CANADA – BRITISH COLUMBIA
WATER QUALITY MONITORING AGREEMENT

WATER QUALITY ASSESSMENT OF SALMON RIVER AT SALMON ARM (1985 – 2000)

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Environment Canada **Environnement Canada**

BRITISH COLUMBIA Ministry of Environment

EXECUTIVE SUMMARY

This report assesses fifteen years of water quality data from the Salmon River. The Salmon River watershed is located within the Interior Plateau of south-central British Columbia. The sampling site is located at Highway 1, near the town of Salmon Arm, B.C.. Known errors were removed and the plotted data were compared to B.C. Environment's Approved and Working Criteria for Water Quality (MELP 2001a, 2001b). Of special interest were water quality levels and trends that are deemed deleterious to sensitive water uses including drinking water, aquatic life, fish and wildlife, recreation, irrigation and livestock watering.

CONCLUSIONS

- The hydrograph for the Salmon River is typical of interior B.C. streams, with flows dominated by a snow-melt freshet in May and June.
- Values in excess of water quality guidelines for metals such as aluminum, cadmium, cobalt, copper, iron, and manganese were likely a result of occasional high concentrations of particulate matter (as evidenced by high turbidity levels). This means that these metals were probably not bio-available and would be removed by the treatment needed before use as drinking water.
- The Salmon River had a low sensitivity to acid inputs (was well-buffered), as evidenced by high alkalinity and calcium concentrations. Both of these parameters showed strong seasonal fluctuations associated with water level.
- Fecal coliform concentrations were generally much higher than the guideline for drinking water undergoing disinfection only, although the sampling frequency was insufficient to determine if the guideline was exceeded.
- Dissolved organic carbon and true colour values frequently exceeded the drinking water guideline at this site
- Detection limits used to analyze metals such as cadmium and silver were too high to accurately assess these metals in comparison to the appropriate water quality guideline. In addition, laboratory problems with cadmium prior to August 2000 render data collected before this time unreliable. Different methods should be

employed in the future to allow these data to be compared to water quality guidelines.

- Fluoride concentrations occasionally exceeded the aquatic life guidelines.
- Salmon River water had relatively high hardness, frequently exceeding the optimum aesthetic range for drinking water.
- Phosphorus concentrations were relatively high at this site, and may be contributing to eutrophication in Shuswap Lake.
- Water temperatures exceeded maximum aesthetic drinking water guidelines in all but one of the 13 years on record (1988 – 2000), and the general fisheries guideline was exceeded in about half of the summers.
- Turbidity values were frequently above guideline levels
- There may have been a slight increasing trend in chloride, magnesium and potassium over the period of record. The reason for these increases is not clear.

RECOMMENDATIONS

We recommend monitoring be continued for the Salmon River near Highway 1. It is an important tributary to the Shuswap Lake, and has high fisheries values. Water quality indicators that are important for future monitoring are:

- flow, water temperature, specific conductivity, pH,
- total dissolved phosphorus, total dissolved nitrogen, periphyton chlorophyll-*a*,
- dissolved oxygen, fecal coliforms, chloride,
- colour (true and total absorbance), turbidity, hardness, dissolved aluminum, total and dissolved or extractable cobalt, copper, lead, nickel, and zinc.
- Low-level cadmium, hexavalent and trivalent chromium, and silver.

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INTRODUCTION

The Salmon River, near Salmon Arm B.C., is located in the southern-interior portion of the province (Figure 1). Its headwaters originate in the vicinity of Tahaetkun and Bouleau Mountains, south of Westwold and northeast of Merritt. The river's headwaters are located in Monte Hills Provincial Forest, some 15 km northeast from Salmon Lake. Some of the river's flow is diverted into Salmon Lake; much of that flow returns to the river via McInnis Creek, the outlet from Salmon Lake. From the confluence with McInnis Creek, the Salmon River flows northeast to Falkland, then southeast and east to Glenemma, and finally north to Salmon Arm before entering Shuswap Lake. The total length and drainage area of the Salmon River are approximately 120 km and 1510 km^2, respectively.

The Salmon River is an important tributary of Shuswap Lake, which drains into the South Thompson River. In addition to supporting anadromous salmonids, resident fish species and other aquatic organisms, the Salmon River and its tributaries provide important sources of raw water for domestic water supplies, irrigation, and livestock watering. Recreation and aesthetics also represent important uses of the aquatic environment, both of which generate social and economic benefits to area residents.

Concerns related to environmental quality conditions in the Salmon River are primarily associated with non-point source contaminant discharges. Such contaminants arise from a variety of land use activities, including forest management, agriculture and urban development. Contaminants of concern in the watershed include suspended solids, turbidity, ammonia, phosphorus, nitrogen, metals and fecal coliforms. In addition, water withdrawals from the river and nearby infiltration galleries have resulted in decreased streamflows and associated effects on water temperatures and other habitat features in the river.

This report discusses water quality data collected by the provincial and federal governments between 1985 and 2000. These objectives specify the water quality

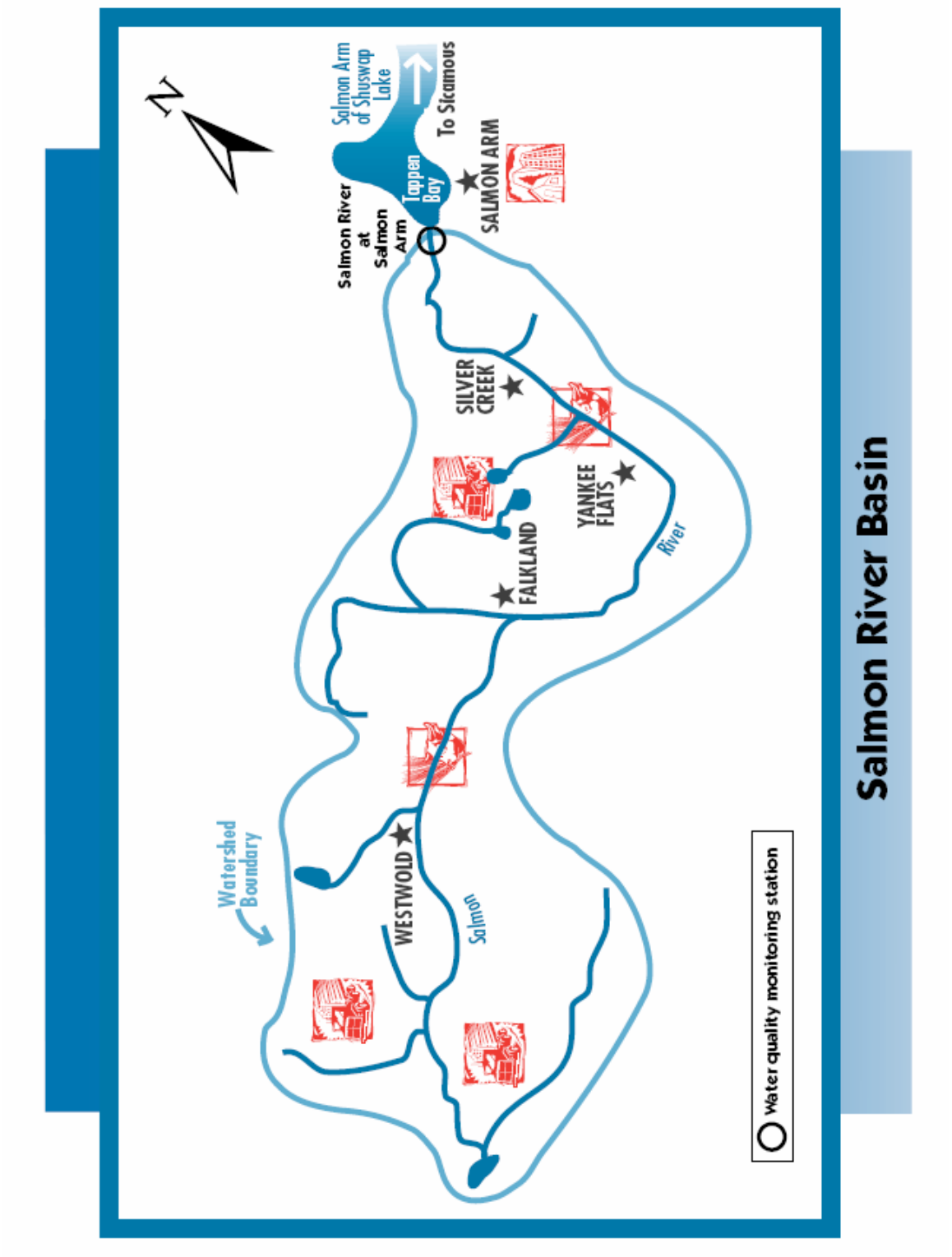

Figure 1. Map of the Salmon River Watershed.

conditions that are necessary to protect aquatic life, wildlife, livestock watering, irrigation, drinking water supplies and aesthetic and recreational water uses in this river system.

QUALITY ASSURANCE

The water quality plots were reviewed, and values that were known outliers were removed. Certain peak values were plotted off-scale using an asterisk, the value, and the sample date to facilitate better viewing and interpretation of the other values around criteria and minimum detectable limits. There were known quality assurance problems for cadmium, chromium, copper, lead, mercury, pH, and zinc at various times, and these data were removed from the data sets.

STATE OF THE WATER QUALITY

The state of the water quality was assessed by comparing the values to B.C. Environment's Approved and Working Criteria for Water Quality (Nagpal *et al.*, 2001a and b). There are no site-specific water quality objectives for the Salmon River. Any levels or trends in water quality that may have been deleterious to sensitive water uses, including drinking water, aquatic life and wildlife, recreation, irrigation, and livestock watering are noted in the following discussion. The following water quality indicators were not discussed as they easily met all water quality guidelines and showed no clearly visible trends: arsenic, barium, beryllium, bromine, lead, lithium, molybdenum, nickel, dissolved oxygen, sodium, sulphate, vanadium, and zinc.

Flow data from 1984 to 2000 is shown in Figure 2. Peak flows generally occur in late May or early June, and are driven by snow-melt.

Total alkalinity concentrations fluctuated significantly in a seasonal pattern, ranging from a low of about 41 mg/L to a maximum of about 228 mg/L (Figure 3). Concentrations were lowest during the early spring (April and May) due to dilution from spring run-off, and highest during the mid-winter low flows. **Calcium** concentrations showed a similar seasonal trend, with values ranging from about 14 mg/L to 72 mg/L (Figure 11). This indicates that the river has a low sensitivity to acid inputs (is well

buffered) – the threshold for this rating is considered to be about 20 mg/L for alkalinity and 8 mg/L for calcium.

Total aluminum concentrations ranged from 0.005 mg/L to a maximum of 9.21 mg/L for 288 samples collected between 1987 and 2000 (Figure 4). Four samples (1%) exceeded the 5 mg/L guideline for irrigation, livestock and wildlife, while 50% of samples (144) exceeded the guideline for drinking water and irrigation (0.2 mg/L **dissolved** aluminum). However, the strong correlation between total aluminum and turbidity (Figure 4) suggests that the majority of the aluminum present in the samples is associated with particulate matter. As elevated turbidity levels would necessitate water treatment to remove excess turbidity, aluminum associated with the particulate matter would also be removed at this time. There is no apparent trend in total aluminum concentrations at this site. Dissolved aluminum should be monitored for direct comparison to the criteria.

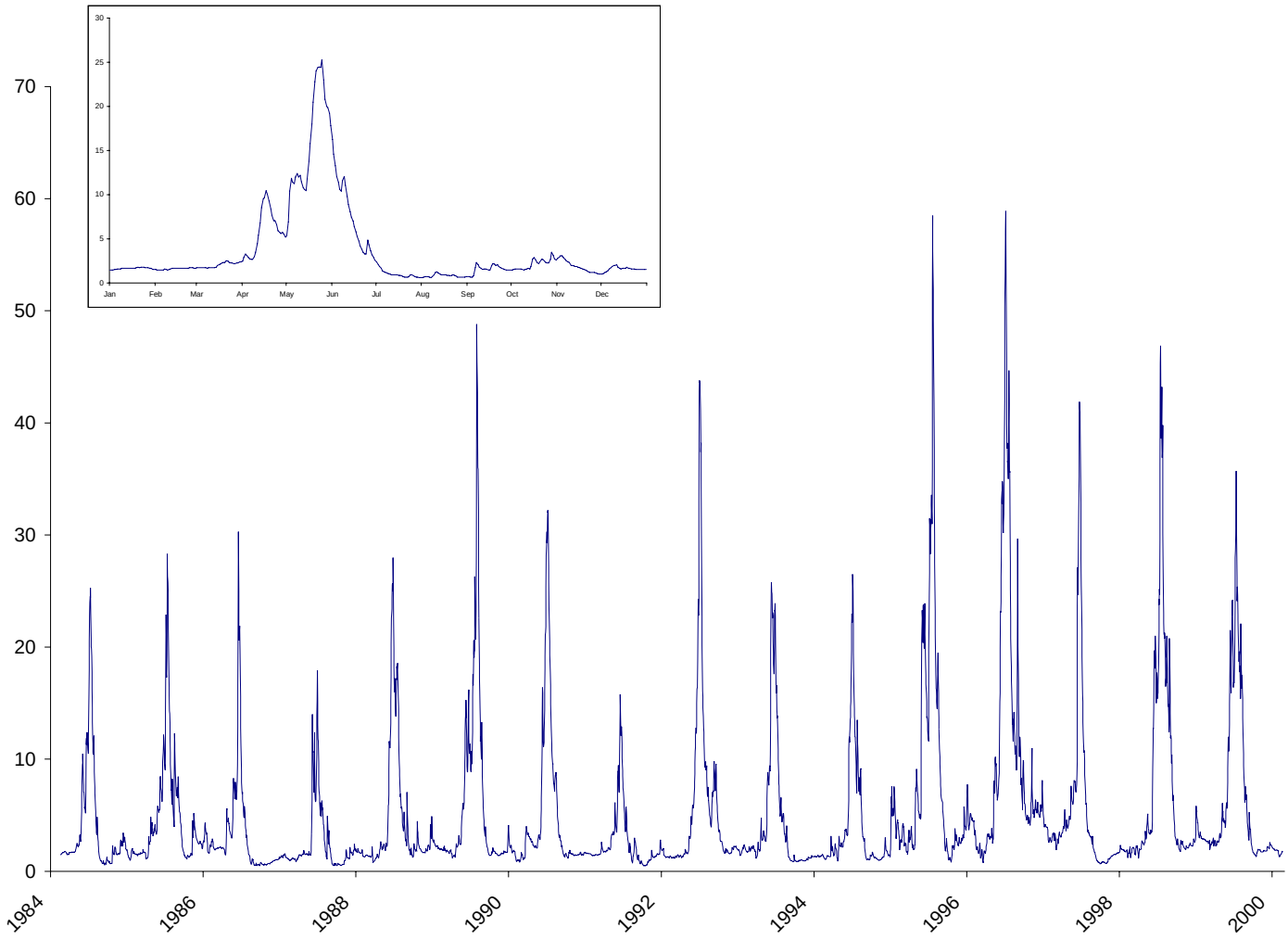

Figure 2. Flow data for the Salmon River near Highway 1. Inset shows typical annual hydrograph.

Total cadmium concentrations measured prior to 1991 were suspect due to preservative vial contamination. After this time, total cadmium was measured 257 times, with a maximum concentration of 0.0022 mg/L (Figure 10). The minimum detection limit used (0.0001 mg/L) exceeded the aquatic life guideline for total cadmium of 0.00001 – 0.00003 mg/L at a hardness of less than 90 mg/L by a factor of 3-10. Therefore, although 197 of the 257 samples had concentrations at or below detectable limits and may have been below the guideline levels, the remaining 60 samples exceeded the guidelines. Maximum cadmium concentrations measured after 1991 tended to coincide with elevated turbidity, suggesting that on some occasions cadmium was associated with particulate matter and probably not bioavailable. In the future, an analytical method should be used with a detection limit at least a factor of 10 lower than the guideline level (a maximum of

0.000001 mg/L) to allow the data to be compared to the guideline. There was no apparent change in cadmium concentrations over time at this site.

Dissolved organic carbon concentrations ranged from below detectable limits (<0.5 mg/L) to a maximum of 12.5 mg/L (Figure 12). The drinking water guideline (4 mg/L) was exceeded by 25 of 78 samples collected between 1994 and 2000. There was some correlation between DOC and turbidity (Figure 12), as organic carbon concentrations tended to peak during spring freshet. There does not appear to be any trend in DOC concentrations at this site.

Total chromium had high values due to suspected preservative vial contamination between 1986 and 1991 (Figure 14). As well, all data collected prior to August 2000 is suspect due to instrument interference. Therefore, no useful assessment of chromium concentrations can be made at this time, but it is hoped that future samples will allow an assessment of this metal.

Total cobalt concentrations were measured 279 times between 1990 and 2000, with values ranging from below detectable limits (<0.0001 mg/L) to a maximum of 0.0074 mg/L (Figure 15). 52 samples (18% of all samples collected) exceeded the aquatic life guideline. However, the strong correlation between cobalt concentrations and turbidity (Figure 15) suggests that much of the cobalt was associated with particulate matter, and therefore not biologically available. There was no apparent trend in cobalt concentrations at this site.

Fecal coliforms were measured 336 times between 1985 and 2000, with values ranging from below detectable limits (<1 CFU/100 mL) to a maximum of 5000 CFU/100 mL (Figure 16). While sampling frequencies were insufficient to determine a proper 90^{th} percentile value (a minimum of five samples in a 30-day period are required to determine 90^{th} percentiles), numerous elevated fecal coliform results suggest that the drinking water guideline for water undergoing disinfection only prior to consumption (a 90^{th} percentile

less than 10 CFU/100 mL) would not be met. The 90th percentile for the 336 values collected was 286 CFU/100 mL. There was no trend in fecal coliform concentrations.

True colour values ranged from 5 to 70 TCU for 92 values collected between 1997 and 2000 (Figure 17). 32 values (35%) exceeded the aesthetic drinking water guideline of 15 TCU, primarily during the spring freshet. There was no trend in colour values over the period of record.

