Protection, the piles had been eroding for decades until diking was carried out along the lower creek in the late 1980s or early 1990s (Jensen, 2001) . Wind dispersal of tailings might also contribute to aquatic exposure.

EPA Region 10 obtained some recent information on arsenic sources and source control at Hedley and Cahill creeks during a field trip in April 2002. Notes from this effort, conducted through the courtesy of the Ministry of Water, Land and Air Protection, and Ministry of Energy

and Mines, can be found in Appendix F. Some anecdotal information on historic waste disposal practices in the Hedley Creek area is also included.

Washington State

Potential arsenic sources to the Similkameen River in Washington include tributaries, mining, the old Oroville Landfill, fruit orchards, groundwater, the Oroville wastewater treatment plant, and in-place sediments, discussed separately below.

Tributaries

The only tributary flowing into the Similkameen year-round is the outlet from Palmer Lake. All other tributaries dry before reaching the river, except briefly in the spring when there is sufficient snowmelt or rarely during heavy winter rains. Ecology collected arsenic data on Palmer Lake outlet and limited data on four other streams during 2000-2001 (Table 9).

Palmer Lake was found to have consistently high levels of total recoverable arsenic, ranging from 5.2 – 14 ug/L. A precise accounting for the impact of Palmer Lake on the arsenic levels in the Similkameen River is not possible with the available data. However, based on the concentrations measured four miles upstream at Cutchie Road, the load from Palmer Lake appeared to be sufficient to explain 60 – 90% of the increase observed in the main stem above Kabba-Texas Mine.

The reason for elevated arsenic levels in Palmer Lake has not been determined. The most likely explanation is contamination from the Similkameen during flow reversals in the spring. It also appears, however, that the inflow to the lake, Sinlahekin Creek, is somewhat elevated in arsenic. Ecology measured 3.0 - 3.2 ug/L total recoverable arsenic in the creek in April and May (Table 9). The Okanogan Conservation District has analyzed arsenic in Sinlahekin Creek and reports the following results: 5/11/00 <3.0 ug/L; 9/14/00 4.3 ug/L; 4/12/01 <3.0 ug/L; and 10/11/01 3.2 ug/L total recoverable (Toni Nelson, unpublished data).

Data on other tributaries is limited to samples from Jewett Creek, Anderson Creek, Lone Pine Creek, and Ellemeham Draw collected in April 2001 (Table 9). Total recoverable arsenic concentrations in these streams ranged from 0.43 – 1.4 ug/L. These concentrations are below the long-term average reported for the river at this time of year (see Table 12). All of these streams had dried up before reaching the Similkameen. No other tributaries were found to be flowing during the April sample collection.

Table 9. Results of Sampling Tributaries and Other Potential Arsenic Sources to the Similkameen River within Washington (Ecology data)

Location	Flow (cfs)	Temp. (^oC)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Tot. Rec. Arsenic (ug/L)
				September 26, 2000		
Palmer Lake Outlet	9.8	15.1	na	227	4	9.7+/-0.2*
				April 19, 2001		
Jewett Creek	0.01	5.1	8.16	149	2	0.81
Anderson Creek	0.04	4.8	8.04	277	3	1.4
Palmer Lake Inlet	- -	13.2	8.27	385	4	3.2
Palmer Lake Outlet	18.1	11.1	8.37	265	18	7.8
Nighthawk Mine	0.04	13.6	7.81	1110	<1	<0.5
Lone Pine Creek	3.4	10.5	8.09	1500	3	0.43 est.
Ellemeham Draw	trickle	8.1	8.96	929	3	1.1
Old Oroville Landfill	0.4	9.6	7.94	1590	<1	3.4
				May 21, 2001		
Palmer Lake Inlet	- -	8.6	na	362	6	3.0
Palmer Lake Outlet	280	12.4	na	254	10	5.2+/-1.1*
				November 8, 2001		
Palmer Lake Outlet	na	na	na	na	na	14

*mean of two field replicates

na = not analyzed

Note: A dissolved arsenic concentration of 4.7 +/- 0.1 ug/L was measured in Palmer Lake outlet on May 21, 2001.

Mining

Some of the mines in the Loomis Quadrangle of Okanogan County are known to contain arsenic sulfides (Rinehart and Fox, 1972). However, mining has been done on a much smaller scale in Washington than in British Columbia.

The only large mine in Washington is the Kabba-Texas, located on the northwest bank of the river at Nighthawk. It was established in the late 1890s and operated until 1951. The known elements of value were lead, silver, copper, gold, and zinc. At its peak, up to 100 tons of ore per day were produced.

Twenty-three acres of tailings were deposited in and along the river bank. In 1999 EPA removed the tailings to a secure upland repository, which was capped and re-seeded (EPA, 2000).

The arsenic concentrations in the Kabba-Texas tailings are modest, 7 – 14 mg/Kg dry, and there is no surface water discharge to the river. Water and sediment sampling conducted by Ecology & Environment, Inc. (1991), the Bureau of Land Management (1994), and Ecology (1997, 2001, present study) has shown no indication that this site is a significant source of arsenic to the Similkameen River.

USGS 7.5 minute topographic maps show 16 small mines or prospects in the foothills bordering the river. Most of these are located between Nighthawk and the border (see Figure 3). As far as could be determined, none have a surface water discharge to the river.

Ecology collected a recent sample of the drainage from the abandoned Nighthawk Mine. The total recoverable arsenic concentration was <0.5 ug/L (Table 9). This discharge disappeared into the ground within a hundred feet of the adit. The Bureau of Land Management capped a small pile of the Nighthawk tailings in November 2001.

The Okanogan County Health District obtained samples from the abandoned Ruby and Golden Zone mines on the east slope of Little Chopaka Mountain. At the Ruby they found high arsenic concentrations in the adit drainage, 198 ug/L, and in the soil, 4,512 mg/Kg, dry (Huchton, 1997a). A water sample at the Golden Zone had a similar arsenic concentration (Huchton, 1997b). These mines are 0.6 – 1.0 miles west of the main stem but have some potential to be arsenic sources to the river during runoff events or via groundwater.

Ecology looked for evidence of off-site drainage from the Ruby, Golden Zone, Mountain Sheep, Prize, King Solomon, Favorite, Nighthawk, Wyandotte, Alice, and Four Metals mines during source sampling in April 2001. None was found.

Old Oroville Landfill

This 16-acre landfill is located on a sloping terrace above the northeast bank of the Similkameen River, approximately one mile downstream of Enloe Dam (Figure 3). It operated from 1967 to 1976. In 1960 the landfill accepted debris from a pesticide warehouse fire in Oroville. It was declared a hazardous waste site by Ecology and cleaned up in the late 1990s under the Model

Toxics Control Act. Arsenic was among the contaminants of concern. Mineral prospecting had occurred on this site, and a soils pile contained 440 mg/Kg of arsenic (Roy F. Weston, 1995).

A leachate collection system was installed as part of the landfill cleanup. So far, no leachate has been produced (Jakabosky, 2001). Among the source samples Ecology analyzed in April 2001 was a water sample from the drainage channel along the west side of the landfill (Table 9). The sample site was located about midway between the leachate collection tank and the Oroville-Nighthawk highway. This was the most downstream point at which surface water was found. Results showed 3.4 ug/L total recoverable arsenic, suggesting the west drainage could be a source of arsenic to the Similkameen during runoff events.

Fruit Orchards

Arsenic-containing compounds were commonly used on soft fruit orchards prior to the introduction of commercial organochlorine pesticides (DDT) in 1945. While some arsenic-containing pesticides were likely used after 1945, their sales for orchard use dropped to near zero at that time (Peryea and Creger, 1994).

Orchard lands in the Similkameen River drainage and in the Sinlahekin sub-watersheds are likely to contain pesticide residues in their soils from long-term agricultural practices associated with fruit trees. While information on the dates of operation of these orchards has not been gathered, there is some general information on pesticide residues to consider when evaluating these orchards as a potential source of arsenic in the drainage.

Study of the vertical distribution of lead and arsenic in soils contaminated with lead-arsenate pesticide residues has found that the highest concentrations of arsenic are in the shallow soils. Elevated arsenic can extend into the soil column, with concentrations decreasing with depth (Peryea and Creger, 1994). The arsenic distribution in the soil and amount of time that has passed since it was in common use indicate that arsenic has a low mobility through soils. Considering its low mobility, orchard soils are an unlikely source of contamination in the Similkameen or Sinlahekin without a large movement of soil from the orchards to the water, which does not occur.

The Okanogan Watershed Water Quality Management Plan (OWAC, 2000) provides information on land use in the Okanogan watershed. The Similkameen watershed includes 1,289 acres of orchard land or 0.6 % of the watershed. The Sinlahekin watershed includes 633 acres of orchard land, 0.3% of the watershed. The Similkameen figures do not include that portion of the watershed in Canada. Including the Canadian portion would significantly lower the percentage of the watershed that is orchard land.

Considering the low mobility of arsenic pesticide residues associated with orchard lands and the small amount of orchard lands in these watersheds, it is unlikely that orchards cause a measurable increase to the arsenic concentrations in the Similkameen River.

Groundwater

Most of the accessible groundwater in the Similkameen basin occurs in alluvial deposits underlying the major stream valleys. Alluvial and/or glacial deposits are largely absent downstream of Nighthawk, where in many places the river flows on bedrock (Roy F. Weston, 1995). Groundwater inflows to the Similkameen upstream of Nighthawk may influence arsenic concentrations, especially during the late summer and fall.

The amount of data available on arsenic concentrations in groundwater is limited. USGS (1997) reports results from seven domestic or livestock wells within the basin. Arsenic was undetected in six wells at or above 1.0 ug/L. One well had an arsenic concentration of 2.0 ug/L.

Oroville Wastewater Treatment Plant

The Oroville wastewater treatment plant (WWTP) discharges into the Similkameen River at r.m. 4.0. The outfall is downstream of Ecology's ambient monitoring station at Oroville (r.m. 5.0).

Ecology analyzed arsenic in two samples of the final effluent collected for the present study on February 28 @ 1315 hours and February 29 @ 0700 hours, 2002. Effluent flow rates were 0.22 and 0.14 million gallons per day (mgd), respectively. Effluent flow at this facility typically peaks around noon and levels off for most of the remainder of the day. Because of input from an apple packing plant, the typical diurnal flow pattern does not occur.

Results showed 2.8 and 2.9 ug/L total recoverable arsenic in the effluent samples. This finding is consistent with arsenic levels reported for the Oroville municipal water supply by the Washington State Department of Health (WDOH). Two WDOH samples collected in August 1998 had 3.0 and 3.5 ug/L total arsenic.

Arsenic loads in the effluent and river were compared to assess the treatment plant's potential to impact arsenic concentrations in the Similkameen under worst-case conditions. The design criteria monthly average flow (maximum month) for the Oroville WWTP is 0.49 mgd (0.76 cfs) (Permit No: WA-002239-0). The 7-day/10-year low flow for the Similkameen River is 186 cfs (USGS gage @ Nighthawk). Assuming an upstream arsenic concentration of 0.40 ug/L (Princeton monthly average for August through March, see Table 12) an arsenic concentration of 3.0 ug/L in the final effluent would result in a downstream concentration of 0.41 ug/L after mixing. An incremental increase of 0.01 ug/L would not be measurable.

Sediments

Resuspension of contaminated sediments deposited on the streambed, river banks, or flood plain is a source of arsenic to the Similkameen River.

Figure 12 summarizes the data on arsenic concentrations in Similkameen sediments collected between Chopaka Bridge and the mouth. The Chopaka Bridge to Oroville data were collected by Ecology (Johnson and Plotnikoff, 2000). The data for Oroville to the mouth were provided by

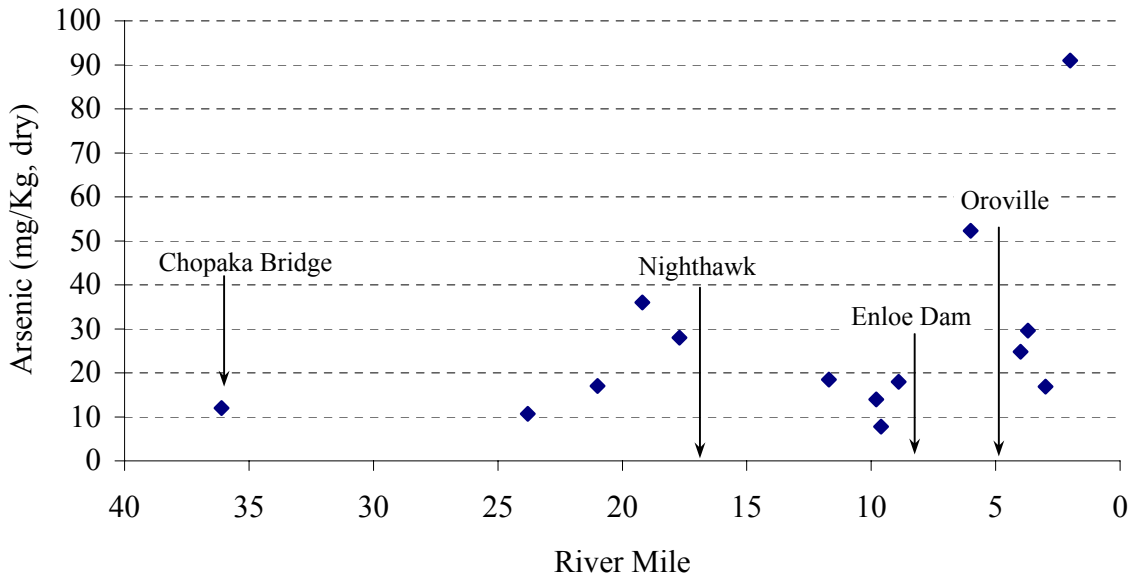

Figure 12. Arsenic Concentrations in Similkameen River Sediments (Ecology and Colville Confederated Tribes data)

the Colville Confederated Tribes (Patti Stone, Office of Environmental Trust, unpublished data). The depth increment analyzed in these samples was either 0-2 cm or 0-10 cm.

Most of the river downstream of Chopaka Bridge is non-depositional. The major depositional areas are the sloughs just upstream of Nighthawk (Champneys Slough, Edwards Slough), the impoundment behind Enloe Dam, and the braided portion of the river near the mouth.