Specific conductivity values varied significantly at this site, from a low of 93 microSiemans/cm to a high of 557 microSiemans/cm (Figure 18). These fluctuations were seasonal, with higher values occurring during low-flow periods (when dilution of ions contribution to conductivity is minimal) and lower values occurring during the spring freshet. All values were below the aesthetic drinking water guideline of 700 microSiemans/cm, and there was no change in this general trend over the period of record.

Total copper concentrations ranged from 0.0002 mg/L to 0.0243 mg/L for 257 samples analyzed between 1991 and 2000 (Figure 19). Samples collected prior to 1991 were potentially contaminated by preservative vials. Aquatic life guidelines for total copper are hardness-dependent: at hardness levels typical for the Salmon River near Salmon Arm, these would typically be a maximum of 0.007 mg/L, and a 30-day average of about 0.017 mg/L. By calculating maximum and average guidelines for each of the 257 samples based on their concurrent hardness concentrations, it was determined that 40 values (14% of all samples) exceeded their appropriate 30-day average guideline, while 18 samples (6%) exceeded the maximum guideline. This comparison is used only as an indication of potential exceedances, because the calculation of a 30-day average requires a minimum of 5 samples collected within a 30-day period (a criterion not met in this instance). Except for a few elevated total copper concentrations measured between 1991 and 1992, there was a good correlation between elevated copper and elevated turbidity levels (Figure 19), suggesting that copper was often associated with particulate matter and therefore not likely biologically available. There was no apparent change over time.

E. coli and **Enterococci** concentrations were similar to those of fecal coliforms, with values frequently exceeding the drinking water guidelines (90^{th} percentile of 10 CFU/100 mL for *E. coli* and 90^{th} percentile of 3 CFU/100 mL for enterococci) (Figure 20, Figure 21). Sampling frequencies were insufficient to determine actual guideline exceedences, but it appears that both of these microbiological indicators frequently exceeded their applicable guidelines. There was no trend for either parameter over the period of record.

Fluoride concentrations exceeded the aquatic life guideline of 0.3 mg/L on four occasions (1% of the 282 samples collected between 1988 and 2000) (Figure 22). The maximum recorded concentration was 0.6 mg/L. There was no trend in fluoride concentrations at this site.

Hardness concentrations in the Salmon River showed that the water was relatively hard, exceeding the optimum range for drinking water (80-100 mg/L) in 38% of samples collected between 1988 and 2000 (Figure 23). This meant that during these periods, the water was considered poor but acceptable. The remainder of the time, hardness was within the optimum range for consumption. There may be a slight increasing trend over the period of record, but this requires statistical analysis to verify.

The majority of **total iron** concentrations (213 of 335 samples, or 64%) exceeded the aesthetic drinking water and aquatic life guideline of 0.3 mg/L (Figure 24). In addition, 11 samples (3%) exceeded the irrigation guideline of 5 mg/L. Iron concentrations were well correlated with turbidity (Figure 24), suggesting that the majority of the iron is associated with particulate matter. In this case, it is likely not bioavailable, and will be removed by water treatment necessary to remove excess turbidity prior to human consumption. There did not appear to be any trend in iron concentrations over the period of record.

Total manganese concentrations ranged from 0.0024 mg/L to a maximum of 0.405 for 335 samples collected between 1987 and 2000 (Figure 28). Half of all values exceeded

the guideline for drinking water (0.05 mg/L), but none exceeded the aquatic life guideline (0.7 mg/L). There was a strong correlation between total manganese and turbidity, suggesting that during times of elevated manganese concentrations, a significant portion is associated with particulate matter. If this is the case, then treatment to remove turbidity prior to consumption will also remove excess manganese. There does not appear to be any trend in manganese over time in the Salmon River at this site.

Nitrogen levels, including **nitrate** (Figures 31, 32), **nitrite** (Figure 32, 33) and **ammonia** (Figure 5) were well below their respective guidelines (10 mg/L for nitrate, 1 mg/L for nitrite and approximately 1 mg/L for ammonia).

The **pH** of the Salmon River near Salmon Arm was slightly basic, with the majority of the values falling between 7.5 and 8.5 pH units (Figure 37). A few values (5 samples, or 1% of the 445 samples collected between 1985 and 2000) exceeded the aesthetic guideline for drinking water (upper pH limit 8.5), but all were within the aquatic life guideline (upper pH limit 9.0). There was no apparent trend in pH at this site.

Total phosphorus concentrations were relatively high, ranging from 0.002 mg/L to 0.61 mg/L (Figure 39). The mean concentration was 0.11 mg/L for the 454 samples collected between 1985 and 2000. While there is no guideline for phosphorus concentrations in streams, the drinking water guideline for lakes is only 0.01 mg/L, a value exceeded by almost all of the samples collected. The Salmon River may therefore be contributing to the eutrophication of Shuswap Lake.

Total selenium concentrations exceeded the aquatic life guideline of 0.001 mg/L on two occasions between 1985 and 2000 (Figure 44). There did not appear to be a strong correlation between total selenium and turbidity. There may be a very slight decreasing trend in selenium concentrations at this site.

Total silver concentrations ranged from below detectable limits (<0.0001 mg/L) to a maximum of 0.0757 mg/L for 127 samples collected between 1997 and 2000 (Figure 45).

The maximum freshwater aquatic guideline for total silver is equal to the detection limit (0.0001 mg/L). Eight values (6%) exceeded the detection limits, and therefore the aquatic life guideline. Only two of these values exceeded the guideline by more than a factor of 10. Values within a factor of 10 of the detection limit are not considered reliable. For this reason, a more sensitive analytical method should be used, with a detection limit of not more than 0.00001 mg/L. No trend was evident in silver concentrations.

Water temperature exceeded the aesthetic drinking water guideline (15 degrees C) in all but one year (1997) between 1988 and 2000, and exceeded the general fisheries guideline of 19 degrees C in seven of the 13 years on record (Figure 48). Of the 347 samples collected between 1988 and 2000, 49 exceeded the drinking water guideline and 14 exceeded the fisheries guideline. There does not appear to be any trend in water temperature over the period of record.

Turbidity values in the Salmon River ranged from 0.1 NTU to a maximum of 200 NTU for 385 samples collected between 1988 and 2000. 293 values (76%) exceeded the drinking water health guideline (1 NTU), and 104 values (27%) exceeded the aesthetic drinking water guideline (5 NTU) (Figure 49). Peak values occurred during spring freshet (April to June), and suggest that treatment to remove turbidity is necessary for this water to be used as a drinking water source. It appears that maximum turbidity values may be increasing during the freshet period over the last four years (1997 to 2000).

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Ministry of Environment, Lands and Parks. 2001a. British Columbia Approved Water Quality Guidelines (Criteria). Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, B.C.

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Figure 3. Salmon River Near Salmon Arm, B.C. - Alkalinity

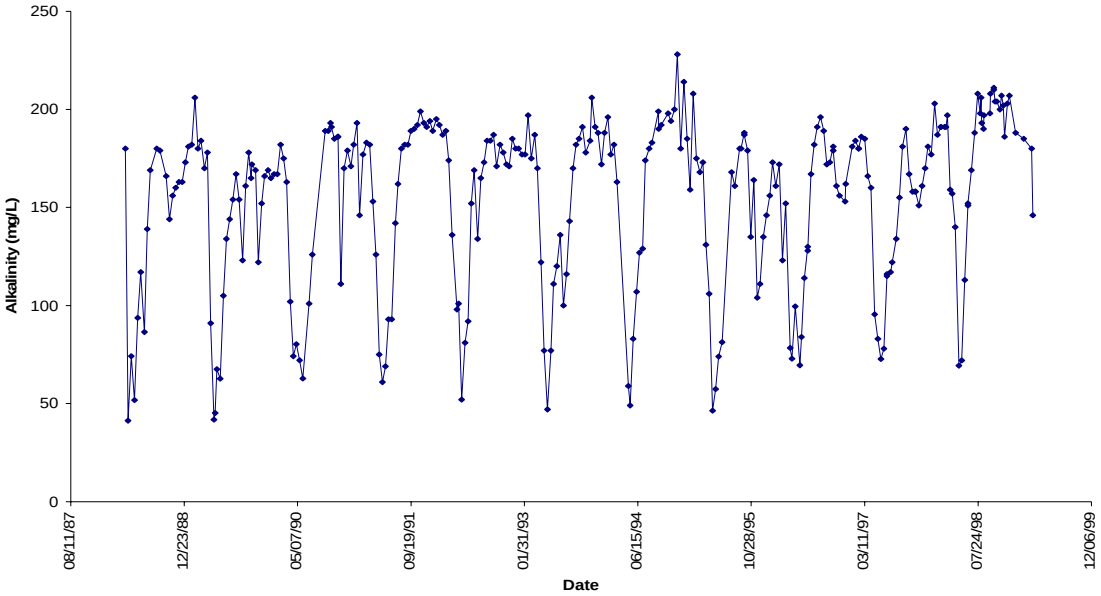

Figure 4. Salmon River Near Salmon Arm, B.C. - Aluminum

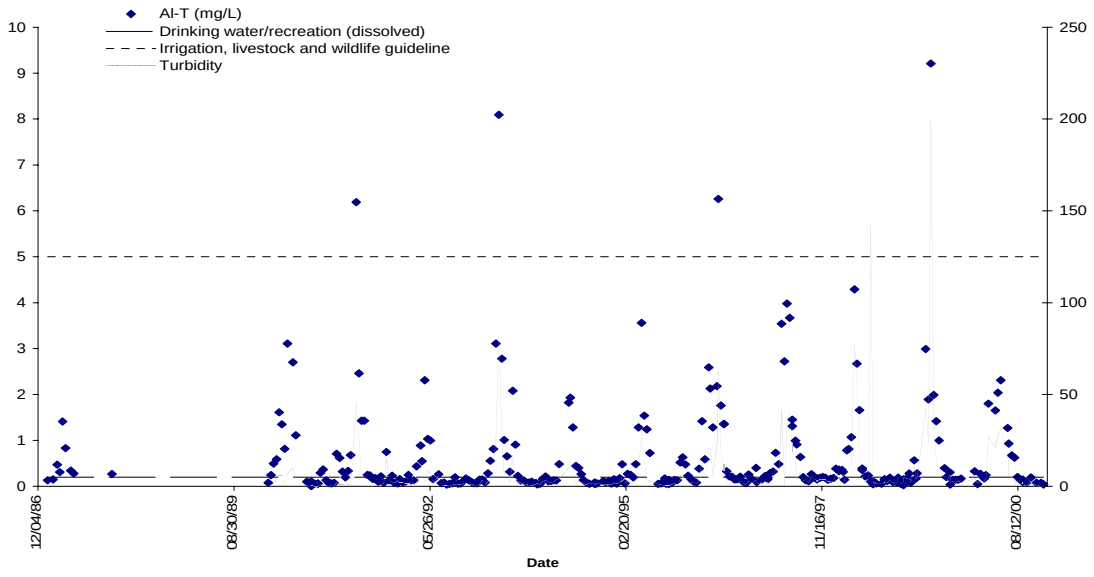

Figure 5. Salmon River Near Salmon Arm, B.C. - Ammonia

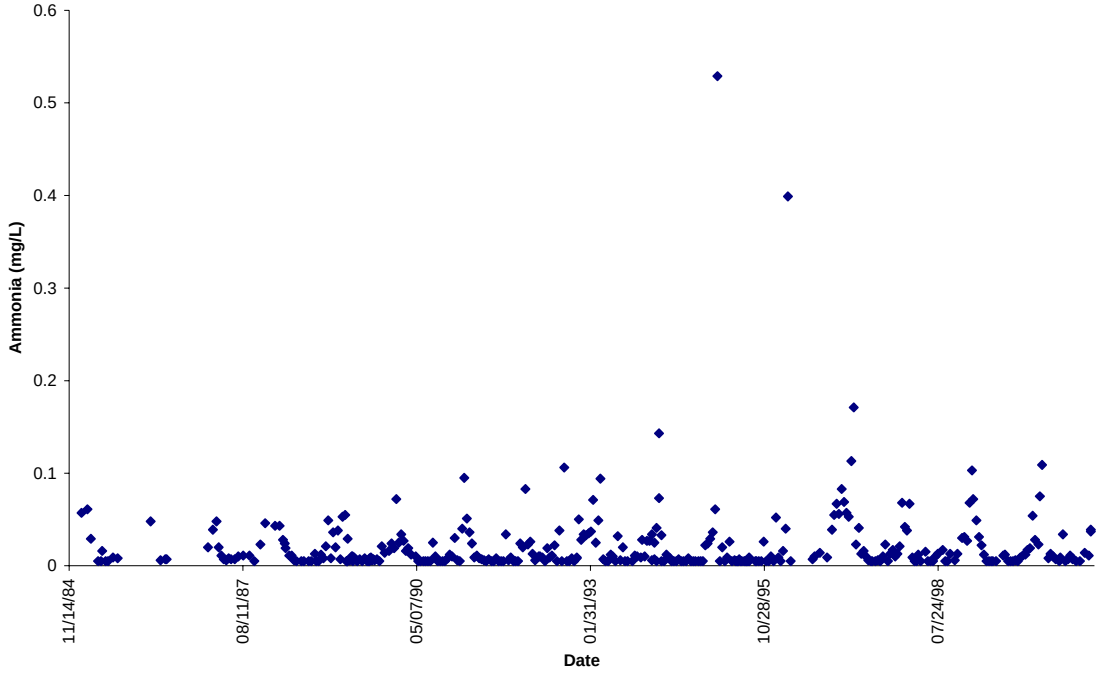

Figure 6. Salmon River Near Salmon Arm, B.C. - Arsenic

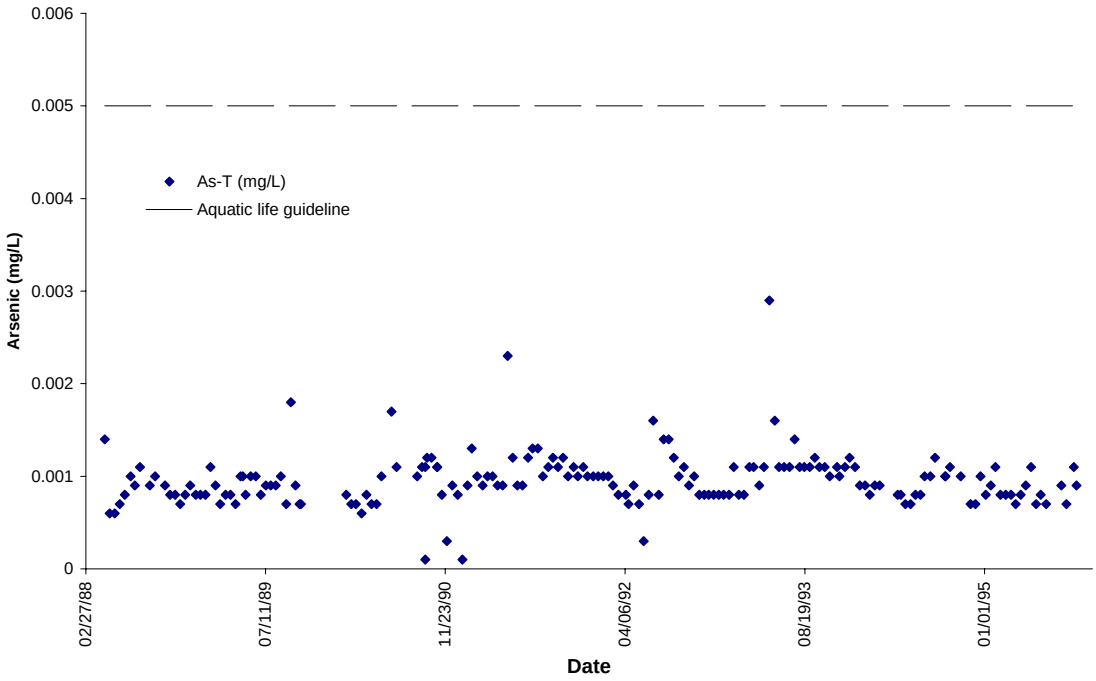

Figure 7. Salmon River Near Salmon Arm, B.C. - Barium

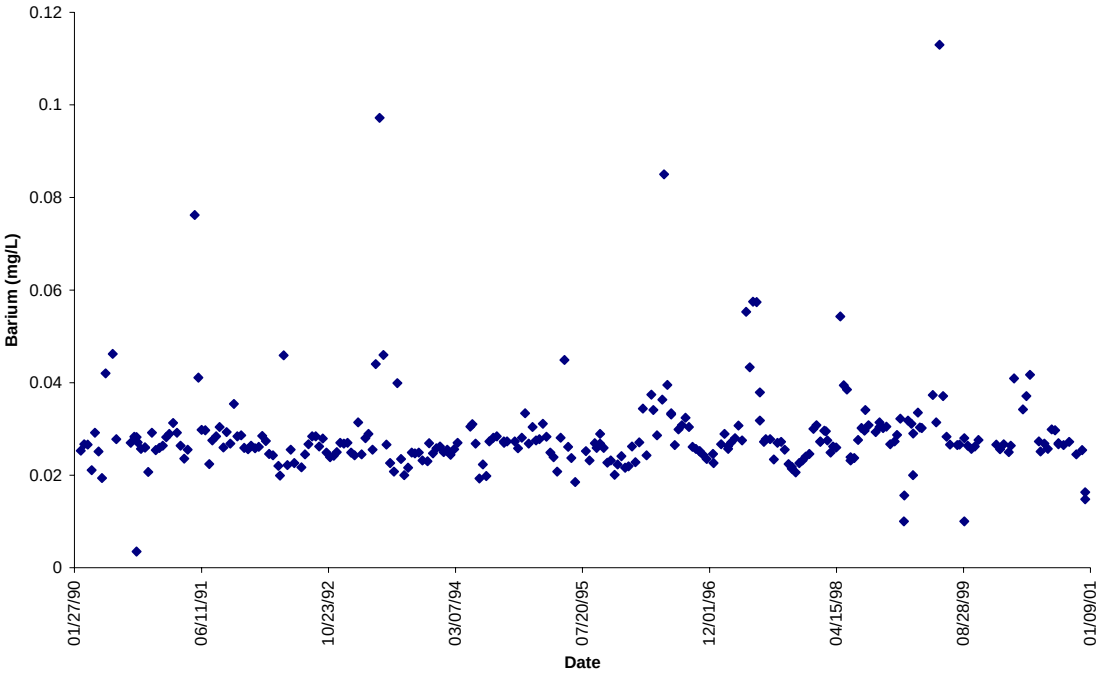

Figure 8. Salmon River Near Salmon Arm, B.C. - Beryllium

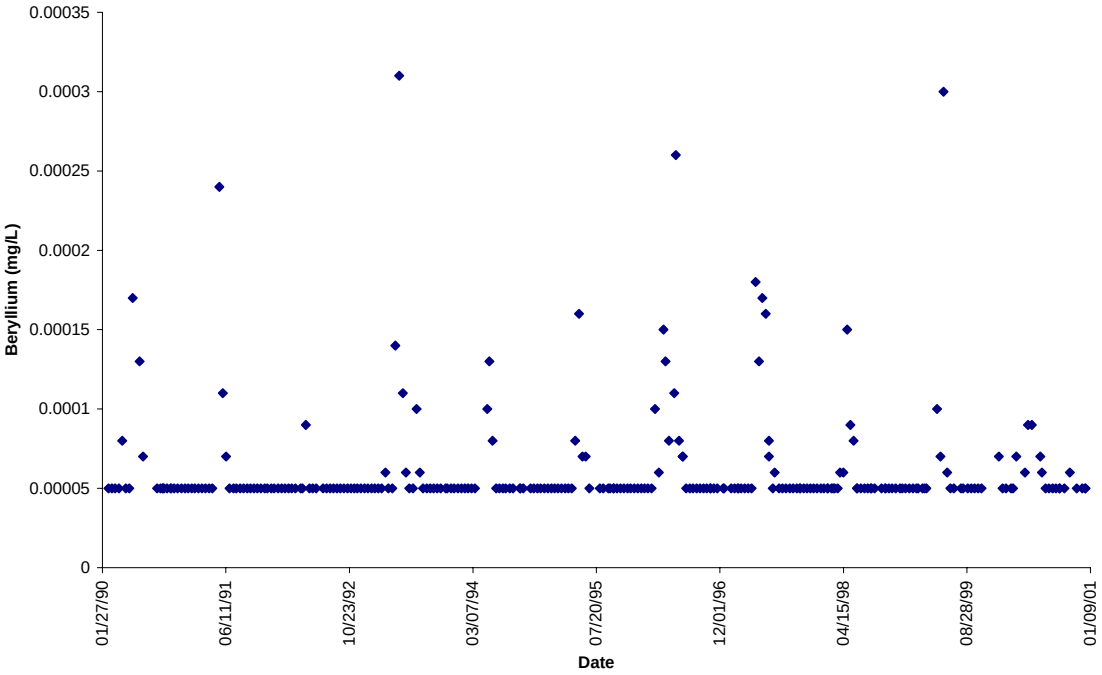

Figure 9. Salmon River Near Salmon Arm, B.C. - Bromide

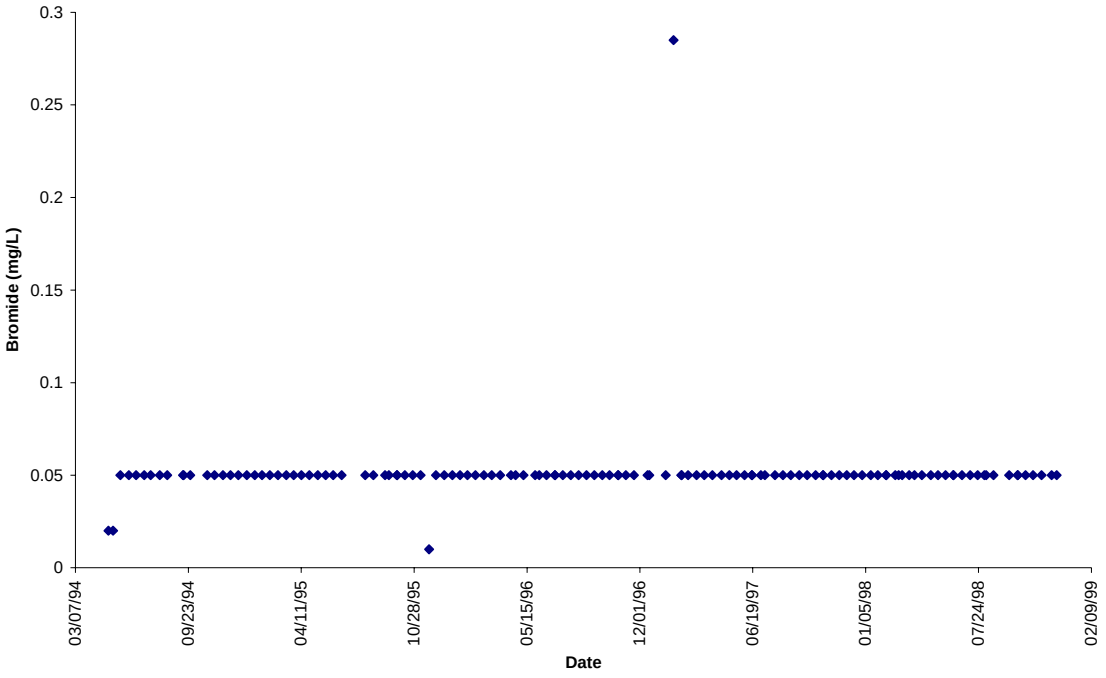

Figure 10. Salmon River Near Salmon Arm, B.C. - Cadmium

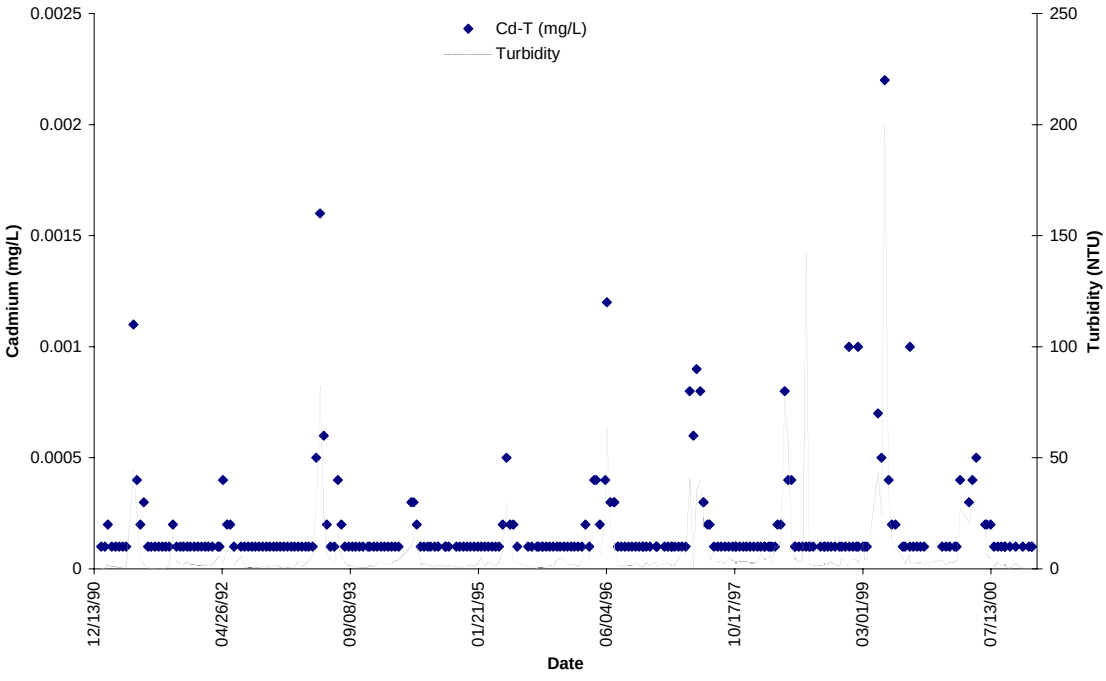

Figure 11. Salmon River Near Salmon Arm, B.C. - Calcium

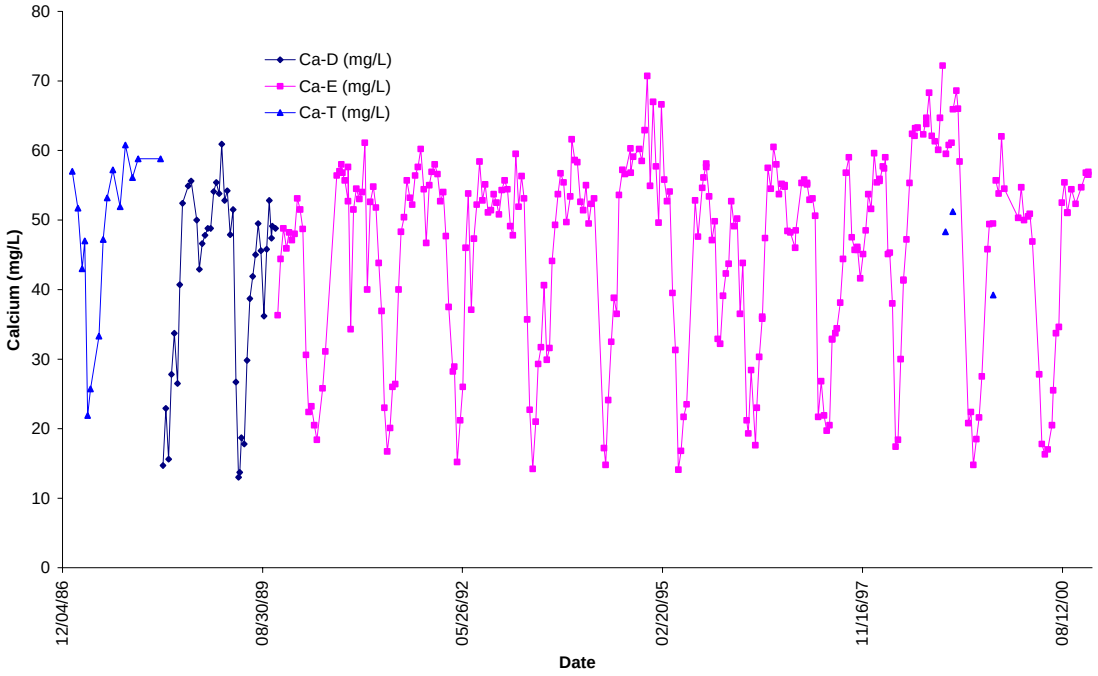