Arsenic concentrations are elevated in Similkameen River sediments compared to other Washington rivers. Background concentrations in freshwater sediments and terrestrial soils in Washington have been put at around 3 mg/Kg (PTI, 1989; San Juan, 1994). Ecology's FSEDQUAL database shows median and 90th percentile concentrations of 5.6 and 23 mg/Kg, respectively, in freshwater sediments statewide. Arsenic concentrations in the approximate range of 10 – 50 mg/Kg are detected in Similkameen sediments, with 91 mg/Kg being reported in a single sample collected near the mouth. A TSS level of 100 mg/L derived from resuspension of sediments having an arsenic concentration of 50 mg/Kg would result in a whole water arsenic concentration of 5 ug/L, some portion of which would be dissolved.

Numerical Targets

Data collected by Ecology and others suggest that the level of arsenic in many Washington State rivers and streams naturally exceeds the EPA human health criteria at issue in the present study. Washington's water quality standards state that water quality conditions in less disturbed or neighboring watersheds may be used to estimate natural conditions (173-201A WAC).

Table 10 summarizes recent total recoverable arsenic data from Ecology's ambient monitoring database. Except for the Wenatchee River, all rivers sampled in the ambient program exceed the criteria. Twelve samples collected from the upper Wenatchee had no arsenic detected at or above 0.2 ug/L. However, an analysis of inorganic arsenic showed 0.050 ug/L in the Wenatchee River which does exceed EPA criteria (Johnson and Golding, 2002).

Table 10. Recent Data on Total Recoverable Arsenic Concentrations in Major Washington Rivers (ug/L) [Median values from Ecology's ambient monitoring database]

Station	Station No.	County	Date	N =	Tot. Rec. Arsenic
Wenatchee R. nr Leavenworth	45A110	Chelan	2001-02	12	<0.20
Yakima R. @ Cle Elum	39A090	Kittitas	2001-02	12	0.19
Lewis R. nr Dollar Corner	27D090	Clark	2001-02	12	0.20
Hoh R. @ DNR Campground	20B070	Jefferson	2001-02	12	0.22
Cowlitz R. @ Kelso	26B070	Cowlitz	2001-02	12	0.36
Methow R. @ Twisp	48A140	Okanogan	2001-02	12	0.39
Cedar R. near Landsburg	08C110	King	2001-02	12	0.39
Columbia R. @ Northport	61A070	Stevens	2001-02	12	0.41
Stillaguamish R. nr Darrington	05B110	Snohomish	2001-02	12	0.49
Spokane R. @ Stateline	57A150	Spokane	2001-02	12	0.51
Puyallup R. @ Meridian Street	10A070	Pierce	2001-02	12	0.65
Snohomish R. @ Snohomish	07A090	Snohomish	1995-97	11	0.80
Stillaguamish R. @ Silvana	05A070	Snohomish	2001-02	12	0.83
Columbia R. @ Umatilla	31A070	Benton	2001-02	12	1.0
Yakima R. @ Kiona	37A090	Benton	2001-02	12	1.2
Similkameen R. @ Nighthawk	49B070	Okanogan	1995-00	16	3.5

The median arsenic concentration in most Washington rivers is in the range of 0.2 - 1 ug/L. After the Similkameen, the highest levels have been found in the lower Yakima River with a median concentration of 1.2 ug/L and a maximum of 2.7 ug/L. The source of arsenic is thought to be historical use of lead-arsenate pesticides (Hughes, in preparation). Unlike the Similkameen, the Yakima basin has had serious problems with erosion of agricultural soils.

Table 11 shows arsenic data for selected eastern Washington rivers and streams. These results are for sites upstream of any known large anthropogenic influences. Arsenic concentrations vary as a result of water chemistry and the geology of the basin in question. The range of the data for these ten background sites is <0.2 - 1.2 ug/L, similar to other rivers and streams in more developed watersheds.

Table 11. Arsenic Concentrations at Eastern Washington River and Stream Locations Considered to Represent Natural Background (ug/L)

Waterbody	County	Sample Location	Date	N =	Tot. Rec. Arsenic	Reference
Stehekin River	Chelan	Lake Chelan	12/86-11/87	5	0.41 +/- 0.18	Patmont et al. (1989)
Railroad Creek	Chelan	Glacier Peak Wilderness	6/96, 9/96	2	0.69, 0.88	Johnson & White (1997)
Douglas Creek	Douglas	Badger Mountain	4/97	1	0.95	Johnson (1998)
Swauk Creek	Kittitas	Blewett Pass	6/97, 10/97	2	0.38, <1.5	Raforth et al.
Toroda Creek	Okanogan	Okanogan Nat. Forest	6/97, 10/97	2	1.2, <1.5	(2000)
Wenatchee River	Chelan	Leavenworth	7/01-11/15	12	<0.20	database
Yakima River	Kittitas	Cle Elum	7/01-11/15	12	0.19 median	Ecology ambient
Methow River	Okanogan	Twisp	7/01-11/15	12	0.39 median	"
Goat Creek	Okanogan	Near Mazama	6/00, 5/01	2	<0.20, 0.62	Raforth (2002)
Clugston Creek	Stevens	Near Colville	6/00, 5/01	2	<0.50, 0.37	"

Figure 13 compares the long-term monthly average arsenic concentrations recorded for the Similkameen River at Princeton and at Chopaka Bridge. Arsenic concentrations at Princeton average 0.3 – 0.4 ug/L through most of the year, rising slightly to 0.5 to 0.6 ug/L in the spring. These concentrations are in the middle to lower end of the range in background rivers and

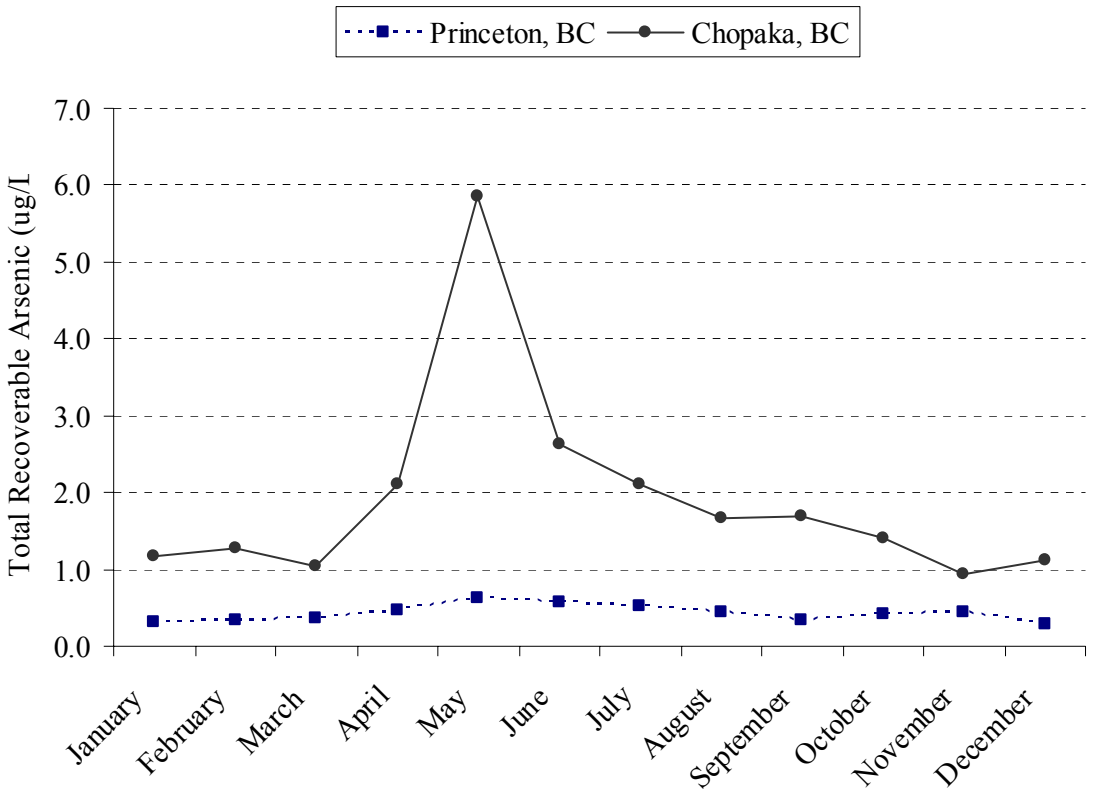

Figure 13. Monthly Average Total Arsenic Concentrations in the Similkameen River at Princeton and Chopaka Bridge, 1990 – 1999 (Canadian federal/provincial data)

streams in Washington. By Chopaka Bridge, the concentrations increase by 0.5 – 5.2 ug/L, on average. Table 12 has a statistical summary of the Princeton and Chopaka data sets.

No large anthropogenic sources of arsenic are know to occur in the Similkameen drainage upstream of Princeton. Upstream land use is primarily agriculture and forestry. The B.C. Ministry of Water, Land and Air Protection considers the arsenic levels at Princeton to be representative of natural background in the Similkameen (Pommen, 2001b).

Washington's antidegradation policy states that "*Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.*" The preceding discussion is offered as justification for basing the arsenic water quality targets for the Similkameen River on the historical data for Princeton. The Princeton monthly averages are proposed as the targets, as shown in Table 13. In practice, it is recommended that the targets be viewed as water quality goals rather than "not to exceed" values.

Table 12. Summary Statistics for Total Arsenic in the Similkameen River at Princeton and Chopaka Bridge, B.C. (ug/L; 1990 - 1999 Canadian federal/provincial data)

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Princeton, B.C.											
mean	0.3	0.3	0.4	0.5	0.6	0.6	0.5	0.4	0.3	0.4	0.5	0.3
median	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
90th perc.	0.4	0.5	0.5	0.7	1.0	0.9	0.6	0.5	0.4	0.4	0.6	0.4
maximum	0.5	0.6	0.6	0.9	1.4	1.3	0.9	0.6	0.4	1.6	3.1	0.4
minimum	0.1	0.15	0.2	0.1	0.3	0.2	0.3	0.3	0.2	0.2	0.1	0.1
	Chopaka, B.C.											
mean	1.2	1.3	1.1	2.1	5.9	2.6	2.1	1.7	1.7	1.4	0.9	1.1
median	1.2	1.1	1.0	1.2	2.9	1.8	1.5	1.7	1.8	1.3	1.0	1.1
90th perc.	1.6	2.1	1.3	2.9	11	4.8	3.6	2.1	2.0	1.8	1.3	1.6
maximum	1.7	2.6	2	15	43	6.2	7.3	2.5	2.2	3.1	1.6	1.8
minimum	0.4	0.5	0.8	0.4	0.6	0.7	0.7	0.8	1.1	0.8	0.4	0.1

Table 13. Proposed Numerical Targets for Total Recoverable Arsenic in the Similkameen River

Month	Target Concentration (ug/L)
May	0.6
June	0.6
April & July	0.5
August - March	0.4

The numerical targets proposed here make no allowance for the downstream increase in arsenic concentrations that might occur naturally as the Similkameen flows between Princeton and the U.S. border, even if anthropogenic sources were removed. If new data or analysis can provide a reliable estimate of what that increase would be, the numerical targets should be revised upward accordingly. In the interim, the proposed targets appear reasonable, given the concentrations typical of other Washington rivers and streams.

Loading Capacity

WAC 173-201A states that "*Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department*."

The Similkameen River exceeds EPA human health criteria for arsenic near the headwaters at Princeton, without anthropogenic input. Natural conditions at Princeton, therefore, constitute the water quality standard (see page 37). EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 CFR 130.2(f)). Therefore, the loading capacity for the river is equal to the natural background.

Wasteload and Load Allocations

EPA requires that a TMDL allocate loads to point sources, nonpoint sources, and natural background. The Similkameen River is over its loading capacity for arsenic compared to natural background at Princeton. The only NPDES[2]-permitted point sources discharging to the Similkameen in Washington is the Oroville WWTP, and its impact on arsenic concentrations in the river was determined to be insignificant (see page 32). No other localized sources of arsenic were detected in Washington as a result of the present investigation. Therefore, no wasteload allocations are required. Load allocations are zero for nonpoint sources.

[2] National Pollution Discharge Elimination System

Load Reductions

Table 14 shows estimates of the load reductions necessary in order to attain Washington State water quality standards for total recoverable arsenic in the Similkameen River during average conditions. The targets and load reductions vary by month in accordance with the various combinations of flow and arsenic concentrations in the river. No effort was made to address the high but variable arsenic loads that are occasionally recorded during spring freshets.

Table 14 incorporates the following methods and assumptions:

- Monthly averages were used for arsenic concentrations and flow in the main stem.
- Arsenic concentrations at the U.S. border are the monthly averages for Chopaka Bridge from 1990 – 1999.
- Arsenic concentrations at the river mouth were estimated as being equal to twice the Chopaka Bridge concentrations, based on 24 pairs of results in the data record (Appendix G).
- Arsenic concentrations for Palmer Lake outlet are from Table 9, except the June value is the average of the concentrations measured in April and May.
- Flow at the U.S. border was assumed equal to the flow at Nighthawk minus the flow from Palmer Lake.
- Outflow from Palmer Lake were assumed equal to the inflow, as reported for the USGS gage near the mouth of Sinlahekin Creek (station no. 12443400, 1957-65; Appendix H). Based on the few flow measurements taken at Palmer Lake outlet, this assumption appears reasonable.
- Flow at Oroville was assumed equal to the flow at Nighthawk[3].

These calculations indicate that the loading reductions needed for arsenic in British Columbia and in Washington are of comparable magnitude, ranging from 213-230 pounds/day in May to 4 pounds/day from August through March. The reductions needed for Palmer Lake, the only significant discharge clearly identified in Washington, range from 6-7 pounds/day in May and June to 1 pound/day for the remainder of the year. The load coming out of the lake is significant relative to the upstream load in August through March.

[3] The previously mentioned Ecology flow data for Oroville were too limited for use.