Figure 12. Salmon River Near Salmon Arm, B.C. - Carbon, Dissolved Organic

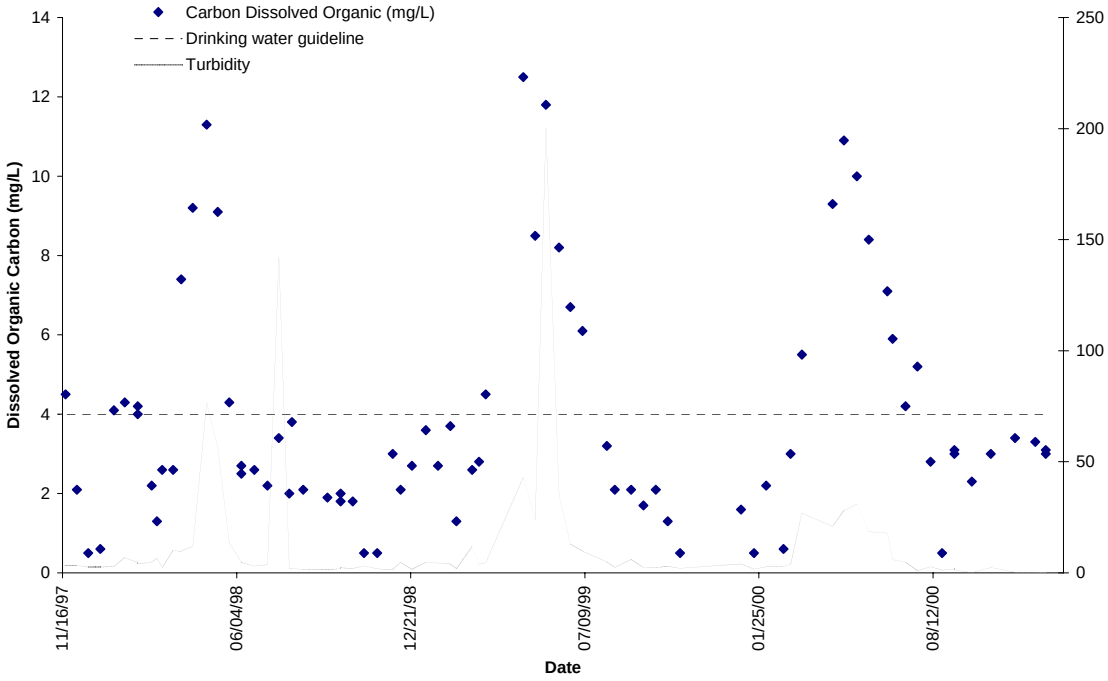

Figure 13. Salmon River Near Salmon Arm, B.C. - Chloride

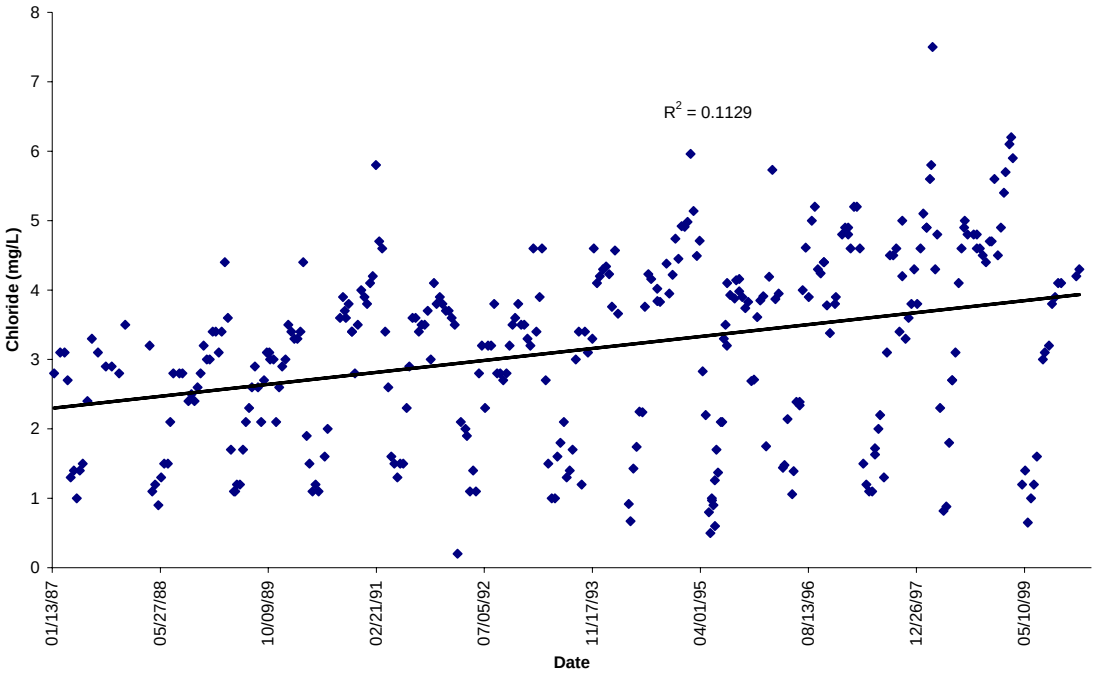

Figure 14. Salmon River Near Salmon Arm, B.C. - Chromium

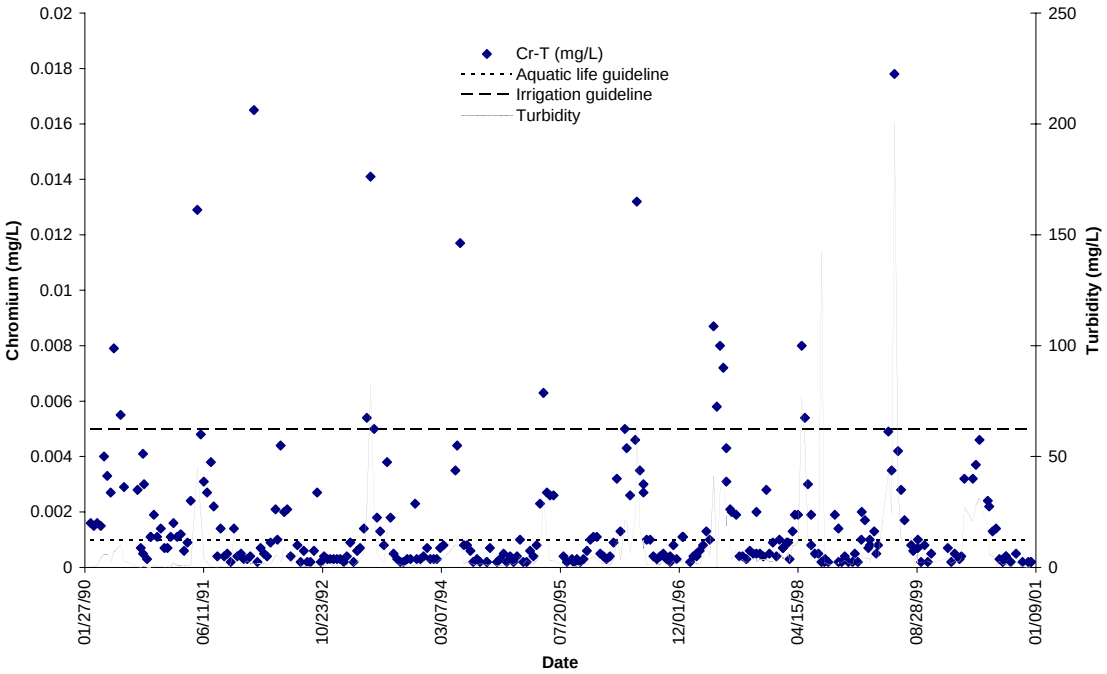

Figure 15. Salmon River Near Salmon Arm, B.C. - Cobalt

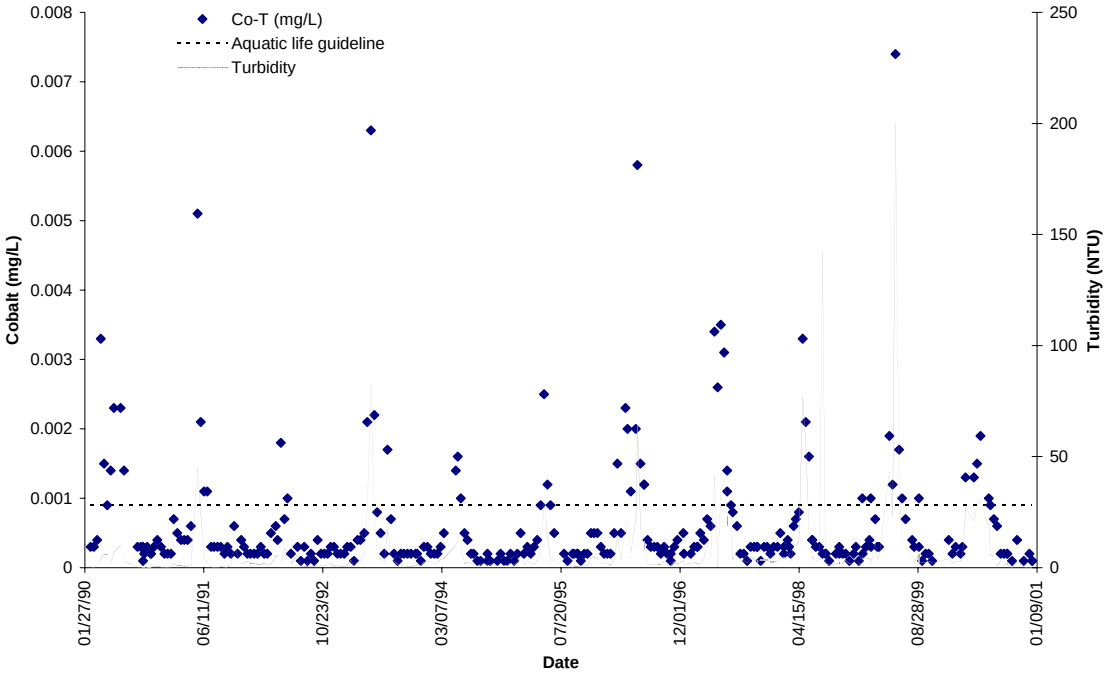

Figure 16. Salmon River Near Salmon Arm, B.C., Fecal coliforms

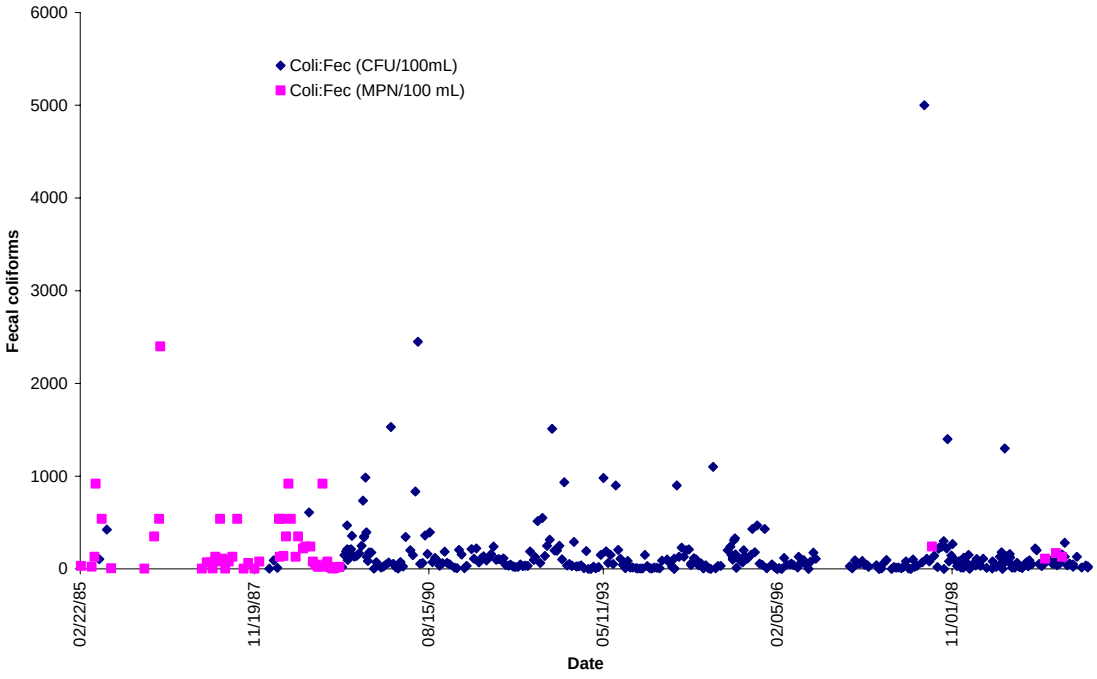

Figure 17. Salmon River Near Salmon Arm, B.C. - Colour

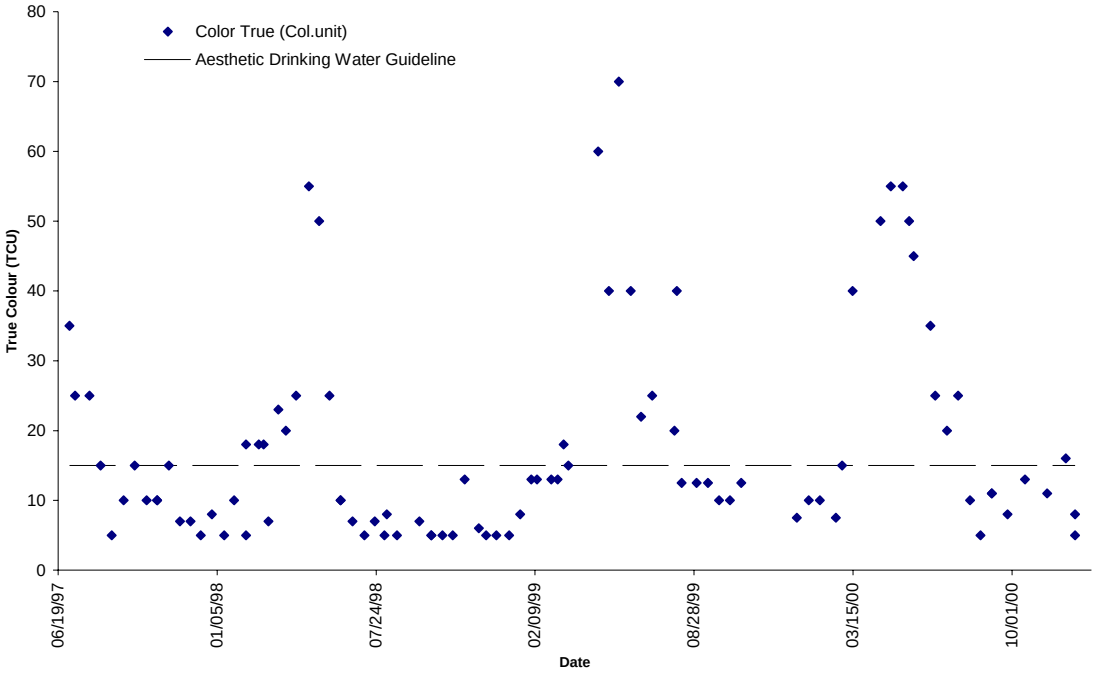

Figure 18. Salmon River Near Salmon Arm, B.C. - Conductivity, Specific

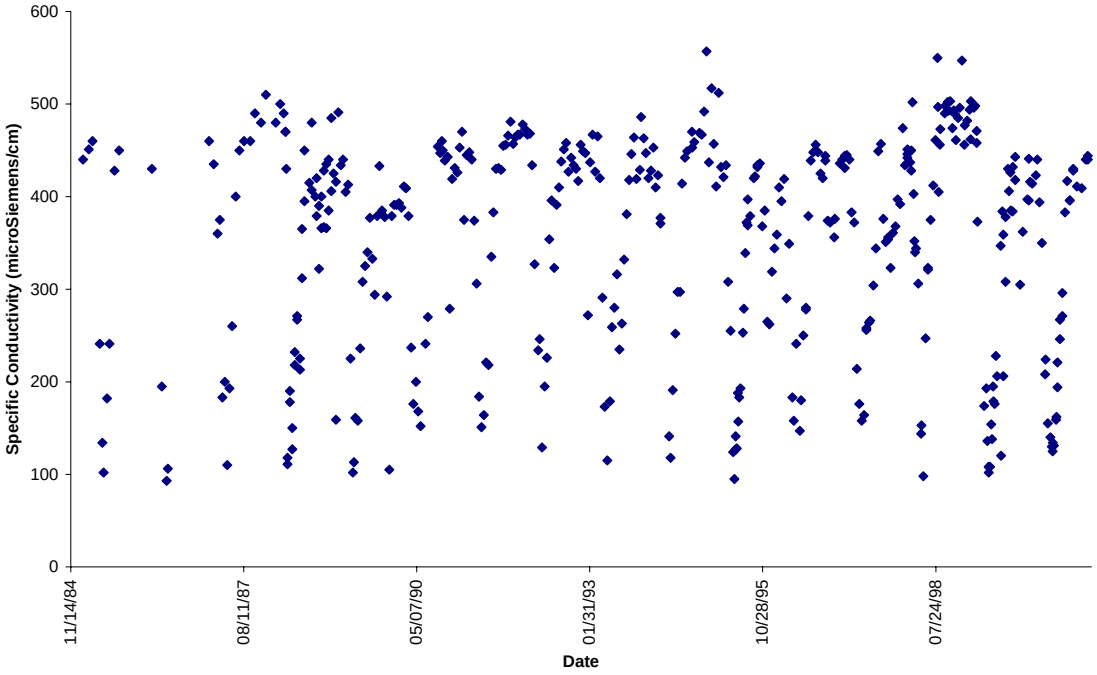

Figure 19. Salmon River Near Salmon Arm, B.C. - Copper