Table 14. Estimates of Load Reductions Required to Meet Water Quality Targets for Total Recoverable Arsenic in the Similkameen River
[Based on averages and approximations described in text]

Location	Season	Water Quality Target (ug/L)	Current Concentration (ug/L)	Mean Flow (cfs)	Current Load (lbs/day)	Current Minus Upstream Load (lbs/day)	Target Load* (lbs/day)	**Load Reduction Required**	
								(lbs/day)	**(%)**
@ U.S. border	May	0.6	5.9	7,442	237	- -	24	**213**	**90**
	June	0.6	2.6	8,392	118	- -	27	**91**	**77**
	April & July	0.5	2.1	2,506	28	- -	6.8	**22**	**76**
	Aug. - March	0.4	1.4	714	5.4	- -	1.5	**4**	**71**
Palmer Lake Outlet	May	0.6	5.2	265	7.4	- -	0.9	**7**	**88**
	June	0.6	6.5	200	7.0	- -	0.6	**6**	**91**
	April & July	0.5	7.8	30	1.3	- -	0.08	**1**	**94**
	Aug. - March	0.4	12	22	1.4	- -	0.05	**1**	**97**
Mouth @ Oroville	May	0.6	12	7,707	499	255	25	**230**	**90**
	June	0.6	5.7	8,592	264	140	28	**112**	**80**
	April & July	0.5	4.6	2,536	63	33	6.8	**26**	**79**
	Aug. - March	0.4	3.1	736	12	5	1.6	**4**	**71**

*Within Washington the target load = loading capacity

Margin of Safety

EPA requires that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between loads and water quality. In this TMDL a major unknown is whether there would be a natural incremental increase in arsenic concentrations downstream of Princeton and, if so, what that rate of increase would be. The numeric targets and load reductions recommended to meet them assume no natural increase, thus constituting an implicit margin of safety. The use of monthly averages for the numerical targets is a conservative approach, further adding to the safety margin.

There is substantial uncertainty in the quantification of tributary loads within Washington. Only four samples were obtained from the major source identified, Palmer Lake, and its average flow to the river was estimated. It seems unlikely, however, that the load is seriously under or overestimated given the consistent difference observed between the arsenic concentrations at Chopaka Bridge and Oroville.

Other than Palmer Lake outlet, Washington tributaries to the Similkameen are dry most of the year. No data were collected to establish tributary loading during storm or snow melt events. Again, there is nothing in the available data to suggest that there are large unaccounted for arsenic inputs to the river within Washington during runoff events.

Seasonal Variation

Seasonal considerations were taken into account in assessing the annual pattern of arsenic contamination (see *Review of British Columbia Data* and *Review of Washington Data* sections in this report) and in setting numeric water quality targets.

Monitoring Plan

The following arsenic monitoring is recommended for the Similkameen River:

1. Periodically review results of the routine monitoring done by Canada at Chopaka Bridge in order to identify trends and be aware of significant contamination episodes.

2. If and when significant cleanups are undertaken in British Columbia or Washington, resume routine arsenic monitoring at the Oroville station and do other focused effectiveness monitoring as appropriate.

3. Analyze arsenic concentrations in Similkameen River and Palmer Lake fish to determine if there is a threat to human health. The analysis should include total arsenic, inorganic arsenic, monomethylarsonic acid, and dimethylarsinic acid

4. Conduct a study of arsenic sources and cycling in Palmer Lake. This study should include a survey of arsenic concentrations in the bottom sediments and an evaluation of potential for release to the water column. Sediment cores should be taken to view the history of arsenic deposition. The importance of the arsenic load from Sinlahekin Creek should be determined, and upstream sources in that drainage identified, if warranted.

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Appendices

Appendix A

Location of Ecology Sampling Sites on the Similkameen River

Appendix A. Location of Ecology Sampling Sites on the Similkameen River

Station Name	Description	Latitude	Longitude	Datum
Main Stem				
Chopaka Bridge, BC	Upstream side of bridge, right bank*	49° 04' 48.0"	119° 42' 36.0"	NAD83
Cutchie Road	At end of private road to Cutchie residence, right bank	48° 57' 59.4"	119° 42' 37.8"	WGS84
Above Kabba-Texas	WDFW access road, right bank	48° 56' 40.0"	119° 38' 20.9"	NAD27
Nighthawk	Just above Nighthawk bridge, left bank	48° 57' 59.1"	119° 38' 34.8"	NAD27
Eagle Rock	Left bank opposite Eagle Rock	48° 58' 56.4"	119° 32' 15.0"	WGS84
Enloe Dam	Approximately 100 ft. above dam, left bank	48° 58' 00.7"	119° 30' 08.1"	NAD27
Oroville	Approximately 100 ft. above bridge, left bank	48° 56' 04.6"	119° 26' 31.2"	NAD83
Tributaries and Miscellaneous Sources				
Palmer Lake outlet	Upstream side of bridge on road to Chopaka	48° 55' 24.6"	119° 39' 22.8"	WGS84
Palmer Lake inlet	Upstream side of Chopaka Creek Road	48° 51' 06.1"	119° 38' 57.8"	NAD27
Jewett Creek	On upstream side of road to Chopaka	48° 59' 44.5"	119° 43' 24.7"	NAD27
Anderson Creek	1/2 mile upstream of road to Chopaka	48° 57' 33.0"	119° 44' 10.5"	NAD27
Nighthawk Mine	At end of rail line, 30 yards from adit	48° 57' 42.5"	119° 38' 14.1"	NAD27
Lone Pine Creek	200 yards upstream of Orville-Nighthawk Road	48° 59' 17.0"	119° 33' 15.4"	NAD27
Ellemeham Draw	Second pool above railroad bridge	48° 57' 53.3"	119° 30' 01.5"	NAD27
Old Oroville Landfill	West drainage 200 ft. downstream from fence	48° 57' 37.9"	119° 29' 20.6"	NAD27

*facing downstream

Appendix B

Field and Laboratory Procedures for Ecology 2000 – 2002 Samples

Field Procedures

Sampling methods for arsenic followed the guidance in EPA Method 1669. Chain of custody was maintained.

1. Routine Monitoring

Sampling methods for the routine arsenic monitoring done by the Freshwater Monitoring Unit were similar to those followed for the intensive surveys. FMU metals sampling methods are described in Hopkins (1996).

2. Intensive Surveys

Arsenic samples were simple grabs collected by hand into pre-cleaned 0.5 liter Teflon bottles. The samples were taken away from the bank by wading into the stream or using a pre-cleaned 0.5 liter Teflon bottle at the end of an aluminum pole. The dissolved samples were filtered in the field through a pre-cleaned 0.45 um Nalgene filter unit (#450-0045, type S). For sites where both total recoverable and dissolved arsenic were determined, half the contents of a Teflon bottle was filtered, the remainder being the total recoverable sample for that site. The samples were acidified in the field to pH<2 using 2-5mL of high-purity 1:1 nitric acid carried in Teflon vials. Teflon sample bottles, acid vials, and Nalgene filters were obtained from Manchester Laboratory, cleaned as described in Kammin et al. (1995), and sealed in plastic bags.

Non-talc nitrile gloves were worn by personnel filtering the samples. Filtering was done in a glove box constructed of a PVC frame and polyethylene cover. Each sample was placed in double polyethylene bags and held on ice for transport to the laboratory.

Arsenic speciation samples were simple grabs collected in 125 mL glass bottles with HCl as preservative, supplied by Frontier Geosciences Inc.

Samples for conductivity, hardness, and total suspended solids were collected and preserved in polyethylene bottles obtained from Manchester and held on ice for transport. The hardness bottles contained sulfuric acid as a preservative.

Flows were measured with a Swoffer or Marsh-McBirney meter and top-setting rod. Temperature was determined with a precision mercury thermometer. pH measurements were obtained with an Orion Model 250A meter.

Laboratory Procedures

Sample analysis was conducted by the Ecology Manchester Environmental Laboratory, Manchester, WA, except arsenic speciation was done by Frontier Geosciences Inc., Seattle, WA.

Arsenic were analyzed by ICP-MS following EPA Method 200.8. Total recoverable arsenic samples were digested with nitric acid following EPA Method 200.2, modified for ICP-MS.

Arsenic speciation was done by a modification of EPA Method 1632, employing hydride generation, cryogenic trapping, and ICP/MS.

Conductivity, hardness, and total suspended solids were analyzed by Standard Methods 2510, EPA Method 130.2, and EPA Method 160.2, respectively

References

EPA. 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. EPA 821-R-95-034.

Hopkins, B. 1996. Ambient Metals Project Proposal – Final Quality Assurance Project Plan. Washington State Dept. Ecology, Olympia, WA.

Kammin, W.R., S. Cull, R. Knox, J. Ross, M. McIntosh, and D. Thomson. 1995. Labware Cleaning Protocols for the Determination of Low-level Metals by ICP-MS. American Environmental Laboratory 7(9).

Appendix C

Data Reports from Manchester Laboratory

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

December 1, 2000

TO: Art Johnson
FROM: Jim Ross, Manchester Lab
SUBJECT: Metals Quality Assurance memo for the Similkameen Arsenic study

SUMMARY

Data for this project can be used without qualification.

SAMPLE RECEIPT

The samples were received by the Manchester Laboratory on 9/27/00 and 10/10/00 in good condition. Samples received on 10/10/00 were collected between 5/02/00 and 10/03/00

HOLDING TIMES

Samples collected on 5/02 were not analyzed for arsenic within the recommended 6 month holding time and values were qualified as estimates.

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards and blanks were within the relevant control limits except for one CCV was slightly high (111%).

PROCEDURAL BLANKS

The procedural blanks associated with these samples showed no analytically significant levels of requested analytes.

SPIKED SAMPLE ANALYSES

The duplicate spike for total recoverable arsenic was slightly high (127%) but data was not qualified.

PRECISION DATA

Precision estimates based on duplicate spike analysis were all within the acceptance criteria for duplicate analysis ($\pm$20%).

LABORATORY CONTROL SAMPLE (LCS) ANALYSES

All LCS analyses were within the acceptance criteria for the individual analytes. True values for M0318DL5 and DL6 were 10ug/L. M0287WL1 and Wl2 were 20ug/L and M0326WL1 and WL2 were 0.68 ug/L (SLRS-4)

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkameen Arsenic

LIMS Project ID: 4295-00

Project Officer: Art Johnson
Date Reported: 01-DEC-00

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
00398230		CHOPAKA	1.7		ug/L	09/26/00	11/16/00
00398230	Duplicate		1.9		ug/L	09/26/00	11/17/00
00398230	Matrix Spike		114 %			09/26/00	11/17/00
00398230	Matrix Spike		112 %			09/26/00	11/17/00
00398231		CHOPAKA	1.7		ug/L	09/26/00	11/16/00
00398232		CUTHIE	2.1		ug/L	09/26/00	11/16/00
00398233		CUTHIE	2.0		ug/L	09/26/00	11/16/00
00398234		AB KABBA	2.4		ug/L	09/26/00	11/16/00
00398235		AB KABBA	2.9		ug/L	09/26/00	11/16/00
00398236		NIGHTHAWK	2.4		ug/L	09/26/00	11/16/00
00398237		NIGHTHAWK	2.6		ug/L	09/26/00	11/16/00
00398238		BOTTLEBLK	0.5	U	ug/L	09/26/00	11/16/00
00398239		FILTERBLK	0.5	U	ug/L	09/26/00	11/16/00
00398240		EAGLEROCK	3.0		ug/L	09/26/00	11/16/00
00398241		EAGLEROCK	3.0		ug/L	09/26/00	11/16/00
00398242		ENLOE DAM	2.8		ug/L	09/26/00	11/16/00
00398243		ENLOE DAM	3.0		ug/L	09/26/00	11/16/00
00398244		OROVILLE	3.4		ug/L	09/26/00	11/16/00
00398244	Duplicate		3.5		ug/L	09/26/00	11/16/00
00398244	Matrix Spike		110 %			09/26/00	11/16/00
00398244	Matrix Spike		112 %			09/26/00	11/16/00
00398245		OROVILLE	3.9		ug/L	09/26/00	11/17/00
00398265		OROVILLE	2.2	J	ug/L	05/02/00	11/17/00
00398266		CHOPAKA	2.2	J	ug/L	05/02/00	11/17/00
00398267		OROVILLE	1.8		ug/L	06/06/00	11/17/00
00398268		CHOPAKA	0.86		ug/L	06/06/00	11/17/00
00398269		OROVILLE	2.7		ug/L	07/11/00	11/17/00
00398270		CHOPAKA	1.6		ug/L	07/11/00	11/17/00
00398271		OROVILLE	5.4		ug/L	08/15/00	11/17/00
00398272		CHOPAKA	2.4		ug/L	08/15/00	11/17/00
00398273		OROVILLE	4.0		ug/L	09/05/00	11/17/00
00398274		CHOPAKA	2.0		ug/L	09/05/00	11/17/00
00398275		OROVILLE	2.9		ug/L	10/03/00	11/17/00
00398276		CHOPAKA	1.8		ug/L	10/03/00	11/17/00
00398276	Duplicate		1.7		ug/L	10/03/00	11/17/00
00398276	Matrix Spike		117 %			10/03/00	11/17/00
00398276	Matrix Spike		116 %			10/03/00	11/17/00
M0318DB3			0.5	U	ug/L		11/16/00
M0318DB4			0.5	U	ug/L		11/16/00

Authorized By: _____ Release Date: 12/1/00

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkameen Arsenic **LIMS Project ID:** 4295-00

Project Officer: Art Johnson
Date Reported: 01-DEC-00

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
M0318DL5			100		%		11/16/00
M0318DL6			104		%		11/16/00

Authorized By: _____ Release Date: 12/1/00

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkameen Arsenic **LIMS Project ID:** 4295-00

Project Officer: Art Johnson
Date Reported: 01-DEC-00

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
00398230		CHOPAKA	1.8		ug/L	09/26/00	11/20/00
00398230	Duplicate		1.7		ug/L	09/26/00	11/20/00
00398231		CHOPAKA	1.8		ug/L	09/26/00	11/20/00
00398232		CUTHIE	2.3		ug/L	09/26/00	11/20/00
00398233		CUTHIE	2.1		ug/L	09/26/00	11/20/00
00398234		AB KABBA	2.4		ug/L	09/26/00	11/20/00
00398235		AB KABBA	3.0		ug/L	09/26/00	11/20/00
00398236		NIGHTHAWK	3.0		ug/L	09/26/00	11/20/00
00398237		NIGHTHAWK	2.7		ug/L	09/26/00	11/20/00
00398240		EAGLEROCK	3.2		ug/L	09/26/00	11/20/00
00398241		EAGLEROCK	3.4		ug/L	09/26/00	11/20/00
00398242		ENLOE DAM	3.1		ug/L	09/26/00	11/20/00
00398243		ENLOE DAM	3.3		ug/L	09/26/00	11/20/00
00398244		OROVILLE	3.4		ug/L	09/26/00	11/20/00
00398244	Duplicate		3.7		ug/L	09/26/00	11/20/00
00398245		OROVILLE	3.6		ug/L	09/26/00	11/20/00
00398246		PALMER CR	9.39		ug/L	09/25/00	11/20/00
00398247		PALMER CR	9.87		ug/L	09/25/00	11/20/00
00398247	Matrix Spike		119 %			09/25/00	11/20/00
00398247	Matrix Spike		127 %			09/25/00	11/20/00
00398265		OROVILLE	3.4	J	ug/L	05/02/00	11/21/00
00398266		CHOPAKA	2.5	J	ug/L	05/02/00	11/21/00
00398267		OROVILLE	4.6		ug/L	06/06/00	11/21/00
00398268		CHOPAKA	2.8		ug/L	06/06/00	11/21/00
00398269		OROVILLE	2.1		ug/L	07/11/00	11/21/00
00398270		CHOPAKA	0.93		ug/L	07/11/00	11/21/00
00398271		OROVILLE	4.4		ug/L	08/15/00	11/21/00
00398272		CHOPAKA	1.8		ug/L	08/15/00	11/21/00
00398273		OROVILLE	3.3		ug/L	09/05/00	11/21/00
00398274		CHOPAKA	1.5		ug/L	09/05/00	11/21/00
00398275		OROVILLE	2.6		ug/L	10/03/00	11/21/00
00398276		CHOPAKA	1.5		ug/L	10/03/00	11/21/00
00398276	Matrix Spike		115 %			10/03/00	11/21/00
00398276	Matrix Spike		122 %			10/03/00	11/21/00
M0287WB1			0.5	U	ug/L		11/20/00
M0287WB2			0.5	U	ug/L		11/20/00
M0287WL1			112		%		11/20/00
M0287WL2			120		%		11/20/00
M0326WL1			0.78		ug/L		11/21/00

Authorized By: _____ Release Date: 12/1/00

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkameen Arsenic

LIMS Project ID: 4295-00

Project Officer: Art Johnson
Date Reported: 01-DEC-00

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
M0326WL2			0.82		ug/L		11/21/00

Authorized By: _____ Release Date: 12/1/00

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Hardness

Project Name: Similkameen Arsenic **LIMS Project ID:** 4295-00

Project Officer: Art Johnson
Date Reported: 30-OCT-00

Method: SM2340B
Matrix: Water
Analyte: Hardness

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
00398230		CHOPAKA	88.0		mg/L	09/26/00	10/27/00
00398232		CUTHIE	91.7		mg/L	09/26/00	10/27/00
00398234		AB KABBA	101		mg/L	09/26/00	10/27/00
00398234	Duplicate		95.4		mg/L	09/26/00	10/27/00
00398236		NIGHTHAWK	102		mg/L	09/26/00	10/27/00
00398240		EAGLEROCK	101		mg/L	09/26/00	10/27/00
00398242		ENLOE DAM	103		mg/L	09/26/00	10/27/00
00398244		OROVILLE	101		mg/L	09/26/00	10/27/00
00398246		PALMER CR	121		mg/L	09/25/00	10/27/00
00398271		OROVILLE	95.4		mg/L	08/15/00	10/27/00
00398273		OROVILLE	88.6		mg/L	09/05/00	10/27/00
00398274		CHOPAKA	81.8		mg/L	09/05/00	10/27/00
M0301DB1			0.5	U	mg/L		10/27/00
M0301DL1			101		%		10/27/00

Authorized By: Randy L Knox Release Date: 11/3/00

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

May 2, 2001

TO: Art Johnson
FROM: Jim Ross, Manchester Lab
SUBJECT: Metals Quality Assurance memo for Similkameen As -12

SUMMARY

Data can be used without qualification. All QA/QC samples and standards met all criteria.

SAMPLE RECEIPT

The samples were received by the Manchester Laboratory on 3/22/01

HOLDING TIMES

All analyses were performed within the specified holding time (28 days for Hg, 180 days all other metals).

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run.

PROCEDURAL BLANKS

The procedural blanks associated with these samples showed no analytically significant level of analyte.

SPIKED SAMPLE ANALYSES

All spike and duplicate spike recoveries met the acceptance criteria (75-125%).

PRECISION DATA

Precision estimates based on duplicate spike analysis were all within QC limits (±20%). One dissolved As value (8236) was slightly higher than the corresponding total recoverable value. The values were only 0.11 ug/L apart, which is well within acceptable precision criteria at the levels measured.

LABORATORY CONTROL SAMPLE (LCS) ANALYSES

All LCS analyses were within the acceptance criteria for the individual analytes.

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkameen As - 12 **LIMS Project ID:** 1310-01

Project Officer: Art Johnson
Date Reported: 11-APR-01

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01128232		CHOPAKA	**1.1**		ug/L	11/08/00	04/11/01
01128232	duplicate		**0.98**		ug/L	11/08/00	04/10/01
01128233		OROVILLE	**1.4**		ug/L	11/08/00	04/10/01
01128234		CHOPAKA	**1.3**		ug/L	12/07/00	04/10/01
01128235		OROVILLE	**1.8**		ug/L	12/07/00	04/10/01
01128236		CHOPAKA	**0.89**		ug/L	01/18/01	04/10/01
01128237		OROVILLE	**1.7**		ug/L	01/18/01	04/10/01
01128238		CHOPAKA	**1.4**		ug/L	02/08/01	04/11/01
01128239		OROVILLE	**1.9**		ug/L	02/08/01	04/10/01
01128240		CHOPAKA	**1.3**		ug/L	03/08/01	04/10/01
01128241		OROVILLE	**1.9**		ug/L	03/08/01	04/10/01
01128241	matrix spike		**96**		%	03/08/01	04/10/01
01128241	matrix spike		**97**		%	03/08/01	04/10/01
M1086WB1			0.5	U	ug/L		04/10/01
M1086WL1			**105**		%		04/10/01

Authorized By: Randy L Knox Release Date: 4/11/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkameen As - 12 **LIMS Project ID:** 1310-01

Project Officer: Art Johnson
Date Reported: 02-MAY-01

Method: EPA206.2
Matrix: Field Filtered water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01128232		CHOPAKA	**0.88**		ug/L	11/08/00	04/10/01
01128233		OROVILLE	**1.4**		ug/L	11/08/00	04/10/01
01128233	matrix spike		**103**		%	11/08/00	04/11/01
01128233	matrix spike		**103**		%	11/08/00	04/11/01
01128234		CHOPAKA	**1.3**		ug/L	12/07/00	04/11/01
01128235		OROVILLE	**1.7**		ug/L	12/07/00	04/10/01
01128236		CHOPAKA	**0.98**		ug/L	01/18/01	05/01/01
01128237		OROVILLE	**1.3**		ug/L	01/18/01	05/01/01
01128238		CHOPAKA	**1.4**		ug/L	02/08/01	04/11/01
01128239		OROVILLE	**1.6**		ug/L	02/08/01	04/10/01
01128240		CHOPAKA	**1.3**		ug/L	03/08/01	04/10/01
01128241		OROVILLE	**1.8**		ug/L	03/08/01	05/01/01
M100DB1			0.5	U	ug/L		04/10/01
M100DL1			**108**		%		04/10/01

Authorized By: Randy L Knox Release Date: 5/02/01

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

May 3, 2001

TO: Art Johnson
FROM: Jim Ross, Manchester Lab
SUBJECT: Metals Quality Assurance memo for Similkameen As -16

SUMMARY

Data can be used without qualification. All QA/QC samples and standards met all criteria. SLRS-4 was analyzed with the samples. For the dissolved samples, it is identified as M1127DL1. For the Total recoverable samples, it is identified as M1124WL3. The certified value for SLRS-4 is 0.68 + 0.06 ug/L

SAMPLE RECEIPT

The samples were received by the Manchester Laboratory on 4/23/01

HOLDING TIMES

All analyses were performed within the specified holding time (28 days for Hg, 180 days all other metals).

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run.

PROCEDURAL BLANKS

The procedural blanks associated with these samples showed no analytically significant level of analyte.

SPIKED SAMPLE ANALYSES

All spike and duplicate spike recoveries met the acceptance criteria (75-125%).

PRECISION DATA

Precision estimates based on duplicate spike analysis were all within QC limits ($\pm$20%).

LABORATORY CONTROL SAMPLE (LCS) ANALYSES

All LCS analyses were within the acceptance criteria for the individual analytes.

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkameen Arsenic - 16 **LIMS Project ID:** 1420-01

Project Officer: Art Johnson
Date Reported: 08-MAY-01

Method: EPA206.2
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01168230		CHOPAKA	1.7		ug/L	04/19/01	05/02/01
01168230	duplicate		1.7		ug/L	04/19/01	05/02/01
01168231		CHOPAKA	1.6		ug/L	04/19/01	05/02/01
01168232		CUTCHIE	2.0		ug/L	04/19/01	05/02/01
01168233		CUTCHIE	2.0		ug/L	04/19/01	05/02/01
01168234		ABKABBA	3.0		ug/L	04/19/01	05/02/01
01168235		ABKABBA	2.8		ug/L	04/19/01	05/02/01
01168236		NIGHTHAWK	2.7		ug/L	04/19/01	05/02/01
01168237		NIGHTHAWK	3.2		ug/L	04/19/01	05/02/01
01168240		EAGLEROCK	3.0		ug/L	04/19/01	05/02/01
01168241		EAGLEROCK	3.1		ug/L	04/19/01	05/02/01
01168242		ENLOEDAM	2.9		ug/L	04/19/01	05/02/01
01168243		ENLOEDAM	3.0		ug/L	04/19/01	05/02/01
01168244		OROVILLE	3.2		ug/L	04/19/01	05/02/01
01168245		OROVILLE	3.2		ug/L	04/19/01	05/02/01
01168246		LANDFILL	3.4		ug/L	04/19/01	05/02/01
01168246	duplicate		3.5		ug/L	04/19/01	05/02/01
01168247		PALMEROUT	7.74		ug/L	04/19/01	05/02/01
01168247	duplicate		7.90		ug/L	04/19/01	05/02/01
01168248		PALMERIN	3.2		ug/L	04/18/01	05/02/01
01168251		LONEDINE	0.5	U	ug/L	04/19/01	05/02/01
01168252		NIGHTMINE	0.5	U	ug/L	04/19/01	05/02/01
01168252	matrix spike		87		%	04/19/01	05/02/01
01168252	matrix spike		87		%	04/19/01	05/02/01
01168253		JEWETT CR	0.68		ug/L	04/19/01	05/02/01
01168253	duplicate		0.85		ug/L	04/19/01	05/02/01
01168254		ANDERSNCR	1.4		ug/L	04/19/01	05/02/01
01168255		ELLEMEHAM	1.1		ug/L	04/19/01	05/02/01
01168255	matrix spike		86		%	04/19/01	05/02/01
01168255	matrix spike		85		%	04/19/01	05/02/01
M1121WB1			0.5	U	ug/L		05/02/01
M1121WB2			0.5	U	ug/L		05/02/01
M1121WL1			109		%		05/02/01
M1121WL2			108		%		05/02/01
M1124WL3			0.67		ug/L		05/02/01

Authorized By: Randy S. Knox Release Date: 5/8/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkameen Arsenic - 16 **LIMS Project ID:** 1420-01

Project Officer: Art Johnson
Date Reported: 08-MAY-01

Method: EPA206.2
Matrix: Field Filtered water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01168230		CHOPAKA	**1.1**		ug/L	04/19/01	05/01/01
01168230	duplicate		**1.1**		ug/L	04/19/01	05/01/01
01168231		CHOPAKA	**0.69**		ug/L	04/19/01	05/01/01
01168232		CUTCHIE	**1.2**		ug/L	04/19/01	05/01/01
01168233		CUTCHIE	**1.3**		ug/L	04/19/01	05/01/01
01168234		ABKABBA	**1.8**		ug/L	04/19/01	05/01/01
01168235		ABKABBA	**1.8**		ug/L	04/19/01	05/01/01
01168236		NIGHTHAWK	**2.2**		ug/L	04/19/01	05/01/01
01168237		NIGHTHAWK	**2.4**		ug/L	04/19/01	05/02/01
01168238		FILTERBLK	0.5	U	ug/L	04/19/01	05/01/01
01168239		BOTTLEBLK	0.5	U	ug/L	04/19/01	05/01/01
01168240		EAGLEROCK	**2.4**		ug/L	04/19/01	05/01/01
01168241		EAGLEROCK	**2.3**		ug/L	04/19/01	05/01/01
01168242		ENLOEDAM	**2.4**		ug/L	04/19/01	05/01/01
01168243		ENLOEDAM	**2.6**		ug/L	04/19/01	05/01/01
01168244		OROVILLE	**3.0**		ug/L	04/19/01	05/01/01
01168245		OROVILLE	**2.8**		ug/L	04/19/01	05/01/01
01168247		PALMEROUT	**5.84**		ug/L	04/19/01	05/01/01
01168247	duplicate		**5.49**		ug/L	04/19/01	05/01/01
01168247	matrix spike		**99**		%	04/19/01	05/01/01
01168247	matrix spike		**102**		%	04/19/01	05/01/01
M1121DB1			0.5	U	ug/L		05/01/01
M1121DL1			**111**		%		05/01/01
M1127DL1			**0.48**		ug/L		05/01/01

Authorized By: Randy S Knox Release Date: 5/8/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Hardness

Project Name: Similkameen Arsenic - 16 **LIMS Project ID:** 1420-01

Project Officer: Art Johnson
Date Reported: 01-MAY-01

Method: SM2340B
Matrix: Water
Analyte: Hardness

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01168230		CHOPAKA	**96.1**		mg/L	04/19/01	04/27/01
01168230	duplicate		**101**		mg/L	04/19/01	04/27/01
01168232		CUTCHIE	**104**		mg/L	04/19/01	04/27/01
01168234		ABKABBA	**105**		mg/L	04/19/01	04/27/01
01168236		NIGHTHAWK	**105**		mg/L	04/19/01	04/27/01
01168240		EAGLEROCK	**106**		mg/L	04/19/01	04/27/01
01168242		ENLOEDAM	**110**		mg/L	04/19/01	04/27/01
01168244		OROVILLE	**108**		mg/L	04/19/01	04/27/01
01168247		PALMEROUT	**130**		mg/L	04/19/01	04/27/01
M1117WB1			0.2	U	mg/L		04/27/01
M1117WL1			**100**		%		04/27/01

Authorized By: Michelle Dee Release Date: 5-1-01

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

July 12, 2001

TO: Art Johnson
FROM: Jim Ross, Manchester Lab
SUBJECT: Quality Assurance memo for Similkameen Arsenic Wk 21

SUMMARY

Data for this project met all quality assurance and quality control criteria and can be used without qualification.