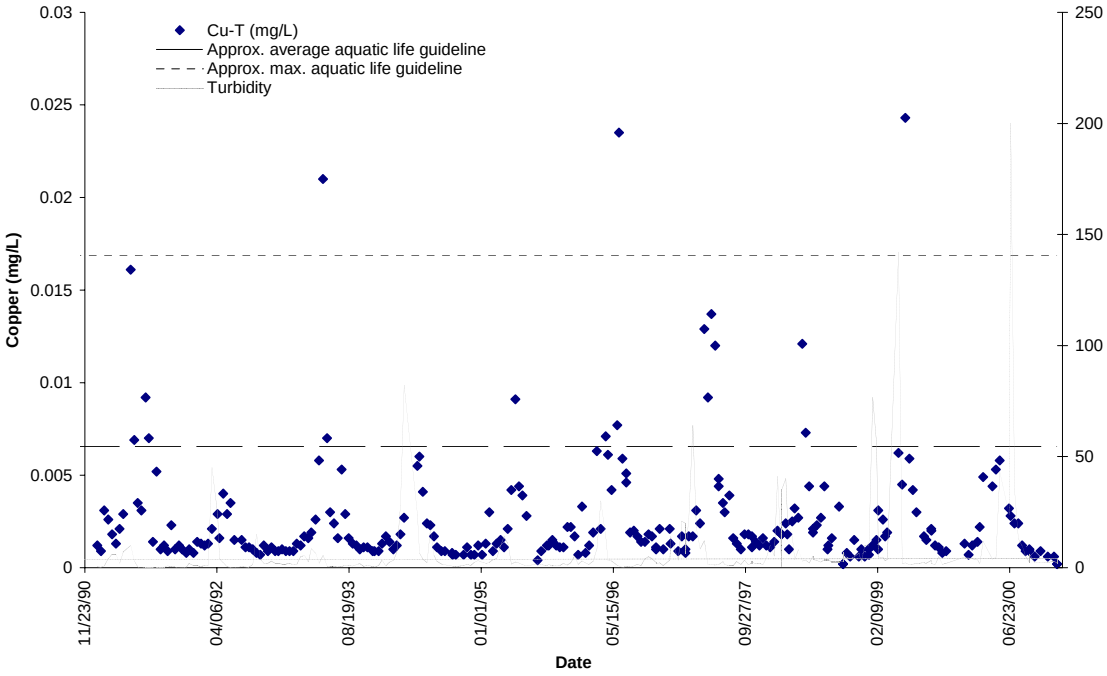

Figure 20. Salmon River Near Salmon Arm, B.C. - *E. coli*

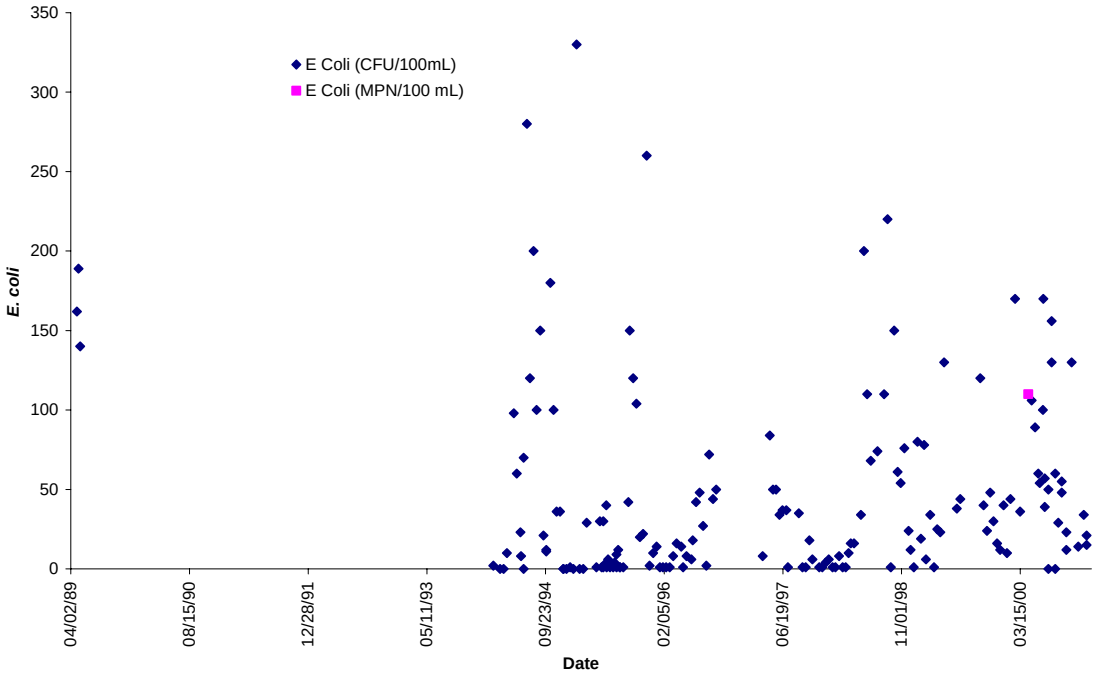

Figure 21. Salmon River Near Salmon Arm, B.C. - Enterococci

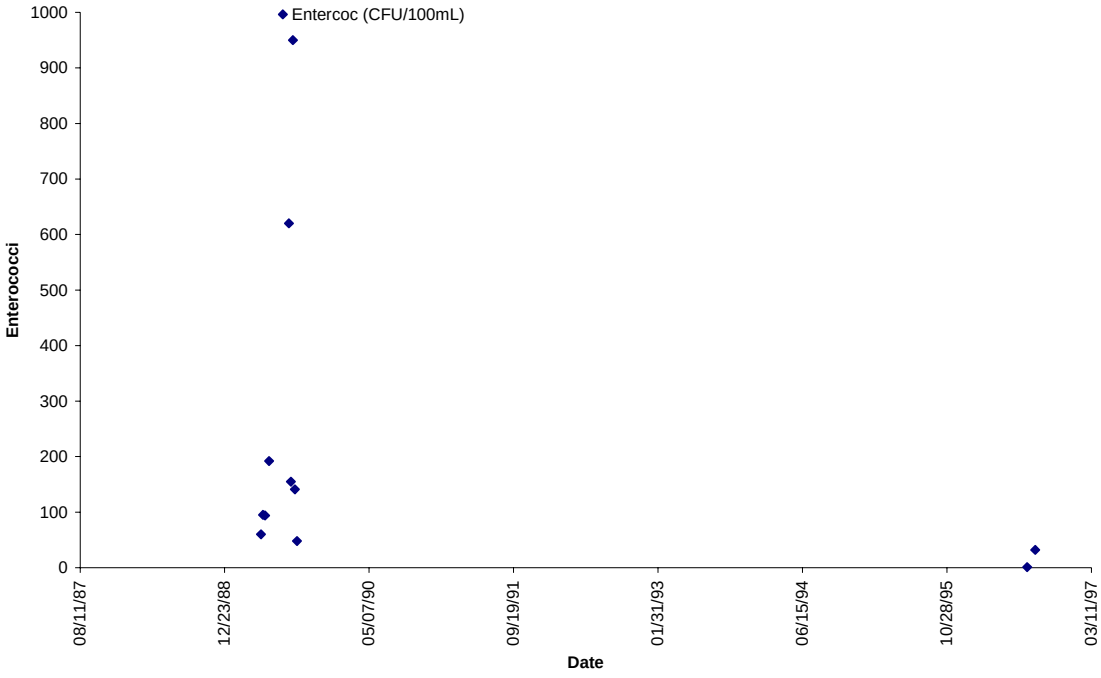

Figure 22. Salmon River Near Salmon Arm, B.C. - Fluoride

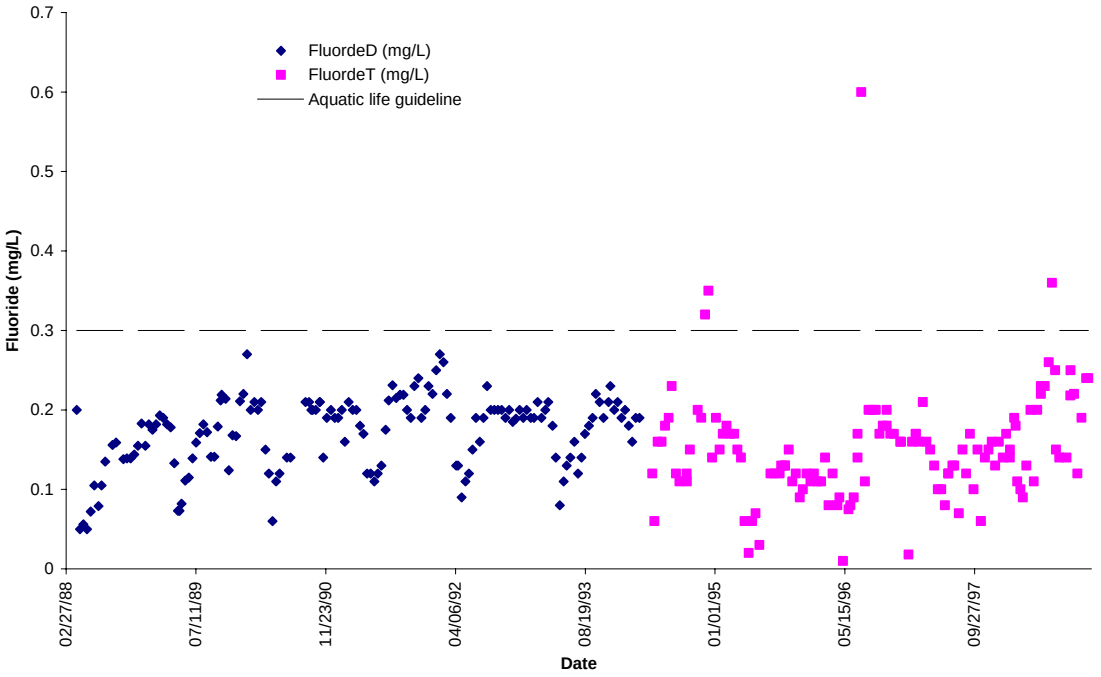

Figure 23. Salmon River Near Salmon Arm, B.C. - Hardness

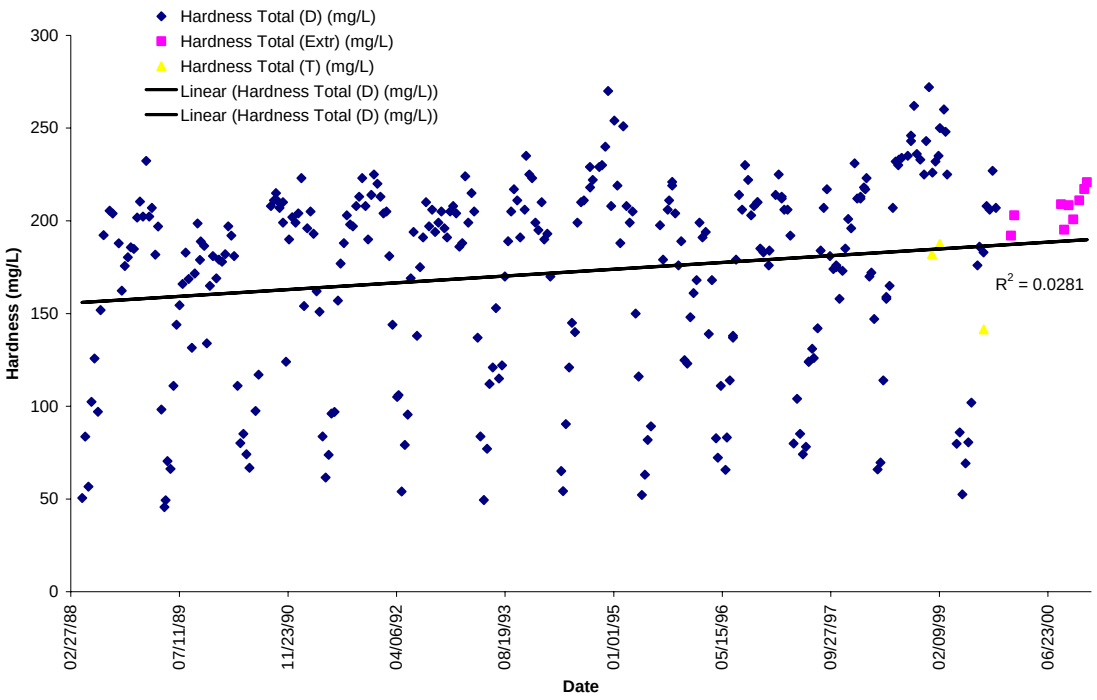

Figure 24. Salmon River Near Salmon Arm, B.C. - Iron

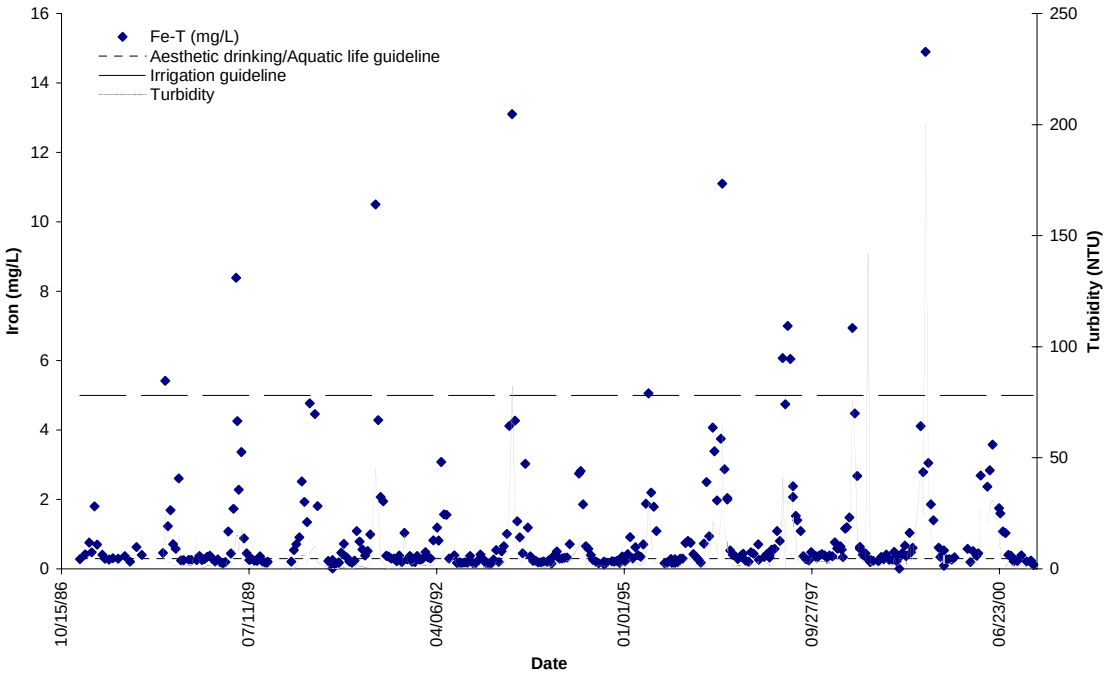

Figure 25. Salmon River Near Salmon Arm, B.C. - Lead

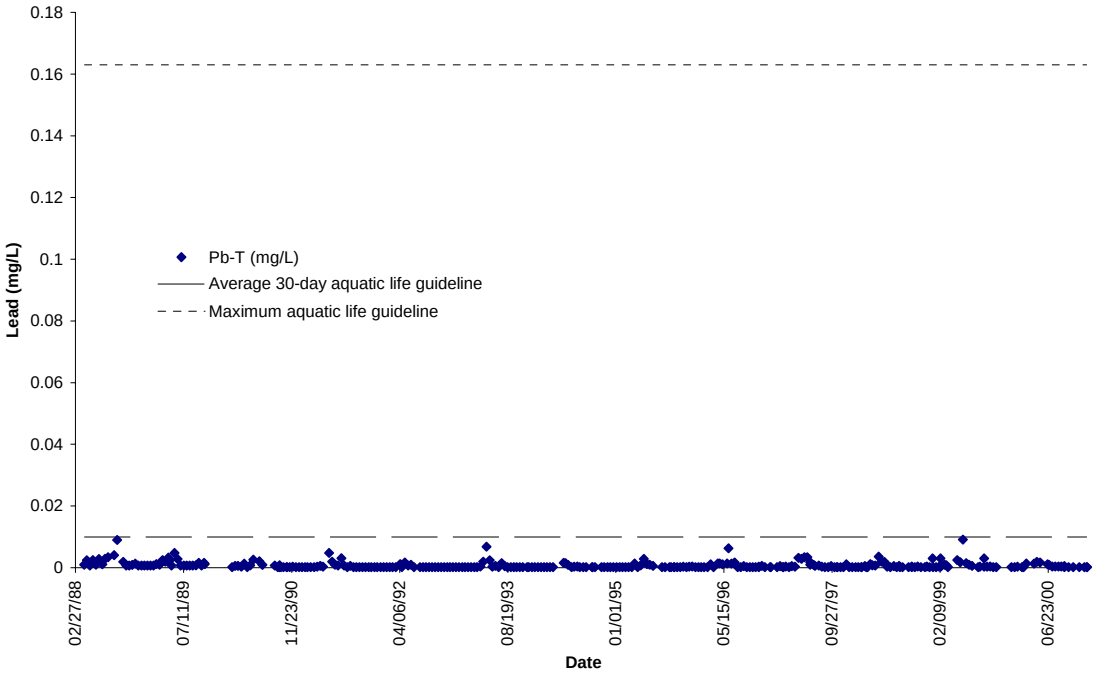

Figure 26. Salmon River Near Salmon Arm, B.C. - Lithium

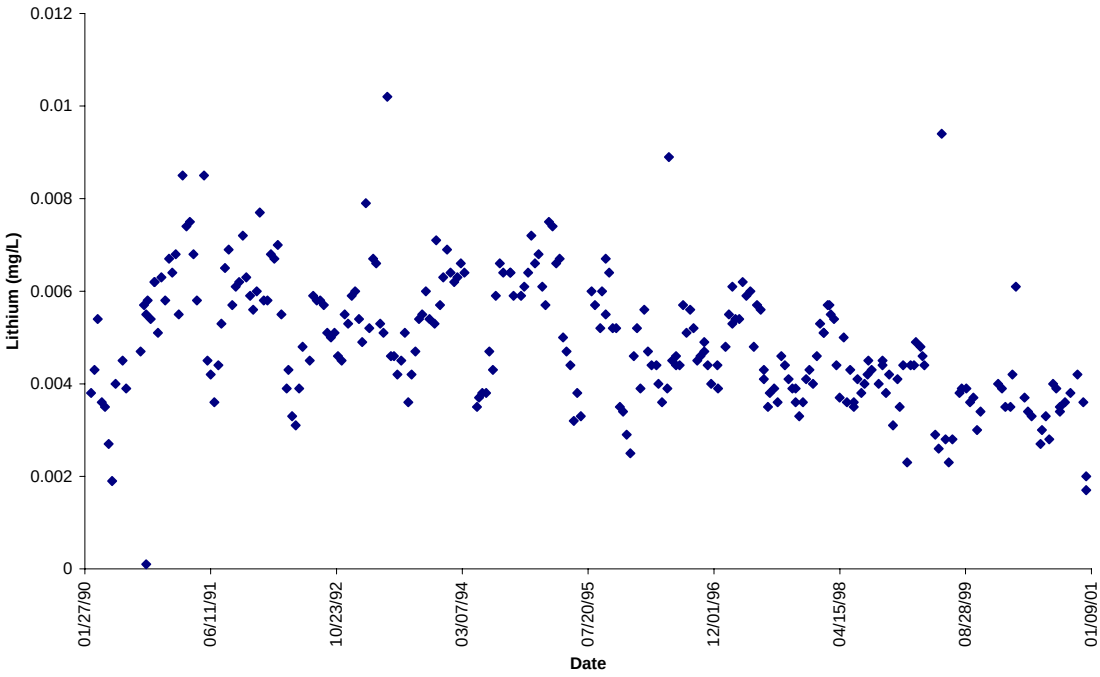

Figure 27. Salmon River Near Salmon Arm, B.C. - Magnesium

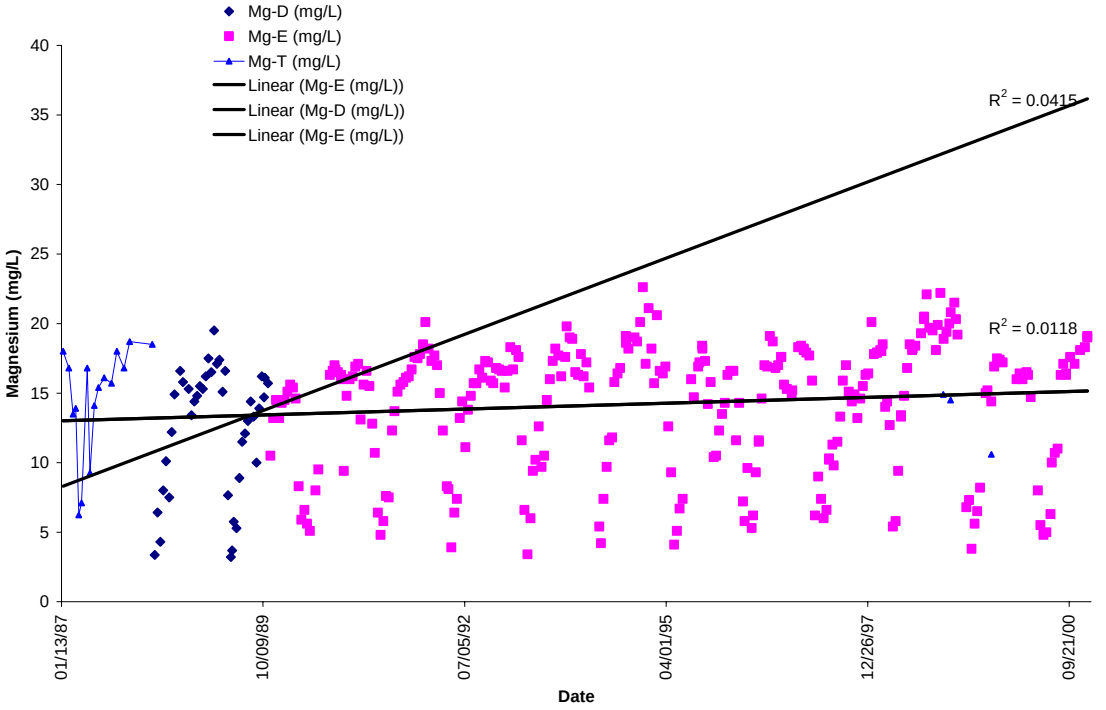