SAMPLE RECEIPT

The samples were received by the Manchester Laboratory on 5/22/01

HOLDING TIMES

All analyses were performed within the specified holding time (180 days).

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards and blanks were within the relevant control limits.

PROCEDURAL BLANKS

The procedural blanks associated with these samples showed no analytically significant level of arsenic.

SPIKED SAMPLE ANALYSES

Matrix spikes were al within the 75-125% control limits.

PRECISION DATA

Precision estimates based on duplicate spike analysis were all within the acceptance criteria (±20%)

LABORATORY CONTROL SAMPLE (LCS) ANALYSES

All LCS analyses were within the acceptance criteria for the individual LCS. Samples M1186DL1-DL3 and M1151WL2 are SLRS-4, with an accepted value of 0.68 ug/L At this level (<5x MDL) we have a control limit of ± the MDL (0.2 ug/L).

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson
Date Reported: 09-JUL-01

Method: EPA200.8
Matrix: Field Filtered water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	0.59		ug/L	05/21/01	07/05/01
01218080	duplicate		0.57		ug/L	05/21/01	07/05/01
01218080	matrix spike		102		%	05/21/01	07/05/01
01218080	matrix spike		101		%	05/21/01	07/05/01
01218081		CHOPAKA	0.56		ug/L	05/21/01	07/05/01
01218082		CUTCHIE	0.77		ug/L	05/21/01	07/05/01
01218083		CUTCHIE	0.79		ug/L	05/21/01	07/05/01
01218086		PALMEROUT	4.71		ug/L	05/21/01	07/05/01
01218087		PALMEROUT	4.62		ug/L	05/21/01	07/05/01
01218088		AB KAHHA	1.2		ug/L	05/21/01	07/05/01
01218089		AB KAHHA	1.2		ug/L	05/21/01	07/05/01
01218090		NIGHTHAWK	1.1		ug/L	05/21/01	07/05/01
01218091		NIGHTHAWK	1.2		ug/L	05/21/01	07/05/01
01218092		EAGLEROCK	1.3		ug/L	05/21/01	07/05/01
01218093		EAGLEROCK	1.2		ug/L	05/21/01	07/05/01
01218094		ENLOE DAM	1.4		ug/L	05/21/01	07/05/01
01218095		ENLOE DAM	1.3		ug/L	05/21/01	07/05/01
01218096		OROVILLE	1.4		ug/L	05/21/01	07/05/01
01218097		OROVILLE	1.4		ug/L	05/21/01	07/05/01
M1186DB1			0.2	U	ug/L		07/05/01
M1186DB2			0.2	U	ug/L		07/05/01
M1186DL1			0.84		ug/L		07/05/01
M1186DL2			0.84		ug/L		07/05/01
M1186DL3			0.83		ug/L		07/05/01
M1186DL4			100		%		07/05/01

Authorized By: _____ Release Date: 7/9/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson
Date Reported: 09-JUL-01

Method: EPA200.8
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	0.87		ug/L	05/21/01	07/05/01
01218080	duplicate		0.80		ug/L	05/21/01	07/05/01
01218081		CHOPAKA	0.87		ug/L	05/21/01	07/05/01
01218082		CUTCHIE	2.52		ug/L	05/21/01	07/05/01
01218083		CUTCHIE	3.69		ug/L	05/21/01	07/05/01
01218084		PALMERIN	3.02		ug/L	05/21/01	07/05/01
01218084	matrix spike		94		%	05/21/01	07/05/01
01218084	matrix spike		95		%	05/21/01	07/05/01
01218085		PALMERIN	3.04		ug/L	05/21/01	07/05/01
01218086		PALMEROUT	5.24		ug/L	05/21/01	07/05/01
01218087		PALMEROUT	4.99		ug/L	05/21/01	07/05/01
01218088		AB KAHHA	1.9		ug/L	05/21/01	07/05/01
01218089		AB KAHHA	1.9		ug/L	05/21/01	07/05/01
01218090		NIGHTHAWK	5.10		ug/L	05/21/01	07/05/01
01218091		NIGHTHAWK	3.42		ug/L	05/21/01	07/05/01
01218092		EAGLEROCK	1.8		ug/L	05/21/01	07/05/01
01218093		EAGLEROCK	1.9		ug/L	05/21/01	07/05/01
01218094		ENLOE DAM	1.8		ug/L	05/21/01	07/05/01
01218095		ENLOE DAM	1.9		ug/L	05/21/01	07/05/01
01218096		OROVILLE	2.0		ug/L	05/21/01	07/05/01
01218097		OROVILLE	2.15		ug/L	05/21/01	07/05/01
M1151WB1			0.2		ug/L		07/05/01
M1151WL1			94		%		07/05/01
M1151WL2			0.68		ug/L		07/05/01

Authorized By: Jim Ross Release Date: 7/9/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Hardness

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson
Date Reported: 20-JUN-01

Method: SM2340B
Matrix: Water
Analyte: Hardness

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	47.4		mg/L	05/21/01	06/13/01
01218082		CUTCHIE	48.3		mg/L	05/21/01	06/13/01
01218084		PALMERIN	172		mg/L	05/21/01	06/13/01
01218084	duplicate		172		mg/L	05/21/01	06/13/01
01218086		PALMEROUT	118		mg/L	05/21/01	06/13/01
01218088		AB KAHHA	54.6		mg/L	05/21/01	06/13/01
01218090		NIGHTHAWK	52.6		mg/L	05/21/01	06/13/01
01218092		EAGLEROCK	51.7		mg/L	05/21/01	06/13/01
01218094		ENLOE DAM	51.6		mg/L	05/21/01	06/13/01
01218096		OROVILLE	52.1		mg/L	05/21/01	06/13/01
M1164DB1			0.2	U	mg/L		06/13/01
M1164DL1			102		%		06/13/01

Authorized By: Michelle Dhl Release Date: 6-26-01

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

August 15, 2001

TO: Art Johnson
FROM: Jim Ross, Manchester Lab
SUBJECT: Metals Quality Assurance memo for Similkameen As wk 24

SUMMARY
Data for this project met all quality objectives and can be used without qualification.

SAMPLE RECEIPT
The samples were received by the Manchester Laboratory on 6-14-01 in good condition.

HOLDING TIMES
All analyses were performed within the specified holding time (28 days for Hg, 180 days all other metals).

INSTRUMENT CALIBRATION
Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards and blanks were within the relevant control limits (90-110%).

PROCEDURAL BLANKS
The procedural blanks associated with these samples showed no analytical significant levels of As.

SPIKED SAMPLE ANALYSES
Spike and duplicate spike recoveries met QA criteria (75-125%)

PRECISION DATA
Precision estimates based on duplicate spike analysis were all within the acceptance criteria for duplicate analysis ($\pm$20%).

LABORATORY CONTROL SAMPLE (LCS) ANALYSES
M1186DL1-DL3 were SLRS-4. The certified value for As is 0.68 $\pm$ 0.06 M1186DL4 is a spiked blank (50 ug/L)

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Dissolved

Project Name: Similkamen Arsenic - 24 **LIMS Project ID:** 1642-01

Project Officer: Art Johnson
Date Reported: 13-AUG-01

Method: EPA200.8
Matrix: Field Filtered water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01248070		CHOPAKA	**1.1**		ug/L	04/03/01	07/05/01
01248071		OROVILLE	**2.36**		ug/L	04/03/01	07/05/01
01248072		CHOPAKA	**0.58**		ug/L	05/09/01	07/05/01
01248073		OROVILLE	**1.6**		ug/L	05/09/01	07/05/01
01248074		CHOPAKA	**0.57**		ug/L	06/06/01	07/05/01
01248075		OROVILLE	**1.3**		ug/L	06/06/01	07/05/01
01248075	matrix spike		**98**		%	06/06/01	07/05/01
01248075	matrix spike		**98**		%	06/06/01	07/05/01
M1186DB1			0.2	U	ug/L		07/05/01
M1186DB2			0.2	U	ug/L		07/05/01
M1186DL1			**0.84**		ug/L		07/05/01
M1186DL2			**0.84**		ug/L		07/05/01
M1186DL3			**0.83**		ug/L		07/05/01
M1186DL4			**100**		%		07/05/01

Authorized By: _____ Release Date: 8/15/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Arsenic, Total Recoverable

Project Name: Similkamen Arsenic - 24 **LIMS Project ID:** 1642-01

Project Officer: Art Johnson
Date Reported: 07-AUG-01

Method: EPA200.8
Matrix: Water
Analyte: Arsenic

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01208203		PALMEROUT	**1.8**		ug/L	05/01/01	08/03/01
01208204		PALMERIN	**3.24**		ug/L	05/01/01	08/03/01
01248070		CHOPAKA	**1.1**		ug/L	04/03/01	08/03/01
01248070	matrix spike		**87.6**		%	04/03/01	08/03/01
01248070	matrix spike		**87.9**		%	04/03/01	08/03/01
01248071		OROVILLE	**2.25**		ug/L	04/03/01	08/03/01
01248072		CHOPAKA	**1.5**		ug/L	05/09/01	08/03/01
01248073		OROVILLE	**2.35**		ug/L	05/09/01	08/03/01
01248074		CHOPAKA	**0.94**		ug/L	06/06/01	08/03/01
01248075		OROVILLE	**1.8**		ug/L	06/06/01	08/03/01
M1192WB1			0.2	U	ug/L		08/03/01
M1192WL1			**89.4**		%		08/03/01
M1192WL2			**96.0**		%		08/03/01

Authorized By: Randy L Knox Release Date: 8/7/01

Washington State Department of Ecology
Manchester Laboratory

October 13, 2000

TO: Art Johnson

FROM: Aileen Richmond, Technician AR

THROUGH: Michelle Lee, Chemist ML

SUBJECT: General Chemistry Quality Assurance memo: Similkameen Arsenic, week 39.

SUMMARY

The data generated by the analyses of these samples is acceptable for use.

SAMPLE INFORMATION

These samples were received by Manchester Laboratory on 9/27/2000 in good condition.

HOLDING TIMES

The samples were analyzed within the EPA holding times for all parameters.

ANALYSIS PERFORMANCE

Instrument Calibration

All balances are professionally calibrated yearly with calibration verification occurring monthly and internal calibration occurring daily. Oven temperatures are recorded before and after analysis to ensure control. Other instrumentation is calibrated as needed and a documented calibration check is used for verification.

Laboratory Control Sample

Accuracy is evaluated through the use of laboratory control standards. All were within the acceptance windows of ± 20 %.

Precision Data

Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than ± the method detection limit.

Results from duplicate analysis were used to evaluate precision. All duplicates were within the acceptance window of ± 20 % RPD.

Method Blanks

Method blanks associated with these samples showed no analytically significant levels of analytes.

Please call Aileen Richmond at 360-871-8823 or Michelle Lee at 360-871-8812 if you have any questions.

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Conductivity of a water solution

Project Name: Similkameen Arsenic **LIMS Project ID:** 4295-00

Project Officer: Art Johnson
Date Reported: 06-OCT-00

Method: EPA120.1
Matrix: Water
Analyte: Conductivity

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
00398230		CHOPAKA	190		umhos/cm	09/26/00	10/02/00
00398232		CUTHIE	193		umhos/cm	09/26/00	10/02/00
00398234		AB KABBA	194		umhos/cm	09/26/00	10/02/00
00398236		NIGHTHAWK	195		umhos/cm	09/26/00	10/02/00
00398240		EAGLEROCK	194		umhos/cm	09/26/00	10/02/00
00398242		ENLOE DAM	194		umhos/cm	09/26/00	10/02/00
00398244		OROVILLE	195		umhos/cm	09/26/00	10/02/00
00398246		PALMER CR	227		umhos/cm	09/25/00	10/02/00

Authorized By: Robin McLean Release Date: 10/6/00

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Total Suspended Solids

Project Name: Similkameen Arsenic

LIMS Project ID: 4295-00

Project Officer: Art Johnson
Date Reported: 10-OCT-00

Method: EPA160.2
Matrix: Water
Analyte: Total Suspended Solids

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
00398230		CHOPAKA	3		mg/L	09/26/00	09/29/00
00398232		CUTHIE	1		mg/L	09/26/00	09/29/00
00398234		AB KABBA	2		mg/L	09/26/00	09/29/00
00398236		NIGHTHAWK	1		mg/L	09/26/00	09/29/00
00398240		EAGLEROCK	2		mg/L	09/26/00	09/29/00
00398240	Duplicate		2		mg/L	09/26/00	09/29/00
00398242		ENLOE DAM	2		mg/L	09/26/00	09/29/00
00398244		OROVILLE	2		mg/L	09/26/00	09/29/00
00398246		PALMER CR	4		mg/L	09/25/00	09/29/00

Authorized By: Julia Sikkink

Release Date: 10-10-00

Washington State Department of Ecology
Manchester Laboratory

May 7, 2001

TO: Art Johnson

FROM: Aileen Richmond, Technician

THROUGH: Michelle Lee, Chemist ML

SUBJECT: General Chemistry Quality Assurance memo: Similkameen Arsenic, week 16.

SUMMARY

The data generated by the analyses of these samples is acceptable for use.

SAMPLE INFORMATION

These samples were received by Manchester Laboratory on 4/23/2001 in good condition.

HOLDING TIMES

The samples were analyzed within the EPA holding times for all parameters.

ANALYSIS PERFORMANCE

Instrument Calibration

All balances are professionally calibrated yearly with calibration verification occurring monthly and internal calibration occurring daily. Oven temperatures are recorded before and after analysis to ensure control. Other instrumentation is calibrated as needed and a documented calibration check is used for verification.

Laboratory Control Sample

Accuracy is evaluated through the use of laboratory control standards. All were within the acceptance windows of ± 20 %.

Precision Data

Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than ± the method detection limit.

Results from duplicate analysis were used to evaluate precision. All duplicates were within the acceptance window of ± 20 % RPD.

Method Blanks

Method blanks associated with these samples showed no analytically significant levels of analytes.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Aileen Richmond at 360-871-8823 or Michelle Lee at 360-871-8812 if you have any questions.

cc: Project file

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Total Suspended Solids

Project Name: Similkameen Arsenic - 16 **LIMS Project ID:** 1420-01

Project Officer: Art Johnson
Date Reported: 07-MAY-01

Method: EPA160.2
Matrix: Water
Analyte: Total Suspended Solids

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01168230		CHOPAKA	8		mg/L	04/19/01	04/25/01
01168232		CUTCHIE	6		mg/L	04/19/01	04/25/01
01168234		ABKABBA	4		mg/L	04/19/01	04/25/01
01168236		NIGHTHAWK	6		mg/L	04/19/01	04/25/01
01168240		EAGLEROCK	4		mg/L	04/19/01	04/25/01
01168242		ENLOEDAM	2		mg/L	04/19/01	04/25/01
01168244		OROVILLE	3		mg/L	04/19/01	04/25/01
01168246		LANDFILL	1	U	mg/L	04/19/01	04/25/01
01168247		PALMEROUT	18		mg/L	04/19/01	04/25/01
01168247	duplicate		18		mg/L	04/19/01	04/25/01
01168248		PALMERIN	4		mg/L	04/18/01	04/25/01
01168251		LONEDINE	3		mg/L	04/19/01	04/25/01
01168252		NIGHTMINE	1	U	mg/L	04/19/01	04/25/01
01168253		JEWETT CR	2		mg/L	04/19/01	04/25/01
01168254		ANDERSNCR	3		mg/L	04/19/01	04/25/01
01168255		ELLEMEHAM	3		mg/L	04/19/01	04/25/01

Authorized By: _____ Release Date: 5/7/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Conductivity of a water solution

Project Name: Similkameen Arsenic - 16 **LIMS Project ID:** 1420-01

Project Officer: Art Johnson
Date Reported: 07-MAY-01

Method: EPA120.1
Matrix: Water
Analyte: Conductivity

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01168230		CHOPAKA	210		umhos/cm	04/19/01	04/23/01
01168232		CUTCHIE	218		umhos/cm	04/19/01	04/23/01
01168234		ABKABBA	222		umhos/cm	04/19/01	04/23/01
01168236		NIGHTHAWK	222		umhos/cm	04/19/01	04/23/01
01168240		EAGLEROCK	224		umhos/cm	04/19/01	04/23/01
01168242		ENLOEDAM	227		umhos/cm	04/19/01	04/23/01
01168244		OROVILLE	228		umhos/cm	04/19/01	04/23/01
01168246		LANDFILL	1590		umhos/cm	04/19/01	04/23/01
01168246	duplicate		1590		umhos/cm	04/19/01	04/23/01
01168247		PALMEROUT	265		umhos/cm	04/19/01	04/23/01
01168248		PALMERIN	385		umhos/cm	04/18/01	04/23/01
01168251		LONEDINE	1500		umhos/cm	04/19/01	04/23/01
01168251	duplicate		1500		umhos/cm	04/19/01	04/23/01
01168252		NIGHTMINE	1110		umhos/cm	04/19/01	04/23/01
01168253		JEWETT CR	149		umhos/cm	04/19/01	04/23/01
01168254		ANDERSNCR	277		umhos/cm	04/19/01	04/23/01
01168255		ELLEMEHAM	929		umhos/cm	04/19/01	04/23/01

Authorized By: Sara Sekucik Release Date: 5-7-01

Washington State Department of Ecology
Manchester Laboratory

June 4, 2001

TO: Art Johnson

FROM: Meredith Jones, Chemist MJ

SUBJECT: General Chemistry Quality Assurance Memo for Similkameen Arsenic week 21

SUMMARY

The data generated by the analysis of these samples can be used without qualification. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Similkameen Arsenic week 21 project were received by Manchester Environmental Laboratory on 05/22/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

Procedural Blanks

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Precision Data

Duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%. Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the method detection limit.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Jim Ross at (360) 871-8808 or Meredith Jones at (360) 871-8833 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Conductivity of a water solution

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson
Date Reported: 01-JUN-01

Method: EPA120.1
Matrix: Water
Analyte: Conductivity

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	103		umhos/cm	05/21/01	05/31/01
01218082		CUTCHIE	103		umhos/cm	05/21/01	05/31/01
01218084		PALMERIN	362		umhos/cm	05/21/01	05/31/01
01218084	duplicate		362		umhos/cm	05/21/01	05/31/01
01218086		PALMEROUT	254		umhos/cm	05/21/01	05/31/01
01218088		AB KAHHA	115		umhos/cm	05/21/01	05/31/01
01218090		NIGHTHAWK	110		umhos/cm	05/21/01	05/31/01
01218092		EAGLEROCK	110		umhos/cm	05/21/01	05/31/01
01218094		ENLOE DAM	110		umhos/cm	05/21/01	05/31/01
01218096		OROVILLE	110		umhos/cm	05/21/01	05/31/01

Authorized By: Sara Sekerak Release Date: 6/1/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

Total Suspended Solids

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson
Date Reported: 31-MAY-01

Method: EPA160.2
Matrix: Water
Analyte: Total Suspended Solids

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	4		mg/L	05/21/01	05/24/01
01218082		CUTCHIE	5		mg/L	05/21/01	05/24/01
01218082	duplicate		4		mg/L	05/21/01	05/24/01
01218084		PALMERIN	6		mg/L	05/21/01	05/24/01
01218086		PALMEROUT	10		mg/L	05/21/01	05/24/01
01218088		AB KAHHA	10		mg/L	05/21/01	05/24/01
01218090		NIGHTHAWK	11		mg/L	05/21/01	05/24/01
01218092		EAGLEROCK	10		mg/L	05/21/01	05/24/01
01218094		ENLOE DAM	8		mg/L	05/21/01	05/24/01
01218096		OROVILLE	10		mg/L	05/21/01	05/24/01

Authorized By: Nat Joyce Release Date: 5/31/01

Manchester Environmental Laboratory

Department of Ecology

Analysis Report for

pH

Project Name: Similkameen Arsenic - 21 **LIMS Project ID:** 1534-01

Project Officer: Art Johnson **Method:** EPA150.1
Date Reported: 22-MAY-01 **Matrix:** Water
Analyte: pH

Sample	QC	Field ID	Result	Qualifier	Units	Collected	Analyzed
01218080		CHOPAKA	7.8		pH	05/21/01	05/22/01
01218082		CUTCHIE	7.7		pH	05/21/01	05/22/01
01218084		PALMERIN	8.1		pH	05/21/01	05/22/01
01218086		PALMEROUT	8.2		pH	05/21/01	05/22/01
01218086	duplicate		8.2		pH	05/21/01	05/22/01
01218088		AB KAHHA	7.9		pH	05/21/01	05/22/01
01218090		NIGHTHAWK	7.9		pH	05/21/01	05/22/01
01218092		EAGLEROCK	7.9		pH	05/21/01	05/22/01
01218094		ENLOE DAM	7.9		pH	05/21/01	05/22/01
01218096		OROVILLE	7.9		pH	05/21/01	05/22/01
01218096	duplicate		7.9		pH	05/21/01	05/22/01

Authorized By: Sara Sukuak Release Date: 5/22/01

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

March 13, 2002

Subject: Metals Quality Assurance Memo for Similkameen Arsenic – 09 Project

Officer(s): Art Johnson

By: Randy Knox

Summary

The data generated by the analysis of these samples can be used without qualification. A spreadsheet is included to summarize laboratory QC.

Sample Information

Samples for Similkameen Arsenic – 09 project were received by Manchester Environmental Laboratory on 3/04/02 in good condition

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

Blanks

No analytically significant level of analyte was detected in the method blank associated with these samples.

Matrix Spikes

Spiked sample analyses were performed where applicable with all spike recoveries within acceptance limits of ± 25%. Spiked sample analysis is performed at a frequency of at least 5%.

Replicates

Relative Percent Differences (RPD) for metal parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 5%. Precision and accuracy specifications are based on sample concentrations greater than five times the reporting limit or on spiked duplicate samples. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the reporting limit.

Laboratory Control Samples

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Meredith Jones at (360) 871-8833 or Randy Knox at (360) 871-8811 to further discuss this project.

cc: Project File

Data Qualifier Codes

U	-	The analyte was not detected at or above the reported result.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Washington State Department of Ecology
Manchester Environmental Laboratory
Analysis Report for
Arsenic, Total Recoverable

Project Name: Similkameen Arsenic - 09 **LIMS Project ID:** 1156-02

Project Officer: Art Johnson **Method:** EPA200.8

Date Reported: 03/08/02 **Analyte:** Arsenic

Sample	QC	Field ID	Matrix	Result	Qualifier	Units	Collected	Analyzed
02098000		OROVILSTP	Water	**2.77**		ug/L	02/28/02	03/07/02
02098000	LMX1 (matrix spike)			**96.4**		%	02/28/02	03/07/02
02098000	LMX2 (matrix spike)			**95.9**		%	02/28/02	03/07/02
02098001		OROVILSTP	Water	**2.86**		ug/L	03/01/02	03/07/02
M2066WB1		Lab BLNK	Water	0.2	U	ug/L		03/07/02
M2066WL1		Lab LCS-	Water	**94.7**		%		03/07/02
M2066WL2		Lab SLRS	Water	**95.1**		%		03/07/02

Authorized By: Randy L. Knox Release Date: 3/11/02

Supplemental information for low level metals projects.

Project Similkameen Arsenic- 09

Element	M2066WL1 "A"			M2066WL2 SLRS-4				matrix spikes sample 02098000					
	"true"	found	% recovery	"true"	found	% recovery		sample	spike	dup spike	spike add	spike recovery	dup spike recovery
Arsenic	20	18.94	94.7	0.68	0.647	95.1		2.773	22.05	21.96	20	96.4	95.9

	M2066WB1	
	Reported	Uncensored
Arsenic	0.2U	-0.007

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

June 18, 2002

Subject: Metals Quality Assurance Memo for Similkameen Arsenic

Officer: Art Johnson

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 06/04/02 in good condition.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than 0.995. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of $\pm$ 25%.

Replicates

All duplicate relative percent differences were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

U - The analyte was not detected at or above the reported result.

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Data Qualifier Codes

J	-	The analyte was positively identified. The associated numerical result is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
NC	-	Not Calculated
E	-	The concentration exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Washington State Department of Ecology
Manchester Environmental Laboratory
Analysis Report for
Arsenic

Project Name: Similkameen Arsenic **LIMS Project ID:** 1522-02

Project Officer: Art Johnson **Method:** EPA200.8

Date Reported: 06/18/02 **Analyte:** Arsenic

Sample	QC	Field ID	Matrix	Result	Qualifier	Units	Collected	Analyzed
02218156		CHOPAKA	Field Filtered water	**0.61**		ug/L	05/23/02	06/11/02
02218158		CHOPAKA	Field Filtered water	**0.67**		ug/L	05/23/02	06/11/02
02218160		CHOPAKA	Field Filtered water	**0.62**		ug/L	05/23/02	06/11/02
02218162		CHOPAKA	Field Filtered water	0.1	U	ug/L	05/23/02	06/11/02
02218162	LMX1 (matrix spike)			**105**		%	05/23/02	06/11/02
02218162	LMX2 (matrix spike)			**108**		%	05/23/02	06/11/02
02218166		CHOPAKA	Field Filtered water	**0.63**		ug/L	05/23/02	06/11/02
02218166	LDP1 (duplicate)			**0.67**		ug/L	05/23/02	06/11/02
02218166	LDP2 (duplicate)			**0.66**		ug/L	05/23/02	06/11/02
M2162DB1		Lab BLNK	Field Filtered water	0.1	U	ug/L		06/11/02
M2162DL1		Lab SLRS	Field Filtered water	**120**		%		06/11/02
M2162DL2		Lab LCS-	Field Filtered water	**108**		%		06/11/02
M2162DL3		Lab SLRS	Field Filtered water	**124**		%		06/11/02
M2162DL4		Lab SLRS	Field Filtered water	**117**		%		06/11/02

Authorized By: Ronald L Knox Release Date: 6/18/02 Page: 1

Washington State Department of Ecology
Manchester Environmental Laboratory
Analysis Report for
Arsenic

Project Name: Similkameen Arsenic **LIMS Project ID:** 1522-02

Project Officer: Art Johnson **Method:** EPA200.8

Date Reported: 06/12/02 **Analyte:** Arsenic

Sample	QC	Field ID	Matrix	Result	Qualifier	Units	Collected	Analyzed
02218155		CHOPAKA	Water	4.56		ug/L	05/23/02	06/11/02
02218157		CHOPAKA	Water	4.15		ug/L	05/23/02	06/11/02
02218159		CHOPAKA	Water	4.29		ug/L	05/23/02	06/11/02
02218159	LMX1 (matrix spike)			99.1		%	05/23/02	06/11/02
02218159	LMX2 (matrix spike)			95.2		%	05/23/02	06/11/02
02218161		CHOPAKA	Water	0.1	U	ug/L	05/23/02	06/11/02
02218163		CHOPAKA	Water	4.11		ug/L	05/23/02	06/11/02
02218163	LDP1 (duplicate)			3.71		ug/L	05/23/02	06/11/02
02218163	LDP2 (duplicate)			3.61		ug/L	05/23/02	06/11/02
02218164		CHOPAKA	Water	1.03		ug/L	05/23/02	06/11/02
02218164	LDP1 (duplicate)			0.96		ug/L	05/23/02	06/11/02
02218164	LDP2 (duplicate)			1.0		ug/L	05/23/02	06/11/02
02218165		CHOPAKA	Water	4.99		ug/L	05/23/02	06/11/02
02218165	LDP1 (duplicate)			4.99		ug/L	05/23/02	06/11/02
02218165	LDP2 (duplicate)			5.00		ug/L	05/23/02	06/11/02
M2161WB2		Lab BLNK	Water	0.1	U	ug/L		06/11/02
M2161WL3		Lab LCS-	Water	102		%		06/11/02
M2161WL4		Lab SLRS	Water	76.9		%		06/11/02
M2161WL5		Lab SLRS	Water	99.3		%		06/11/02
M2161WL6		Lab SLRS	Water	91.0		%		06/11/02

Authorized By: Randy J Knox Release Date: 6/12/02

Appendix D

Data Reports from Frontier Geosciences, Inc.