Figure 28. Salmon River Near Salmon Arm, B.C. - Manganese

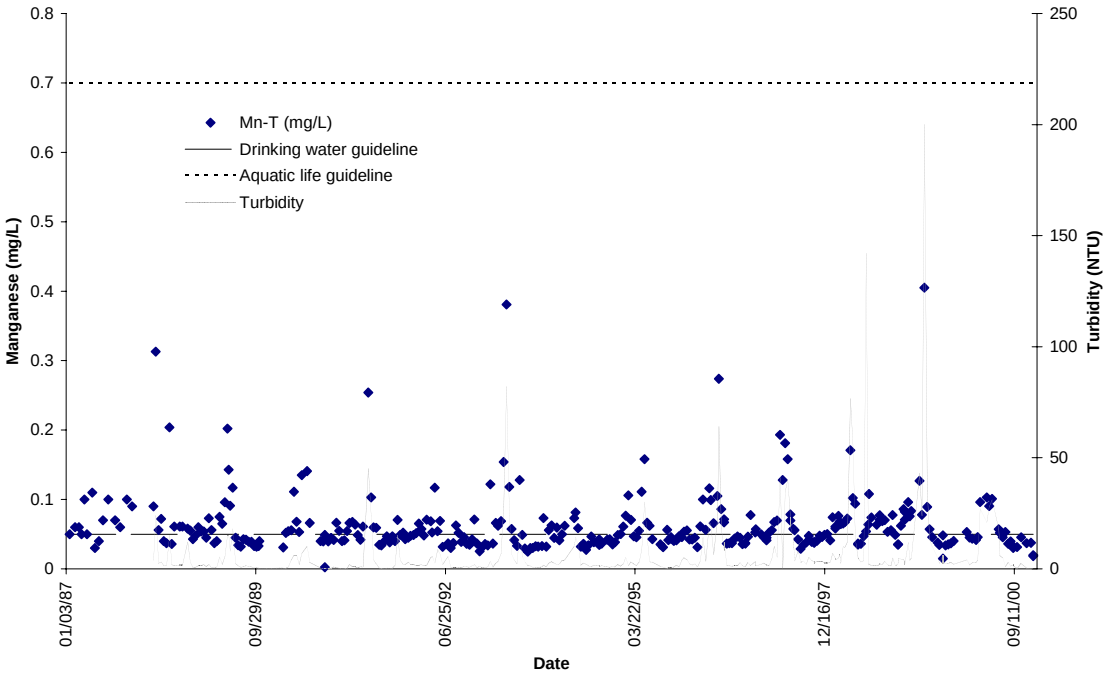

Figure 29. Salmon River Near Salmon Arm, B.C. - Molybdenum

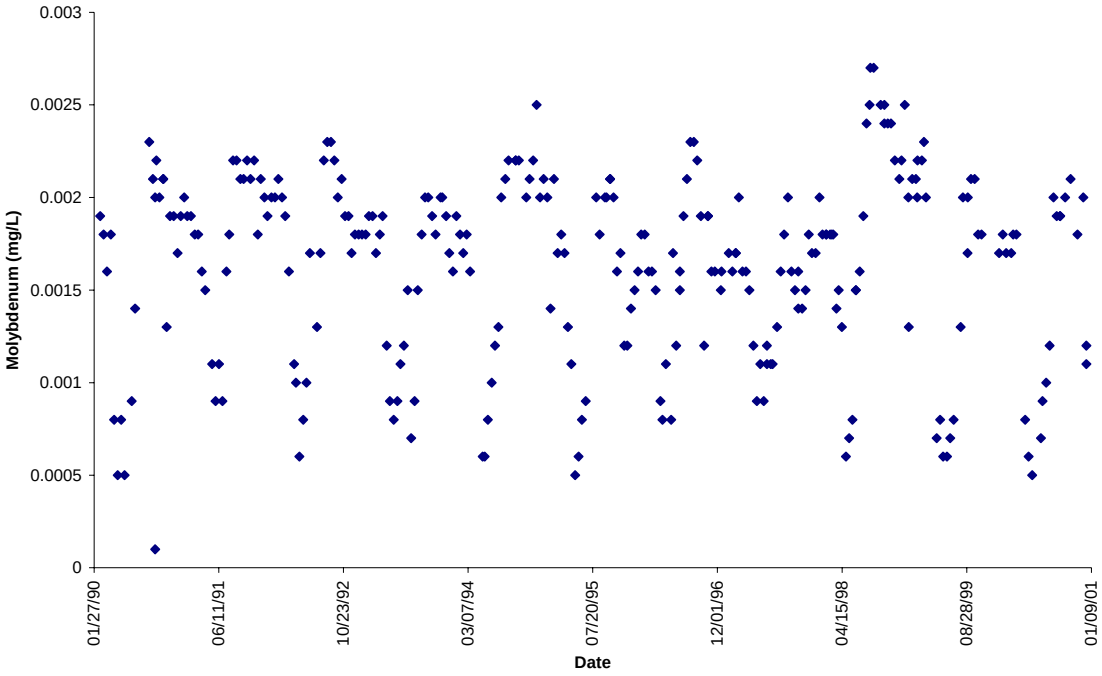

Figure 30. Salmon River Near Salmon Arm, B.C. - Nickel

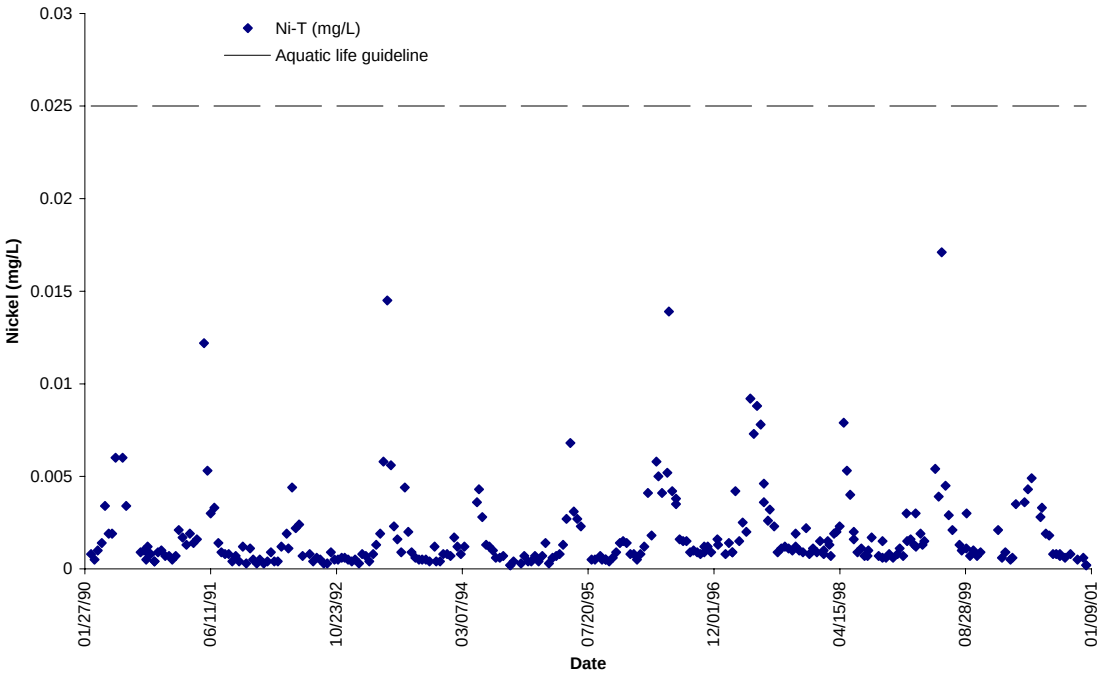

Figure 31. Salmon River Near Salmon Arm, B.C. - Nitrate

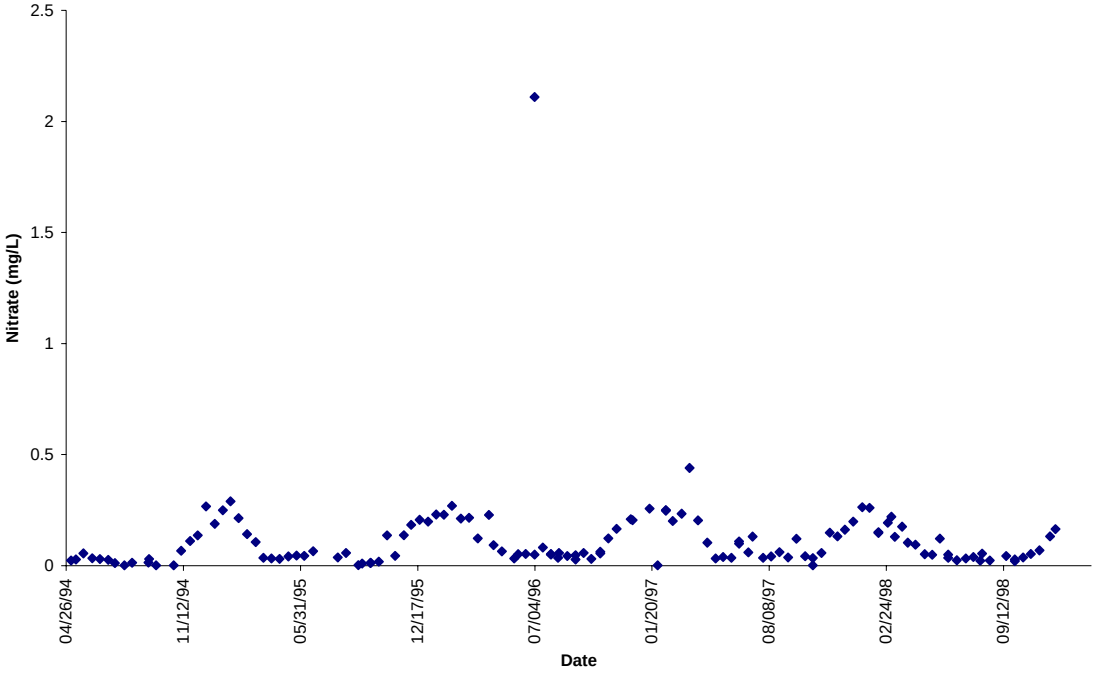

Figure 32. Salmon River Near Hyder, Alaska - Nitrate + Nitrite

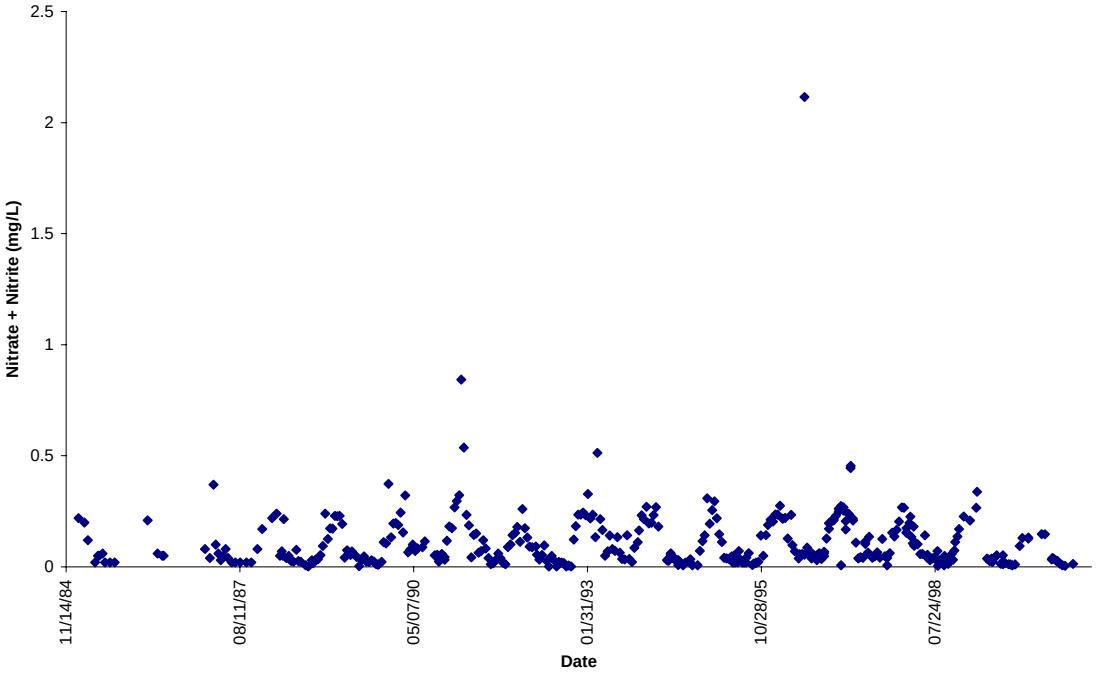

Figure 33. Salmon River Near Salmon Arm, B.C. - Nitrite

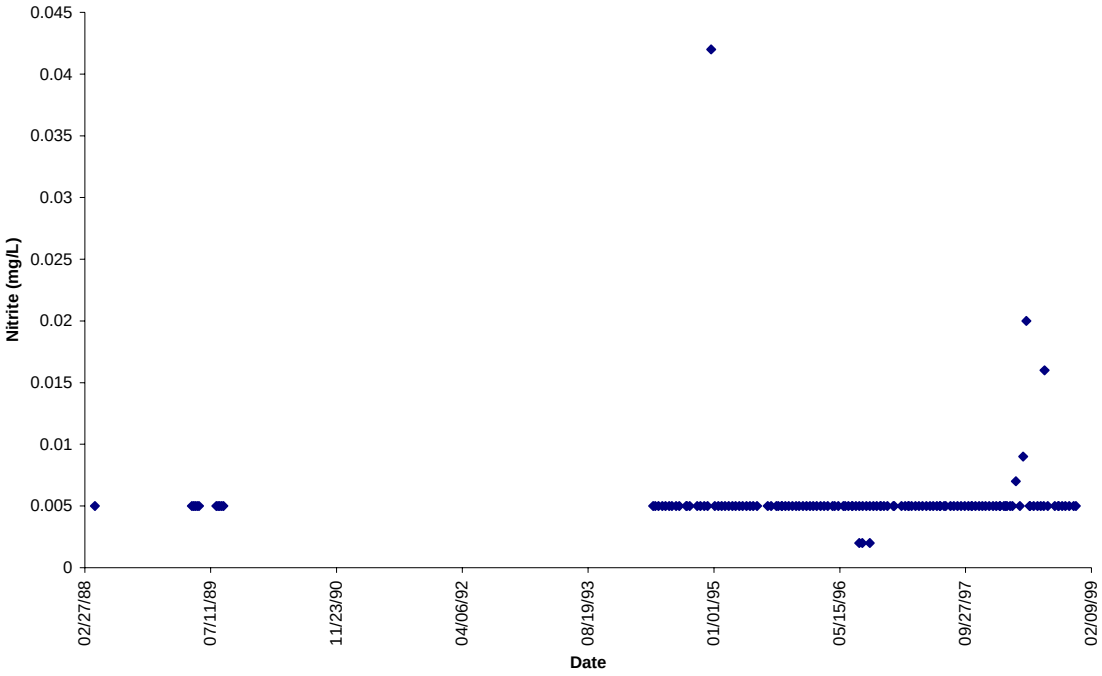

Figure 34. Salmon River Near Salmon Arm, B.C. - Nitrogen

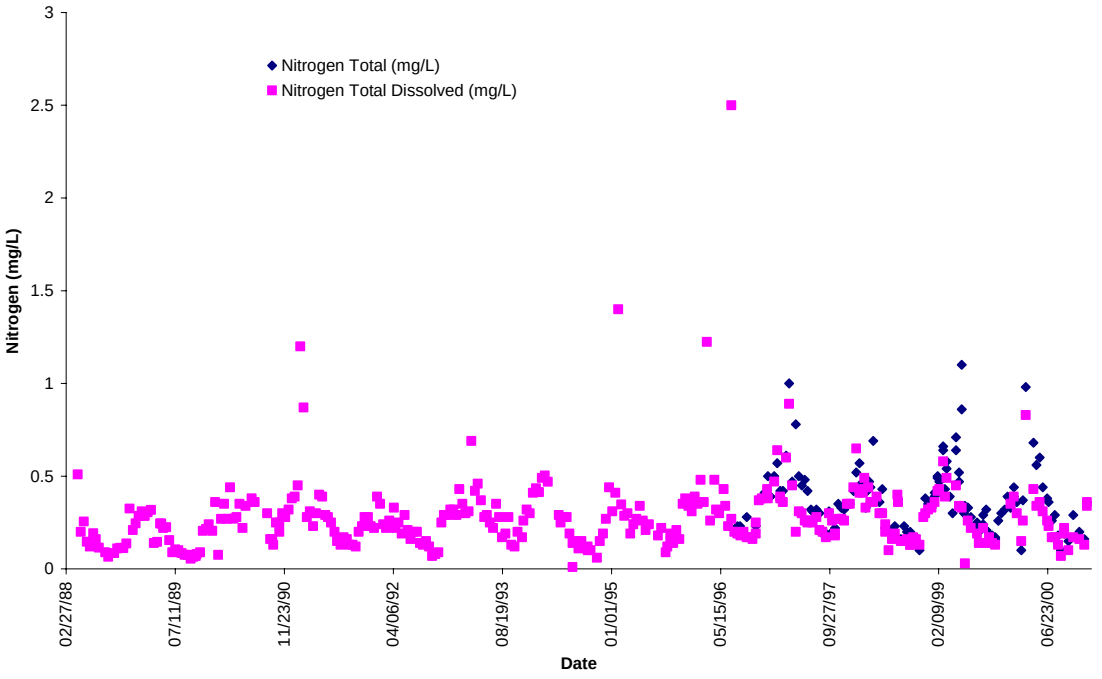

Figure 35. Salmon River Near Hyder, Salmon Arm, B.C., Kjeldahl

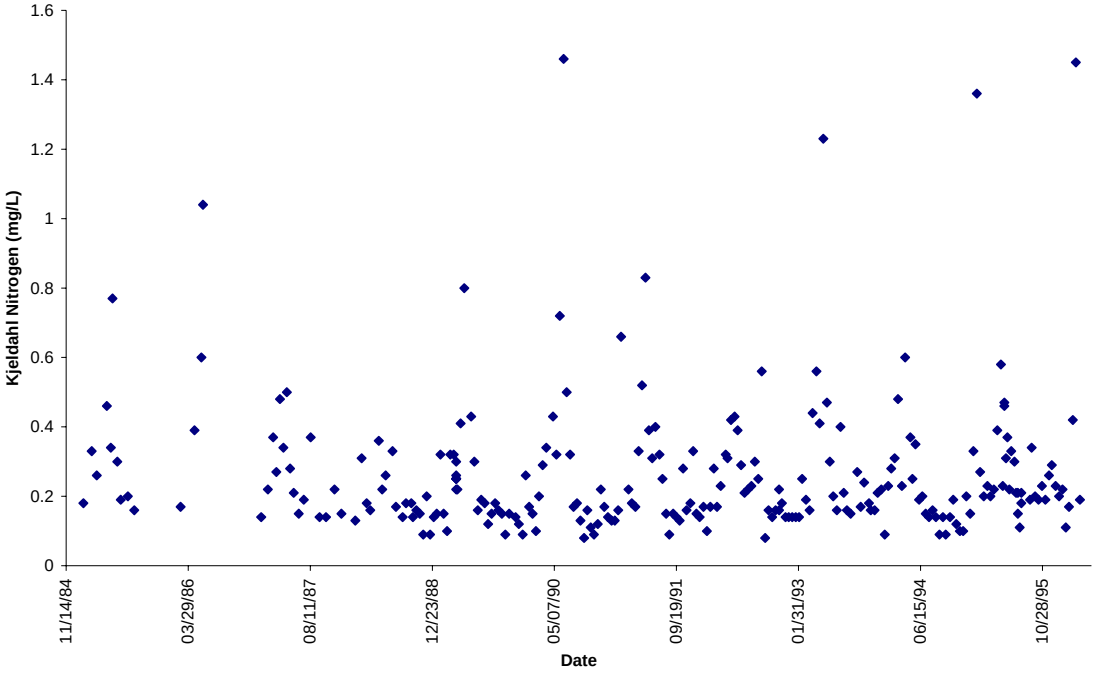