FRONTIER GEOSCIENCES INC.
Environmental Research & Specialty Analytical Laboratory
(206) 622-6960 · fax: (206) 622-6870
e-mail: info@frontier.wa.com
414 Pontius North · Seattle, WA 98109

Dirk Wallschläger, Ph.D.
Research Scientist
email: DirkW@Frontier.WA.com

Art Johnson
WA State Dep. of Ecology
300 Desmond Drive
Olympia, WA 98504-7710

Seattle, 10/16/00

Analysis report: Arsenic speciation in Similkameen River water samples

Dear Mr. Johnson,

On 9/27/00, we received eight water samples from you, collected at the Similkameen River on the two previous days. The sample set consists of duplicates from four sites. There was one difference between the samples IDs on the bottles and on the accompanying COC form: we received two bottles labeled "398246", whereas the COC states that there should be one sample "398247". However, since the two samples appear to be field duplicates collected at Palmer Creek, and give virtually the same results, I assume that it is not important for you to distinguish between the two individual samples (listed as "398246A" and "398246B" in the results table). The samples were preserved in the field with HCl, and arrived cooled and in apparently good condition. The samples appeared to be free of particulate matter, so we analyzed them without further treatment besides dilution. We determined As(III) directly at pH 6.2 by hydride generation-cryotrapping-gas chromatography-atomic absorption spectrometry (HG-CT-GC-AAS). Afterwards, total inorganic As [TIAs = As(III) + As(V)] was measured by the same technique, but under acidic conditions (pH = 1), so that As(V) could be calculated by difference [= TIAs – As(III)].

There were no analytical issues. The reproducibility of matrix and spike duplicates was very good, and matrix spikes and the certified reference material were recovered quantitatively, even though the spike recoveries for As(III) appear to be somewhat elevated. The field duplicates also yielded very similar results. We did detect methylated As species in all samples, but I estimated their concentration to be ≤ 10 % of the TIAs, so – as agreed before the project - we did not perform separate analyses to quantify their concentrations. If you become interested in quantifying the methylated As species, we can always perform those analyses in the next few weeks.

I hope that our results help you understand the As biogeochemistry in the investigated system, and I'm looking forward to working with you again in the future.

Yours sincerely,

Dirk Wallschläger, Ph.D.

Table 1: Arsenic speciation in river waters
client: WA Dep. of Ecology / Art Johnson
project: Similkameen River
prepared by Dirk Wallschlaeger, Ph. D., Frontier Geosciences, Inc., Seattle

sample	As(III)	TIAs	As(V) [by difference]
Chapaka Bridge (398230)	0.892	1.45	0.56
Chapaka Bridge (398231)	0.867	1.38	0.51
Nighthawk (398236)	0.911	2.44	1.53
Nighthawk (398237)	1.09	2.51	1.42
Oroville (398244)	1.02	2.64	1.62
Oroville (398245)	0.725	2.84	2.12
Palmer Creek (398246A)	0.438	7.12	6.68
Palmer Creek (398246B)	0.433	6.96	6.53

QA

matrix duplicates

analysis	As(III)	TIAs
sample	Chapaka Bridge (398231)	Chapaka Bridge (398230)
M	0.827	1.36
MD	0.906	1.54
average	0.8665	1.45
RPD [%]	9.1	12.4

matrix spikes

original	0.8665	1.45
spike level	2.50	3.00
MS	4.00	4.30
recovery [%]	125.3	95.0
MSD	3.83	4.63
recovery [%]	118.5	106.0
mean recovery [%]	121.9	100.5
RPD [%]	4.3	7.4

certified reference materials

identity	NIST 1643d
measured concentration	52.2
certified concentration	56.02
recovery [%]	93.2

all concentrations in µg/L

Frontier Geosciences Inc.
Environmental Research & Specialty Analytical Laboratory
414 Pontius Ave N · Seattle WA 98109

May 1, 2001

Art Johnson
WA Department of Ecology
300 Desmond Drive
Olympia, WA 98504-7710

Dear Art,

Enclosed are our results for seven samples collected on April 18 and 19, 2001. The samples were received in good condition on April 21, 2001, with the exception of sample Chopaka (168230), which arrived broken. Fortunately, some of the sample could be rescued, which was used for all analyses.

The samples were field-acidified with ultra-clean HCl to 0.1% and after arrival at Frontier stored dark and cold until analysis. Arsenite (As(III)) and total inorganic arsenic was determined by hydride generation-cryogenic trapping- gas chromatography-AFS (HG-CT-GC-AFS). Arsenate (As(V)) is calculated by difference.

The overall quality of the data looks very good. All quality control measurements are within established control limits. The field duplicate shows good reproducibility. Methylated species were only observed in one sample ("Oroville"), but the concentration is estimated to be 0.06-0.15 ppb, therefore no analyses for the methylated species were performed.

Please feel free to contact me if you have any questions or concerns. It has been a pleasure working for you, and I'm looking forward receiving the next sample set.

Sincerely,

Jacqueline London
Project Manager
JaxL@frontier.wa.com

206 622 6960
fax 206 622 6870
email: info@Frontier.WA.com
www.FrontierGeosciences.com

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported May 1, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Sample Results

Sample ID	As (III)-Arsenite	Total Inorganic Arsenic	*As(V) - Arsenate
Chopaka - 168230	0.395	1.243	0.848
Oroville - 168244	0.532	2.652	2.120
OrovilRep - 168245	0.506	2.687	2.181
Palmer - 168247	0.938	8.077	7.139
LonePine - 168251	0.135	0.534	0.399
Nighthawk - 168252 Mine	0.212	0.482	0.270
Jewett Cr - 168253	0.057	0.809	0.752

All results in µg/L

* : Arsenate is calculated by difference: As(V)=TIAs-As(III)

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported May 1, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Quality Control Data - Preparation Blank Report

Analyte (µg/L)	IBW1	IBW2	IBW3	IBW4	Mean	Std Dev	Est. MDL
As(III)	0.000	0.000	0.001	0.000	0.000	0.0005	0.002
TIAs	0.007	0.007	0.008	0.009	0.008	0.0007	0.003

Std Dev = Standard deviation
Est. MDL = Estimated method detection limit

Quality Control Data - Standard Reference Material Report

Analyte (µg/L)	SRM Identity	Cert. Value	Obs. Value	% Rec.
TIAs	NIST1643d	56.02	67.04	119.7

SRM Identity = Standard reference material identity
Cert. Value = Certified value
Obs. Value = Experimental result
% Rec. = Percent recovery

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported May 1, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Quality Control Data - Duplicate Report

Analyte (µg/L)	Sample QC'd	Rep. 1	Rep. 2	Mean	RPD
As(III)	Oroville - 168244	0.532	0.549	0.540	3.1
TIAs	Oroville - 168244	2.652	2.683	2.668	1.2

Quality Control Data - Matrix Spike / Matrix Spike Duplicate Report

Analyte (µg/L)	Sample QC'd	Sample conc.	Spike Level	MS	% Rec.	MSD	% Rec.	RPD
As(III)	Oroville - 168244	0.532	1.000	1.625	109.3	1.607	107.5	1.1
TIAs	Oroville - 168244	2.652	5.000	7.405	95.1	7.868	104.3	6.1

MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference

Frontier Geosciences Inc.
Environmental Research & Specialty Analytical Laboratory
414 Pontius Ave N · Seattle WA 98109

June 4, 2001

Art Johnson
WA Department of Ecology
300 Desmond Drive
Olympia, WA 98504-7710

Dear Art,

Enclosed are our results for nine samples collected on May 21, 2001. All samples were received in good condition on May 23, 2001. The temperature of the cooler upon receipt was 10 °C, which is higher than the recommended shipping/storage temperature of 4 °C. It is recommended to ship speciation samples with overnight carriers to avoid prolonged shipping times.

The samples were field-acidified with ultra-clean HCl to 0.1% and after arrival at Frontier stored dark and cold until analysis. Arsenite (As(III)) and total inorganic arsenic was determined by hydride generation-cryogenic trapping- gas chromatography-AFS (HG-CT-GC-AFS). Arsenate (As(V)) is calculated by difference.

The overall quality of the data looks very good. All quality control measurements are within established control limits. No significant amounts of methylated species were observed, therefore no analyses for the methylated species were performed. It still seems that the major source of arsenic is Palmer Lake, but interesting enough, the outlet concentration is higher than the inlet concentration, indicating that Palmer Lake might actually be a source of arsenic. I don't know if last time Palmer Lake inlet or outlet was sampled, so I can't compare last sampling event with this one.

Please feel free to contact me if you have any questions or concerns. It has been a pleasure working for you, and I'm looking forward receiving the next sample set.

Sincerely,

J. London

Jacqueline London
Project Manager
JaxL@frontier.wa.com

206 622 6960
fax 206 622 6870
email: info@Frontier.WA.com
www.FrontierGeosciences.com

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported June 4, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Sample Results

Sample ID	As (III)-Arsenite	Total Inorganic Arsenic	*As(V) - Arsenate
Chopaka - 218080	0.168	0.564	0.396
Cuttchie - 218082	0.305	0.876	0.571
Palmer Lk Inlet - 218084	0.509	3.394	2.885
Palmer Lk Outlet - 218086	0.872	5.602	4.730
Above Kabbg - 218088	0.435	1.628	1.193
Nighthawk - 218090	0.403	1.947	1.544
Eagle Rock - 218092	0.301	1.723	1.422
Enloe Dam - 218094	0.400	1.849	1.449
Oroville - 218096	0.427	2.004	1.577

All results in µg/L

* : Arsenate is calculated by difference: As(V)=TIAs-As(III)

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported June 4, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Quality Control Data - Preparation Blank Report

Analyte (µg/L)	IBW1	IBW2	IBW3	IBW4	Mean	Std Dev	Est. MDL
As(III)	0.000	0.000	0.000	0.002	0.000	0.0008	0.002
TIAs	0.006	0.004	0.004	0.003	0.004	0.0009	0.003

Std Dev = Standard deviation
Est. MDL = Estimated method detection limit

Quality Control Data - Standard Reference Material Report

Analyte (µg/L)	SRM Identity	Cert. Value	Obs. Value	% Rec.
TIAs	NIST1640	26.67	29.24	109.6

SRM Identity = Standard reference material identity
Cert. Value = Certified value
Obs. Value = Experimental result
% Rec. = Percent recovery

Arsenic Speciation Results for WA Department of Ecology-Art Johnson

Reported June 4, 2001 - Jacqueline London
Frontier Geosciences Inc., 414 Pontius Ave. N, Seattle WA 98109

Quality Control Data - Duplicate Report

Analyte (µg/L)	Sample QC'd	Rep. 1	Rep. 2	Mean	RPD
As(III)	Chopaka - 218080	0.168	0.199	0.184	17.0
TIAs	Chopaka - 218080	0.564	0.601	0.583	6.4

Quality Control Data - Matrix Spike / Matrix Spike Duplicate Report

Analyte (µg/L)	Sample QC'd	Sample conc.	Spike Level	MS	% Rec.	MSD	% Rec.	RPD
As(III)	Chopaka - 218080	0.168	0.333	0.523	106.5	0.541	112.0	3.4
TIAs	Chopaka - 218080	0.564	1.500	2.200	109.1	2.244	112.0	2.0

MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference

Appendix E

Preliminary Results from a Sample Exchange / Laboratory Intercomparison Study Conducted for the Similkameen River Arsenic TMDL (as summarized by Vic Jensen, BC Ministry of Water, Land and Air Protection)

Appendix E. Preliminary Arsenic Data from Similkameen River Sample Exchange, March 23, 2002 (ug/L except mg/L for NFR and turbidity)

Quality Assurance Data			2002-04-15	2002-04-15				
			Fed As-T	Fed As-D	Prov As-T	Prov As-D		
Cahill Creek @ Hwy 3A			10.1??	10.4??				
Cahill Creek (duplicate)			10.1	10.4				
Cahill Creek (blank)			0.1	0.1				
			2002-05-02	2002-05-02	2002-05-02	2002-05-02	2002-05-02	2002-05-02
			Fed As-T	Fed As-D	Prov As-T	Prov As-D	NFR	Turbidity
Similkameen River at Chopaka Bridge (duplicate)			0.7	0.4				
Similkameen River at Chopaka Bridge			0.8	0.5				
			2002-05-13	2002-05-13	2002-05-13	2002-05-13	2002-05-13	2002-05-13
			Fed As-T	Fed As-D	Prov As-T	Prov As-D	NFR	Turbidity
Similk R at Chopaka					1.2		23	3.15
Similk R at Intake (blind rep)					1.2		19	1.93
	5/23/02	5/23/02	5/23/02	5/23/02	5/23/02	5/23/02	5/23/02	5/23/02
	Ecy As-TR	Ecy As-D	Fed As-T	Fed As-D	Prov As-T	Prov As-D	NFR	Turbidity
Similkameen River at Princeton (blank or river water???)			<0.1	0.4				
Similkameen River at Princeton (duplicate)			0.4	0.4				
WASH-BCWLAP study								
Similkameen River at Intake (blind blank)			0.1	<0.1				
Similkameen River at Intake (blind blank duplicate)				<0.1				
Similkameen River at Intake (blind blank NLET duplicate)				<0.1				
Similkameen River d/s Intake at1600 hrs ref TM24.2			4.6					
Similkameen River d/s Intake at 1600 hrs (duplicate)			4.8					
Similkameen River d/s Intake at 1600 hrs (NLET duplicate)			4.8					
Similkameen River d/s Intake at1610 hrs ref TMRAIN-95			1					
Similkameen River d/s Intake at1610 hrs (duplicate)			1.1					
Similkameen River d/s Intake at 1610 hrs (NLET split)			1.1					
Similkameen River at Chopaka Bridge (Co-Sample #1)	4.56	0.61	0.7??	0.5				
Similkameen River at Chopaka Bridge (Co-Sample #2)	4.15	0.67	0.7??	0.5				
Similkameen River at Chopaka Bridge (Co-Sample #3)	4.29	0.62	0.7??	0.5				
Ecology Bottle Blank or Filter Blank	<0.1	<0.1						
Similkameen River at Chopaka (CBS)	4.11	0.63	0.7??	0.5				
Similkameen River at Chopaka (CBS) duplicate	3.71	0.67	1??	0.5				
Similkameen River at Chopaka (CBS) duplicate	3.61	0.66						
Similkameen Rover at Chopaka (CBS) NLET duplicate			1??	0.5				
Manchester EL lab blank		<0.1						
Environment Canada SRM TMRAIN-95 ref (0.996)	1.03		?1 need to check sample label					
Environment Canada SRM TMRAIN-95 ref (0.996)	0.96		?1.1					
Environment Canada SRM TMRAIN-95 ref (0.996)	1.0		?1.1					
Environment Canada SRM TM-24.2 ref (5.0)	4.99		?4.6 need to check sample label					
Environment Canada SRM TM-24.2 ref (5.0)	4.99		?4.8					
Environment Canada SRM TM-24.2 ref (5.0)	5.0		?4.8					
Manchester Lab blank	<0.1							
Similkameen River @ Oroville			1.8	1.5			122	71.7
Similkameen River @ Oroville duplicate				1.5				
Similkameen River @ Oroville (NLET duplicate)				1.5				

Sampler's Remarks

1D = Bridge sample; Collected concurrent with Ecology; Collected with Fed/Prov carousel off Chopaka Bridge; As-D #1 (collected @ river edge)
2D = Bridge sample; Collected concurrent with Ecology; Collected with Fed/Prov carousel sampler; As-D sample #2 collected @ rivers edge
3D = Bridge sample; Collected concurrent with Ecology; Collected with Fed/Prov carousel sampler; As-D sample #3 @ rivers edge
1T = Bridge sample; Collected concurrent with Ecology; Collected with Fed/Prov carousel sampler; Co-sample #1 for total As @ rivers edge
2T = Bridge sample; Collected concurrent with Ecology; Collected using Fed/Prov carousel; Total As sample #2 collected @ rivers edge
3T = Bridge sample; Collected concurrent with Ecology; Collected with Fed/Prov carousel sampler; Collection of total As sample #3 from rivers edge
CBS = Churn Bridge Split ; Shore sample; Used Churn sample splitter to split sample for NLET and Ecology analyses; Sample collected from rivers edge upstream of Chopaka Bridge in current

Appendix F

Notes from Tour of the Upper Similkameen TMDL Basin, April 19, 2002

Lorraine Edmond, EPA Region 10

Field Trip Attendees:

Mark Peterschmidt, Washington Department of Ecology
Lorraine Edmond, US Environmental Protection Agency
Jake Jakabosky, US Bureau of Land Management
Vic Jensen, BC Ministry of Water, Land and Air Protection
Daymon Trachsel, BC Ministry of Water, Land and Air Protection
Robert McCandless, Environment Canada
Russ Horton, BC Ministry of Energy and Mines
Rick Adams, BC Ministry of Energy and Mines
Barry Given, Barrick Gold Corporation

Nickel Plate Mine, tour hosted by Barry Given

The historic Nickel Plate mine was discovered in 1989, and was mined underground intermittently from 1902 until 1954.

The "new" Nickel Plate mine was an open pit mine, mined 1987-1997, and is now reclaimed on the surface. Only the water treatment plant is currently active. There were 6 pits mined (Central Pit, North Pit, South Pit, Canty Pit, and two smaller pits), and they resulted in 12 million tons of tailings.

Sunset Creek flows under the Canty Pit and then into Cahill Creek, and is considered the main source of arsenic. (The Canty Pit was always higher in arsenopyrite than the other pits).

The Inco/SO2 process was eventually selected as the most effective process to reduce the cyanide content in the wastewater.

The tailings impoundment was built in compacted glacial till, with the idea that the fines would plug up any leaks over time, but this did not happen. The impoundment has always leaked, but the seepage re-emerges in the seepage capture ditch. From there it goes to the treatment plant. A bacterial treatment system uses local microbes to treat the waste water. Ferric sulfate is used to precipitate the arsenic. Discharge from the plant is

piped to Hedley Creek. Toxicity tests (rainbow trout and Ceriodaphnia) as well as chemical analyses of the waste water are required as part of the permit.

Precipitation has been low the past few years, so flushing of tailings has been reduced. It looks like it will be necessary to treat the water for "a couple more years." (This has been the prediction for the last several years.)

The permitted discharge limit for arsenic is 0.07 mg/l or 70 ug/l. They have 10 years worth of data (total and dissolved As via ICP) from the Cahill 3 monitoring point, which drains the Canty pit, but not much downstream data in the Similkameen below Cahill. They do have discharge data from Cahill, so some loading estimates can be made. Barry has estimated that Cahill Creek might contribute around 2% of the arsenic load of the Similkameen (using the flow at Chopaka.)

Arsenic content increased when the Canty pit refilled. The maximum concentration in Sunset Creek was 0.06 mg/l but has now dropped to 0.04 mg/l.

An onsite lab at the water treatment plant analyzes metals using atomic adsorption, with a 0.05 ug/l detection limit for arsenic. Each quarter, samples are sent to a Vancouver lab for comparison. (The onsite lab also participates in round robin analyses and has been certified proficient.) They have a million gallon capacity for storage of water in case of a treatment plant upset, and are confident that their regular monitoring will tell them if something is wrong that is affecting the treatment.

Tailings at Hedley

We stopped at an overlook to look down at the area where the Candorado Operating Company Ltd. had a project to heap leach the historic mining tailings from the old Nickel Plate Mine. The two largest piles, adjacent to the Similkameen, are referred to as the Old Tailings and the New Tailings, though both are from the first half of the 20th century. (Old = up to the 30s, New = from the 50s).

Two additional piles are nearer the town of Hedley, along Hedley Creek. West of Hedley Creek are the tailings from the historic Mascot Mine. Tailings on the east side of the creek are from the original Nickel Plate Mine. These two tailings piles are in a relatively narrow part of the Hedley Creek valley and may have only been 8 ft thick or so originally. Some of the tailings were removed, but some remain. Much of the area covered by these two piles has been revegetated, but bare areas remain, and appear to be used by children as a bicycle track. Recent data from the area adjacent to the ball field indicate these tailings may contain 1000-15,000 ppm arsenic. Because the valley is so narrow, the remaining tailings are very close to the creek in some locations. Hedley Creek is a small, but steep stream and is very high-energy.

The foundations of the stamp mill can be seen at the confluence of Hedley Creek and the Similkameen. It was used until the underground operations ceased in the 1950s, and the structure burned in the 1970s.

Jake asked about the old tailings dams bursting adjacent to Hedley Creek. He has heard the local residents around Nighthawk (Washington) talk about times the Similkameen ran milky when the tailings at Hedley burst out during floods. 1948 was a big year for floods. The last big floods were in 1976 or 1978.

In 1996 flow in the Similkameen was 800,000 gpm (where it is normally about 5,000 gpm)

A flood in the 1970s changed course of Hedley Creek, took some tailings with it. Some of these have been removed since then.

Tour of the Old Tailings

Batter-board construction was used to build up the tailings piles. This construction technique resulted in very steep-sided piles. The highway was built across the tailings piles. Large areas of tailings were removed from here for the Candorado heap leach project. The perimeter of the pile appears to be intact, but there are large central swales where the reprocessed tailings were removed. Prior to revegetation, the tailings were often picked up by the wind, and made the area chronically dusty. Most of the pile was revegetated in 1997. Biosolids were applied prior to revegetation, but because of a regulation restricting the distance between biosolids application and the river, a rim of unvegetated tailings exists along the edge of the pile. While touring the piles, we observed fine dust blowing off the unvegetated portions.

The tailings pile we walked over was separated by the active channel of Hedley Creek by a swale and then a coarse gravel berm. This was constructed in the late 1980s or early 1990s, presumably to prevent Hedley Creek and the Similkameen from eroding the base of the tailings piles. Although the unvegetated edges of the pile are steep and are eroding as rills develop down the face of the steep sides, I did not observe any active channels extending continuously from the tailings to the active part of the river channel.

The top of the Old and New Tailings piles are perched high above the river. The base is at the original level of the historic floodplain. There may be some information in the Candorado permit application or other documents that would define the thickness and arsenic content of the tailings here. The company conducted extensive sampling in preparation for the heap leach operation.

We observed some remnants of a historic dam that was used in the early days to provide power to the mine.

Research on historic mining practices

It is difficult to know what the waste disposal practices were in the period from 1900 to 1955 or so, when underground mining ceased. The local historic museum sells a book on the history of the mine, called Mines of the Eagle Country, Nickel Plate and Mascot, by Doug Cox. While the book contains an abundance of detail on mining practices, power generation, and mining camp life, it is short on detail regarding tailings disposal. Here are the few tidbits I gleaned:

The Nickel Plate was discovered in 1989, and by 1902, sufficient ore was found to justify a mill. By 1904, the stamp mill was operational and the process included 20 large tanks for the cyanide plant.

P 19 "In the early picture of the mine taken in 1908, there is a tailings pond in the foreground. These tailings were pumped back in when a later company, the Kelowna Exploration Company, took over." It is not clear what this means. It may mean that the recoveries were poor and these tails were reprocessed.

P 22 Another caption from a June 1908 photo says "the early operation of the plant was unable to extract all of the gold from the processed ore. This test slag pond was a temporary measure and the ore was later reprocessed as the plant's technology improved." The photo shows a large pond in front of the Daly Reduction Plant. (I did not find mention of an on-site smelter, so it may be that this is actually tailings, not slag.)

P 23 Vanner concentrates were dried, sacked, shipped to Tacoma Smelter. "... tailings from vanners carried by launders down to the cyanide plant below for treatment there."

P 24 After cyanidation... roasting in the refinery... Cleanup twice a month made "two gold bricks, one from the free gold caught on the plates, and the other from gold caught in the cyanide plant."

P 27 As mining went deeper, extraction became more difficult. They switched to finer grinding and direct cyanidation by 1917.

P 28-30 The Report of the Ministry of Mines, 1929 is quoted extensively
The only discussion of tailing disposal ends with "from ... the vanners, the tailings are passed out of the mill." There is no additional information regarding the ultimate disposal of the tailings.

P 50 A 1910 photo of Hedley, looking down the valley toward the mill. The caption says "the mill has started one slag pond." The pond does not show up well in the reproduction.

P 107 A man's job description in a newspaper article is "watchman of slag pond."

P 73 The dam for the power plant was built in 1913-1914 to assure a more stable power supply, but the river often froze and the power sometimes shut down. (Prior to this, power was supplied by a small hydroelectric plant on Twentymile Creek, P 87)

P 76 "A particularly severe winter in 1935 created ice jams which caused washouts on either end of the dam." By this time, they had the option to switch to power from a commercial source, so they did not repair it.

P 110 Photo and caption: "Flooding devastated Hedley in 1948 as it did many communities...Levees and dams were constructed to contain the waters of Twenty Mile Creek."
(A photo shows houses in Hedley damaged by flood. It was not clear where Twenty Mile Creek is. It could be an old name for Hedley Creek. There is no map in the book that would help relate the two spatially.)

P 132 The mine was reactivated by Kelowna Exploration in the 1930s, and some changes were made.
"A water line went across the side hill onto the crusher floor down through the mill, and took the waste down to the tailings pond. This water system was used until a flood in 1972 destroyed the dam and intake."

Kelowna started the mill up again in 1934.
P 140 Water went from dam in flume to powerhouse 3 miles down valley.
P 141 In 1935 or '36, they connected to Kootenay Power when the dam collapsed as the result of high flows.

P 147, caption on a photo of the assay building. "The concentrated ore was sent to the smelter in Tacoma, Washington, where the arsenic pyrite, which turned the gold black, could be removed."

P 151, quote from Jack Bottaro, who began working at the mine in 1934.
"They never made gold bricks in my time, but before, with the old Hedley Gold Mining Company, they actually operated a refinery and poured gold bars. They were not able to refine them to where they were mint quality... they recovered the copper and a certain amount of cobalt, a little cadmium, a little nickel, and the gold. The Nickel Plate property paid a penalty to the American company because of the amount of arsenic, which made the gold a black color.... If you drive by Hedley now, you can see that they are rehandling the tailings from down at the river. In the early days it's true that they had several accidents, where real rich values got away on them and ran down into that river, but the bulk of all that tonnage (of tailings) that's down there went through in the years that I worked there."

Appendix G

Available Data Pairs for Total Recoverable Arsenic in the Similkameen River at Chopaka Bridge, B.C. and Oroville, WA.

Appendix G. Available Data Pairs for Total Recoverable Arsenic in the Similkameen River at Chopaka Bridge, B.C. and Oroville, WA. (ug/L)

Date	Chopaka, B.C.	Oroville, WA	Ratio
24-Apr-96	6.4	4.6	0.7
29-Aug-95	2.0	4.0	2.0
15-Apr-96	0.4	3.6	9.0
11-Jun-96	2.7	6.3	2.3
15-Oct-96	1.1	2.8	2.5
15-Apr-97	1.2	2.0	1.7
10-Jun-97	5.4	8.3	1.5
02-May-00	2.5	3.4	1.4
06-Jun-00	2.8	4.6	1.6
11-Jul-00	0.93	2.1	2.3
15-Aug-00	1.8	4.4	2.4
05-Sep-00	1.5	3.3	2.2
03-Oct-00	1.5	2.6	1.7
08-Nov-00	1.0	1.4	1.4
07-Dec-00	1.3	1.8	1.4
18-Jan-01	0.89	1.7	1.9
08-Feb-01	1.4	1.9	1.4
08-Mar-01	1.3	1.9	1.5
03-Apr-01	1.1	2.2	2.0
09-May-01	1.5	2.4	1.6
06-Jun-01	0.94	1.8	1.9
01-Sep-00	1.8	3.6	2.0
01-Apr-01	1.7	3.2	1.9
01-May-01	0.85	2.0	2.4
		mean =	2.1
		median =	1.9

Appendix H

Monthly Mean Flow in Sinlahekin Creek

Appendix H. Monthly Mean Flow in Sinlahekin Creek (cfs)
[1957-65 data from USGS station 12443200 Sinlahekin Creek above Chopaka Creek]

Month	Flow
Jan	24.9
Feb	25.7
Mar	26.5
Apr	26.6
May	265
Jun	200
Jul	33.1
Aug	13.5
Sep	14.9
Oct	22.5
Nov	26.5
Dec	25.1