Figure 36. Salmon River Near Salmon Arm, B.C. - Oxygen, Dissolved

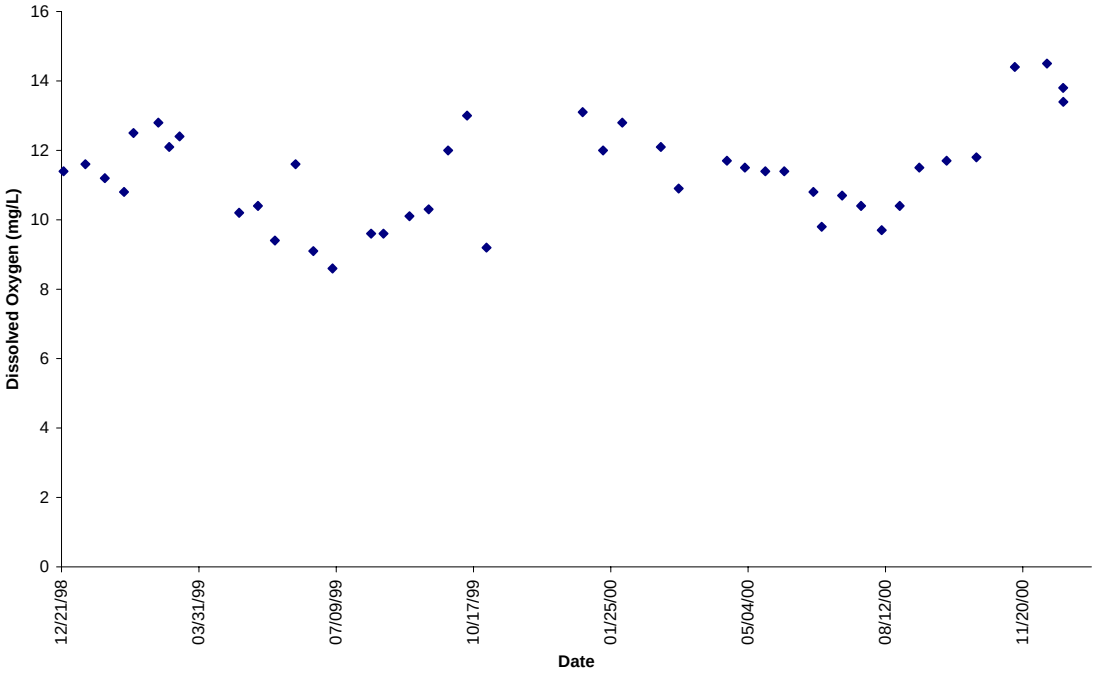

Figure 37. Salmon River Near Salmon Arm, B.C. - pH

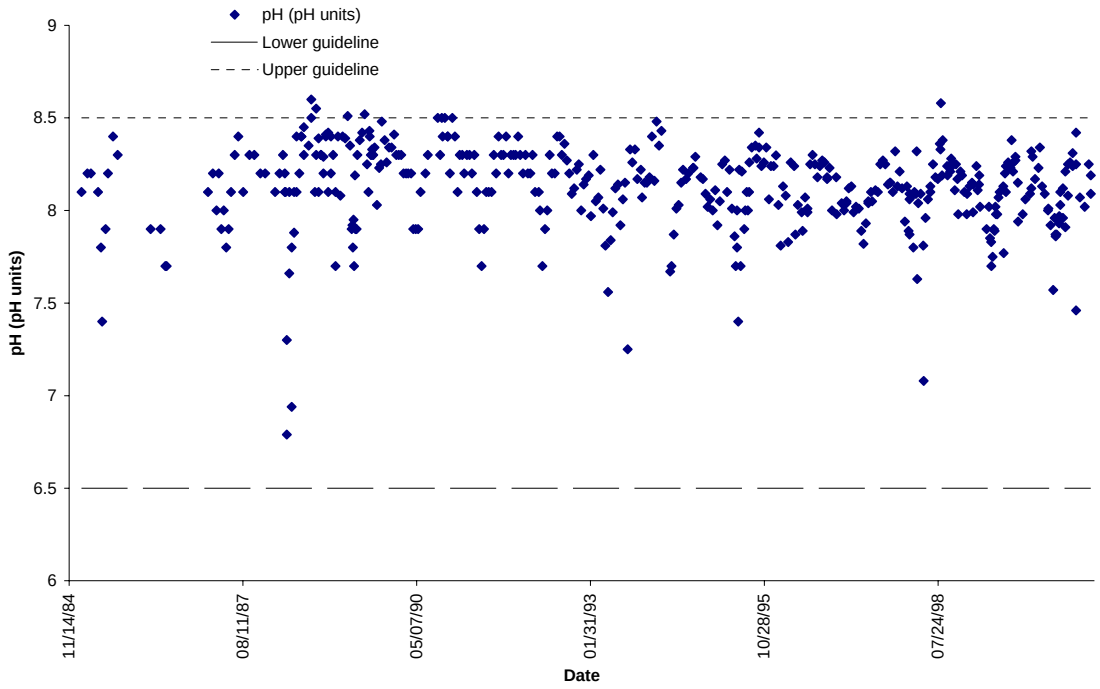

Figure 38. Salmon River Near Salmon Arm, B.C. - Phosphorus, Dissolved

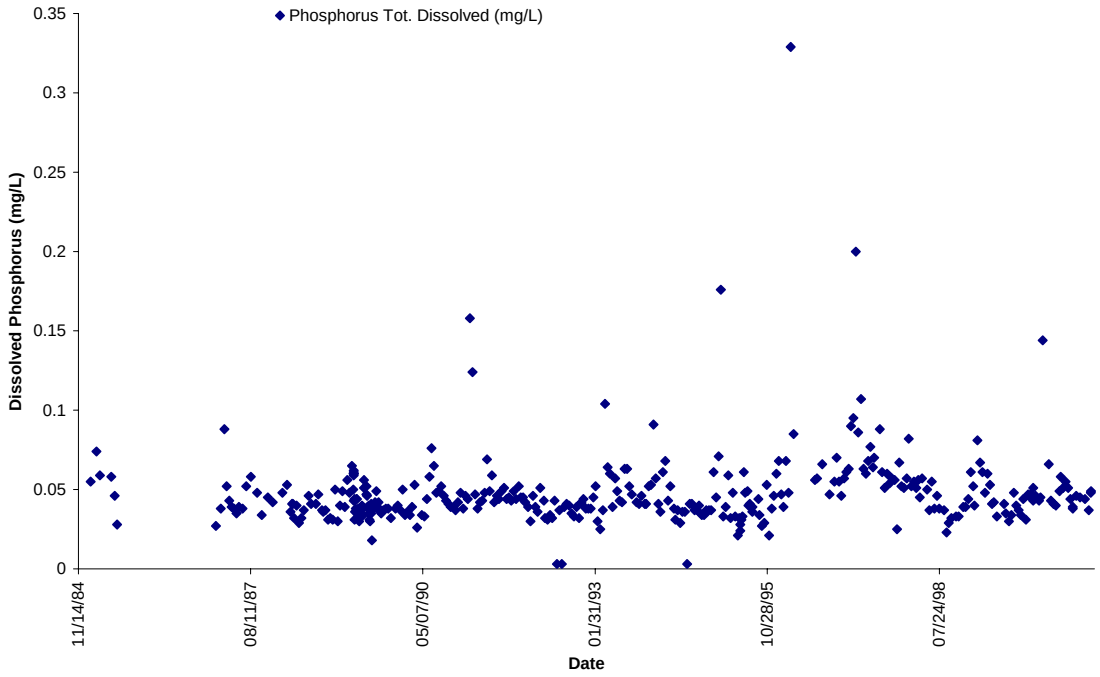

Figure 39. Salmon River Near Salmon Arm, B.C. - Phosphorus, Total

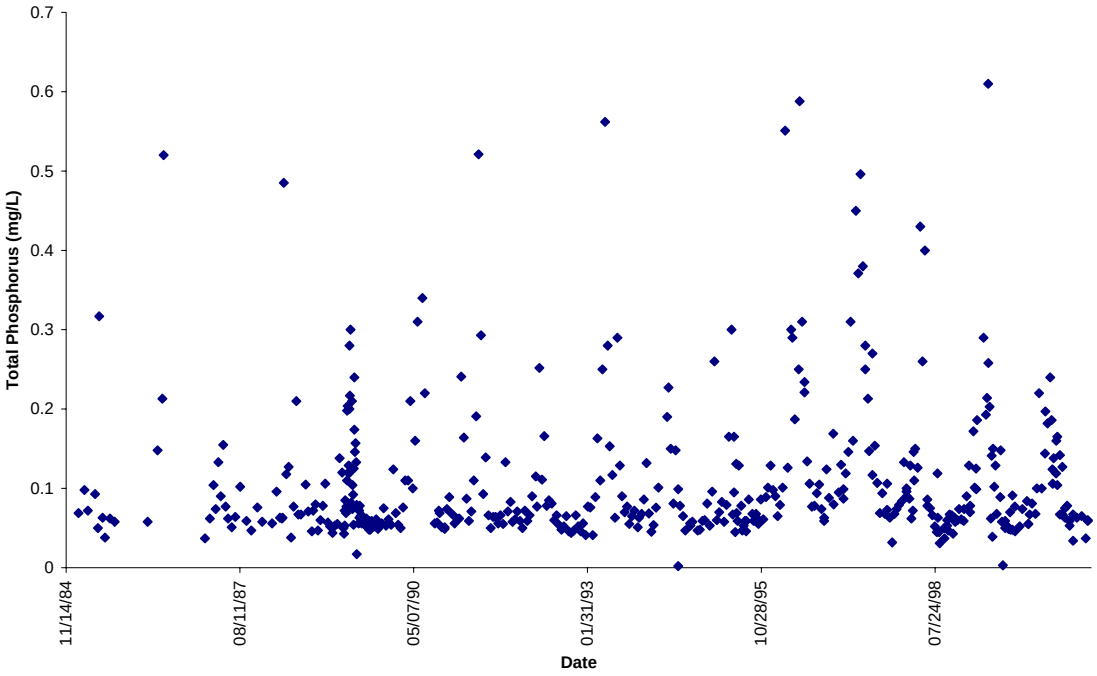

Figure 40. Salmon River Near Salmon Arm, B.C. - Phosphorus, Ortho-

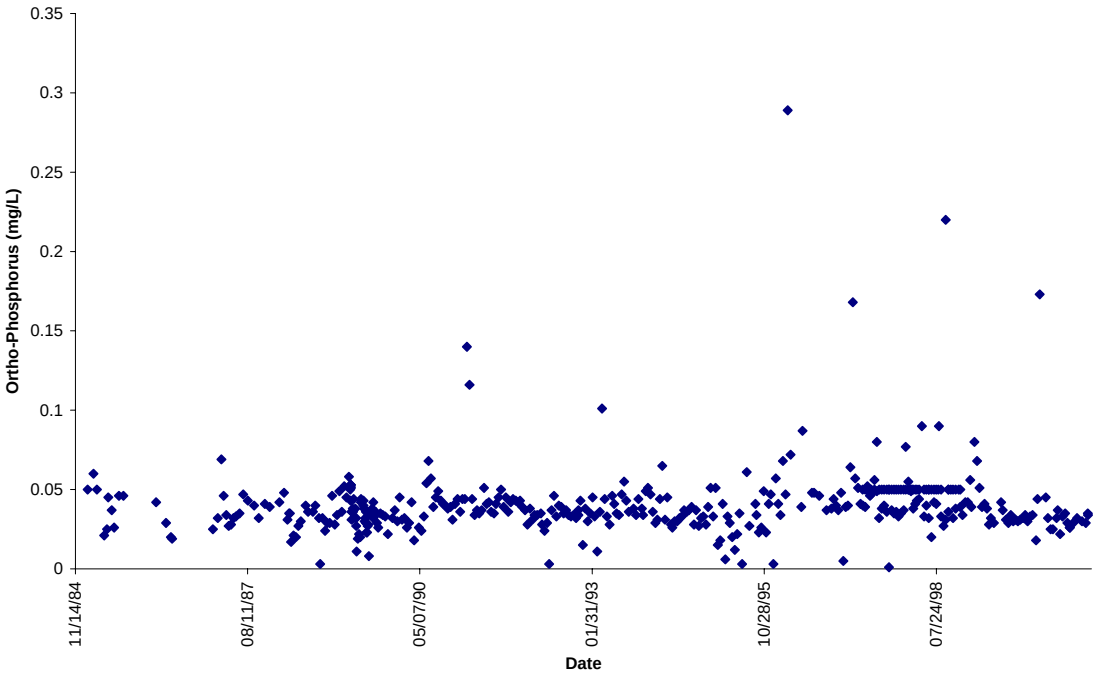

Figure 41. Salmon River Near Salmon Arm, B.C. - Potassium

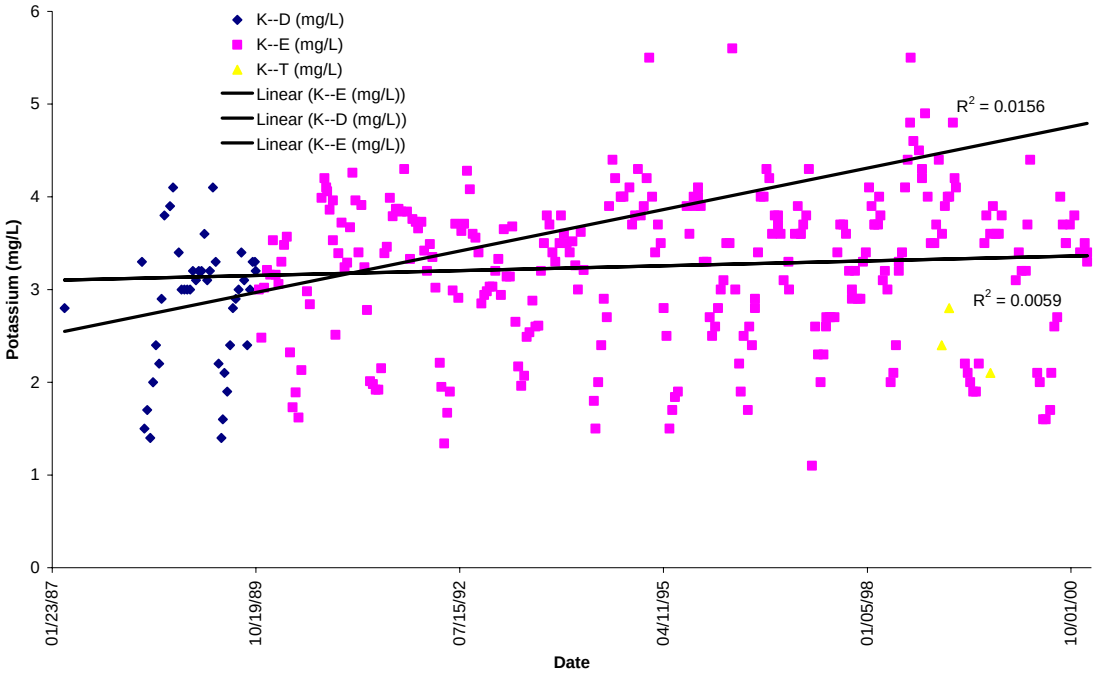

Figure 42. Salmon River Near Salmon Arm, B.C. - Residue, Filterable

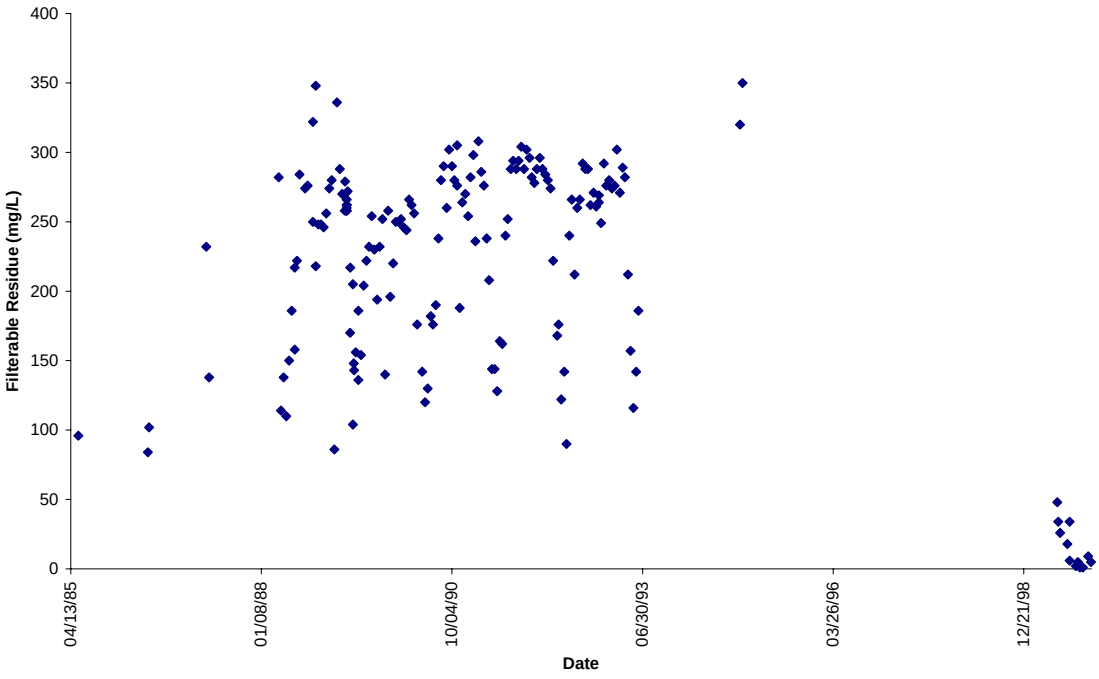

Figure 43. Salmon River Near Salmon Arm, B.C. - Residue, Non-Filterable

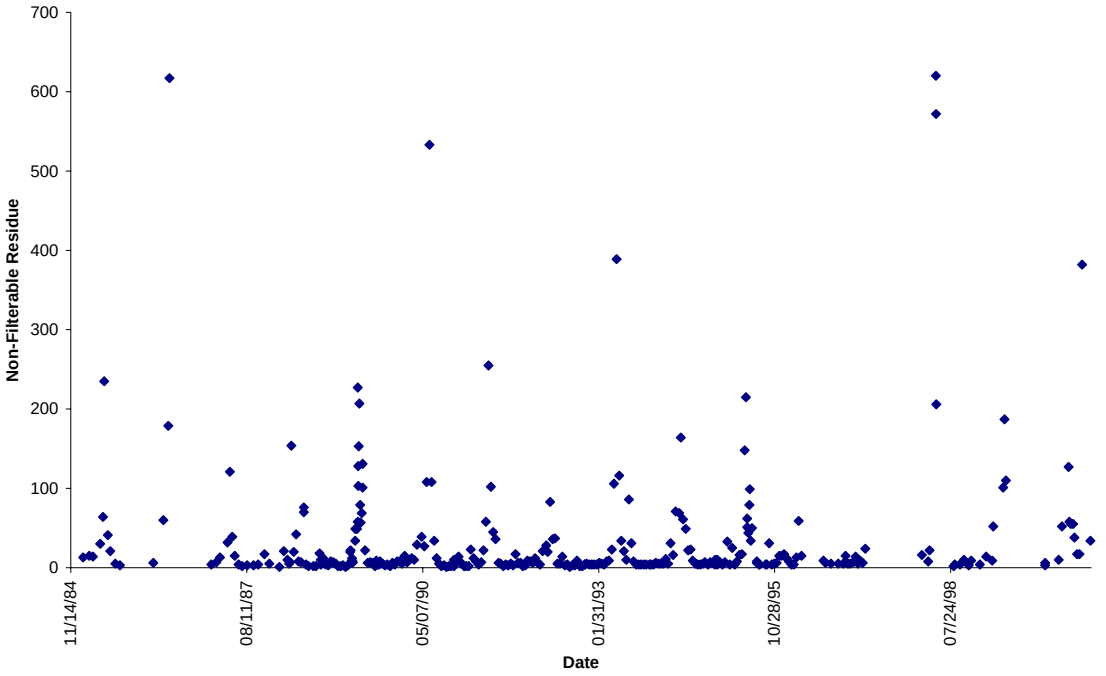

Figure 44. Salmon River Near Salmon Arm, B.C. - Selenium

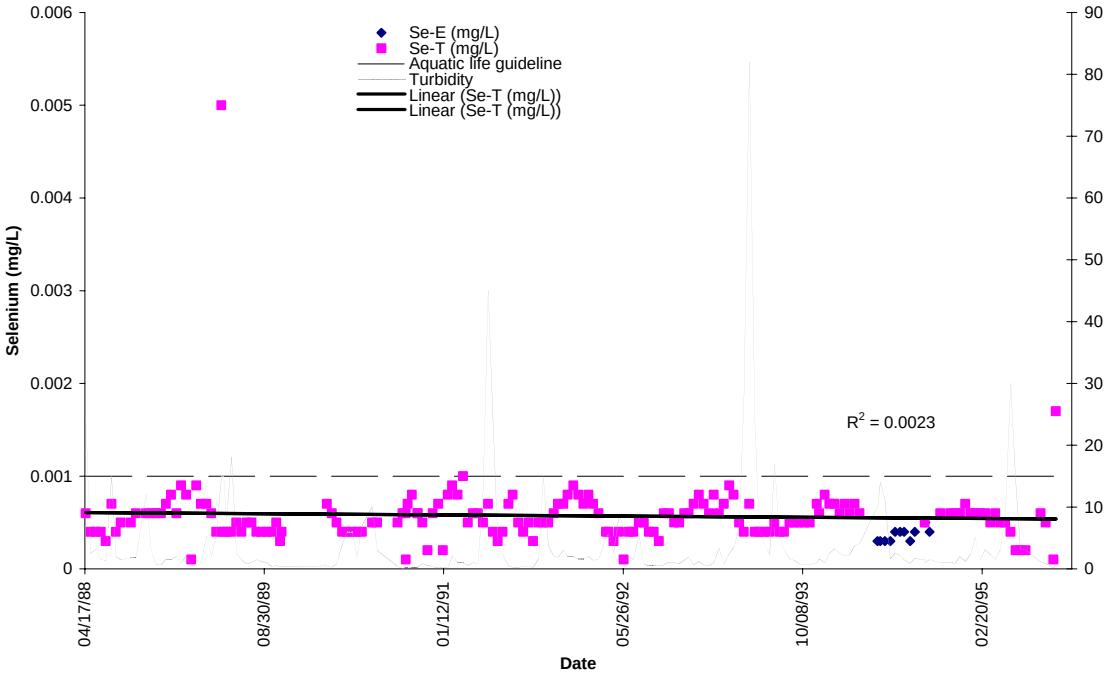

Figure 45. Salmon River Near Salmon Arm, B.C. - Silver

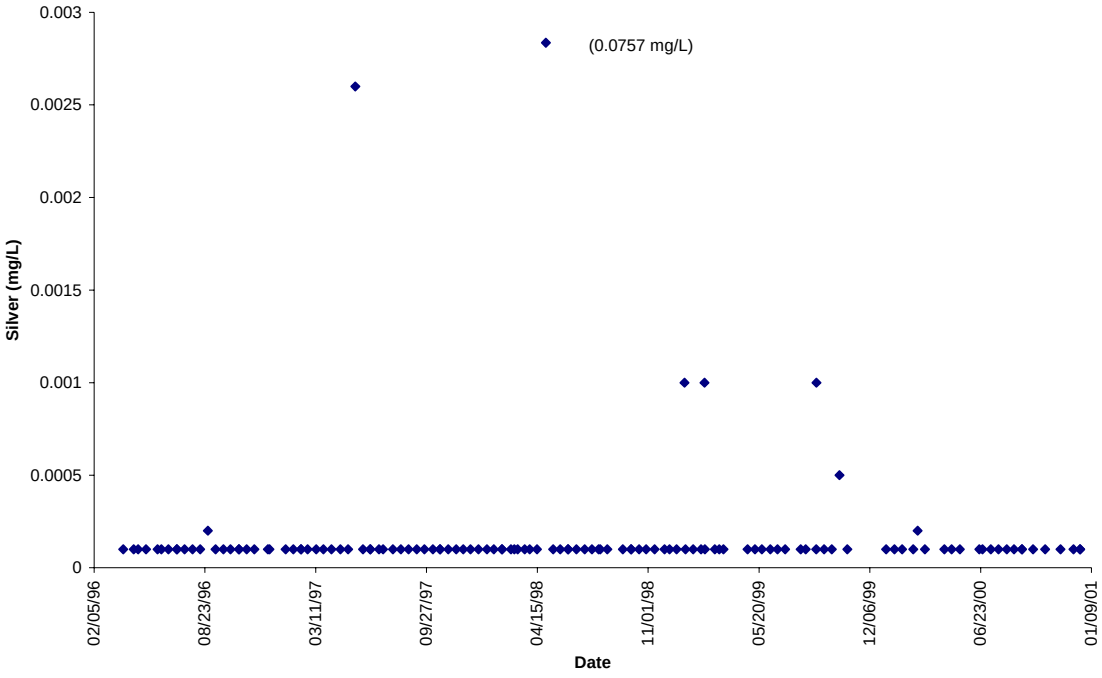

Figure 46. Salmon River Near Salmon Arm, B.C. - Sodium

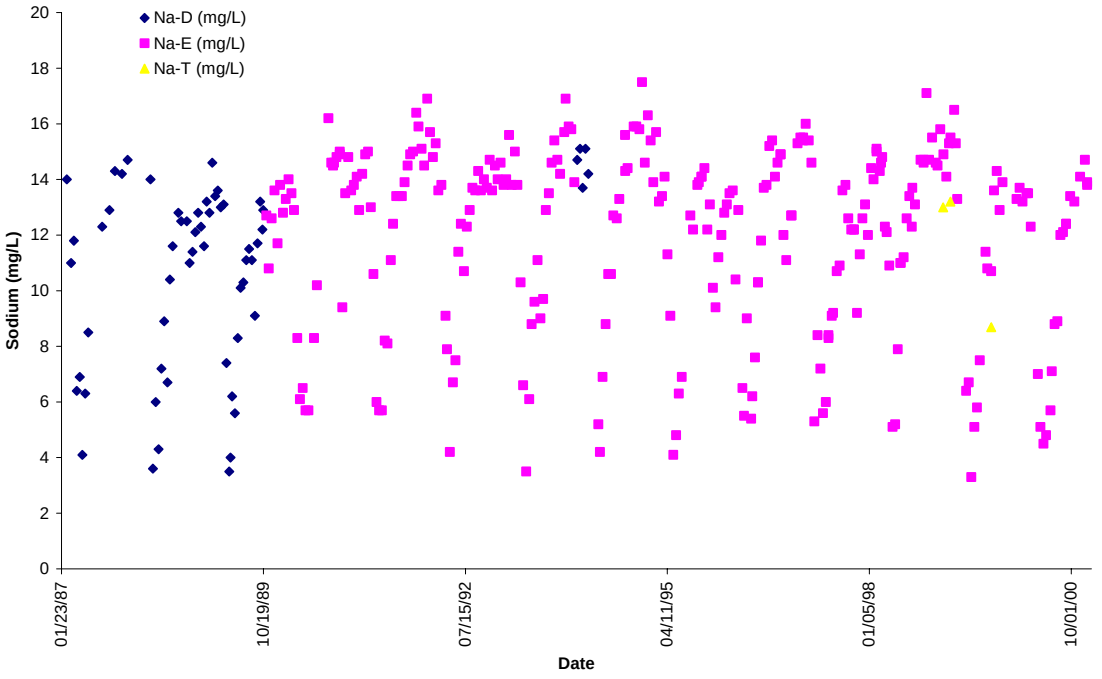

Figure 47. Salmon River Near Salmon Arm, B.C. - Sulphate

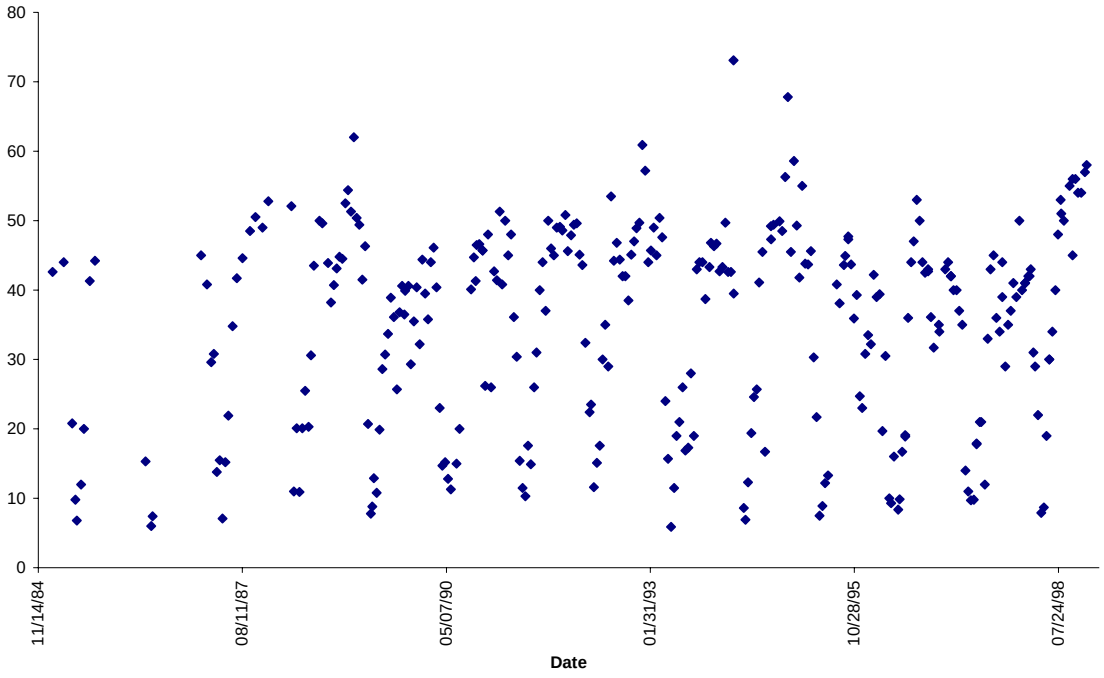

Figure 48. Salmon River Near Salmon Arm, B.C. - Temperature

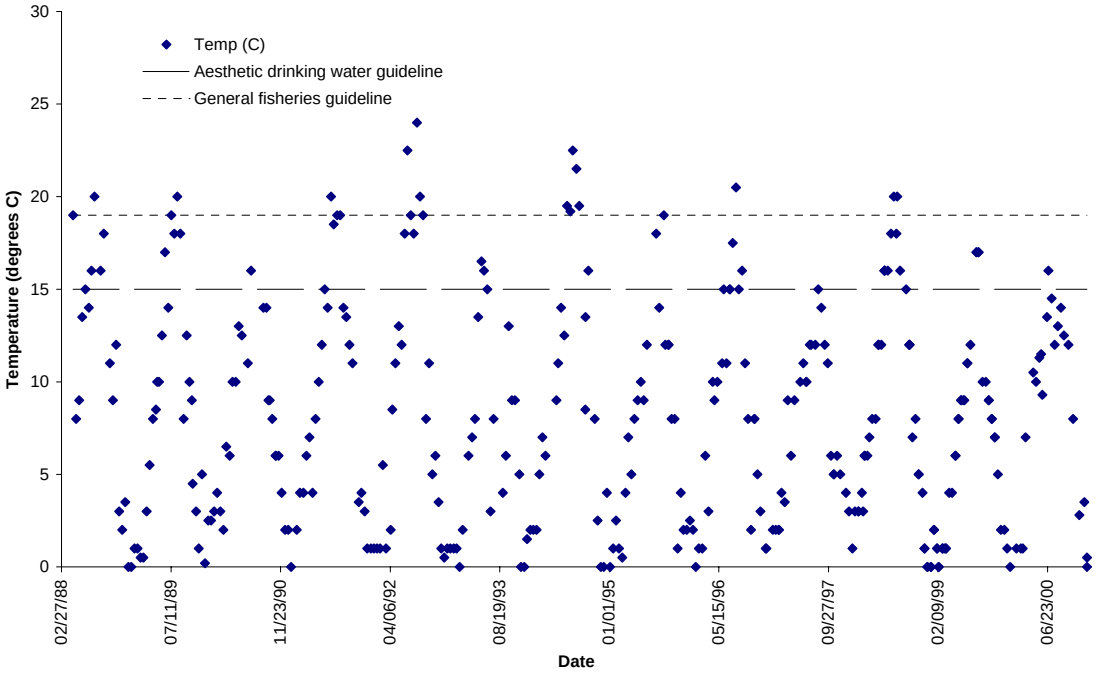

Figure 49. Salmon River Near Salmon Arm, B.C. - Turbidity

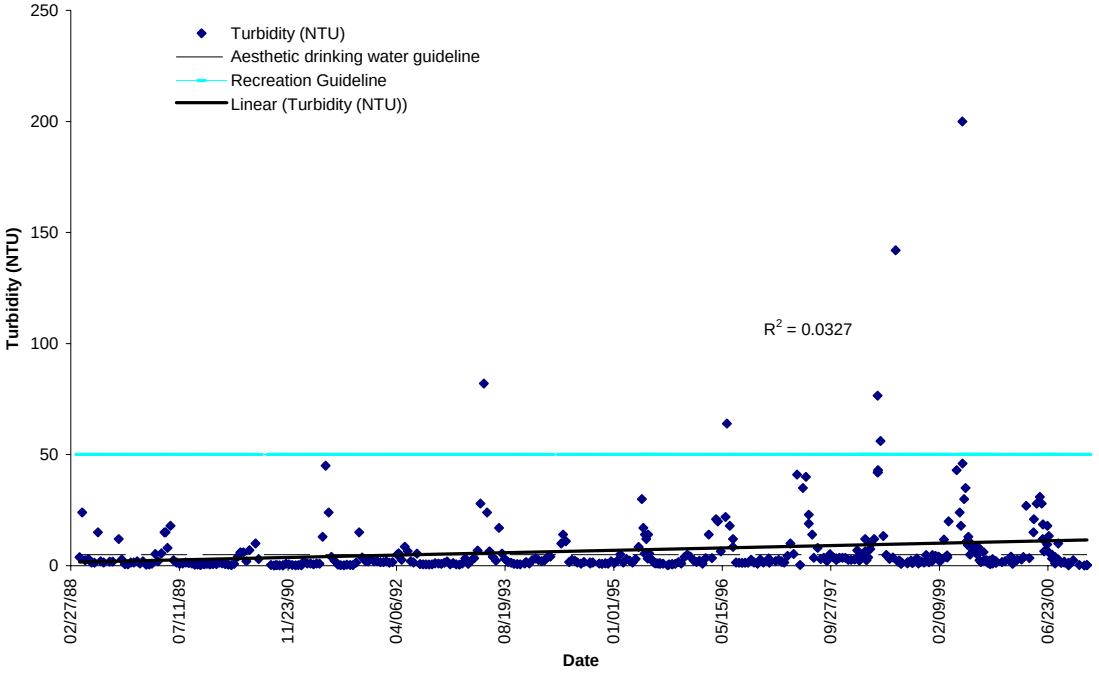

Figure 50. Salmon River Near Salmon Arm, B.C. - Vanadium

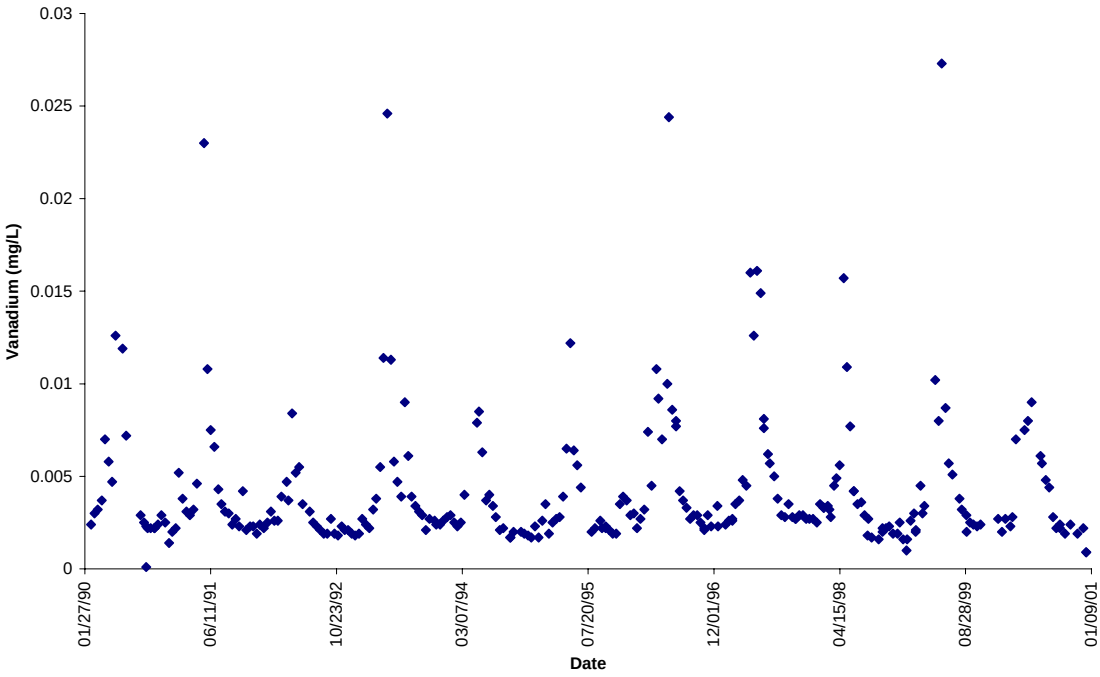

Figure 51. Salmon River Near Salmon Arm, B.C. - Zinc