State of Water Quality of Columbia River at Revelstoke 1984-1995

Water Quality Section
Water Management Branch
Environment and Resource Management Department
Ministry of Environment, Lands and Parks

Aquatic Sciences Section
Environmental Conservation Branch
Environment Canada
Pacific and Yukon Region

September, 1999

Canadian Cataloguing in Publication Data
Holms, G. B.
State of water quality of Columbia River at Revelstoke, 1984-1995

At head of title: Canada-British Columbia Water Quality Monitoring Agreement.
Author: Holms, G.B. Cf. p.
Co-published by Province of British Columbia, Ministry of Environment, Lands and Parks.
Includes bibliographical references: p.
ISBN 0-7726-2994-3

1. Water quality - Columbia River. 2. Water quality - British Columbia - Revelstoke Region. 3. Water - Pollution - Columbia River. 4. Water - Pollution - British Columbia - Revelstoke Region. I. Canada. Environment Canada. II. British Columbia. Ministry of Environment, Lands and Parks. III. Canada-British Columbia Quality Monitoring Agreement. IV. Title.

TD227.B7H65 1999 363.73'942'0971168 C96-960272-3

Authors

Holms, G. B. Water Quality Section,

Water Management Branch,
Environment and Resource Management Department,
Ministry of Environment, Lands and Parks,
Victoria. B.C.

Contributors

Beatty, J. Pollution Prevention,

Ministry of Environment, Lands and Parks,
Nelson, B.C.

Boettger, B. Environmental Health Programs,

Public Health Protection Branch,
Ministry of Health
Victoria. B.C.

Butcher, G. Water Quality Section,

Water Management Branch,
Environment and Resource Management Department,
Ministry of Environment, Lands and Parks,
Victoria. B.C.

Miller, G. Water Quality Sample Collector for the Columbia River
at Revelstoke. Revelstoke, B.C.

McDonald, L. Pollution Prevention,

Ministry of Environment, Lands and Parks,
Cranbrook, B.C.

Pommen, L.W. Water Quality Section,

Water Management Branch,
Environment and Resource Management Department,
Ministry of Environment, Lands and Parks,
Victoria. B.C.

Ryan, A. Aquatic & Atmospheric Sciences Division,

Pacific and Yukon Region,
Environment Canada,
Vancouver, B.C.

Shaw, P. Aquatic & Atmospheric Sciences Division,

Pacific and Yukon Region,
Environment Canada,
Vancouver. B.C.

Executive Summary

The City of Revelstoke and surrounding regions are located in the interior of eastern British Columbia, approximately 220 km north from the Canadian - American international boundary. The drainage area for the Columbia River at Revelstoke is approximately 26,700 km^2 (Figures 1 and 2). The Mica and Revelstoke dams have a substantial effect on the water quantity and quality in this section of the river. The water uses for Columbia River water at Revelstoke are: irrigation, livestock watering, primary-contact recreation (i.e., swimming), drinking water, industry, wildlife, and aquatic life.

We concluded that:

· There was a declining trend in total phosphorus, probably due to the trapping effect of upstream dams and reservoirs.

· The river had a low sensitivity to acid inputs.

· Water hardness was lower than the optimum range for drinking water, but was still quite acceptable.

· Iron and manganese values that exceeded aquatic life and drinking water guidelines were probably in a particulate form and not biologically available, and would be removed by the drinking water treatment needed to remove turbidity.

· Turbidity values were lower than other natural rivers in the Kootenay area during freshet because of settling in the Kinbasket Lake and Lake Revelstoke reservoirs.

· Columbia River water at Revelstoke must be treated to remove turbidity and disinfected prior to drinking.

· One selenium value exceeded the maximum guideline for aquatic life in 1995. This value was collected in a sample with low suspended sediments (non-filterable residues or turbidity), indicating that the selenium was not in a particulate form, and may have been biologically available. The Bethlehem Resources Corporation's zinc mine in the Goldstream River Valley (now closed) may have been a source of the selenium.

· Water temperature met the guidelines for aquatic life and drinking water aesthetics, but was too cold for water-contact recreation (e.g., swimming).

· One zinc value exceeded the maximum guideline for aquatic life (algae) in 1991. This value was collected in a sample with low suspended sediments (non-filterable residues or turbidity), indicating that the zinc was not in a particulate form, and may have been biologically available.

We recommend that routine monitoring be discontinued on the Columbia River at Revelstoke with the exception of total phosphorus to track the trends in phosphorus input to the Arrow Lakes.

Figure 1 Columbia River Watershed

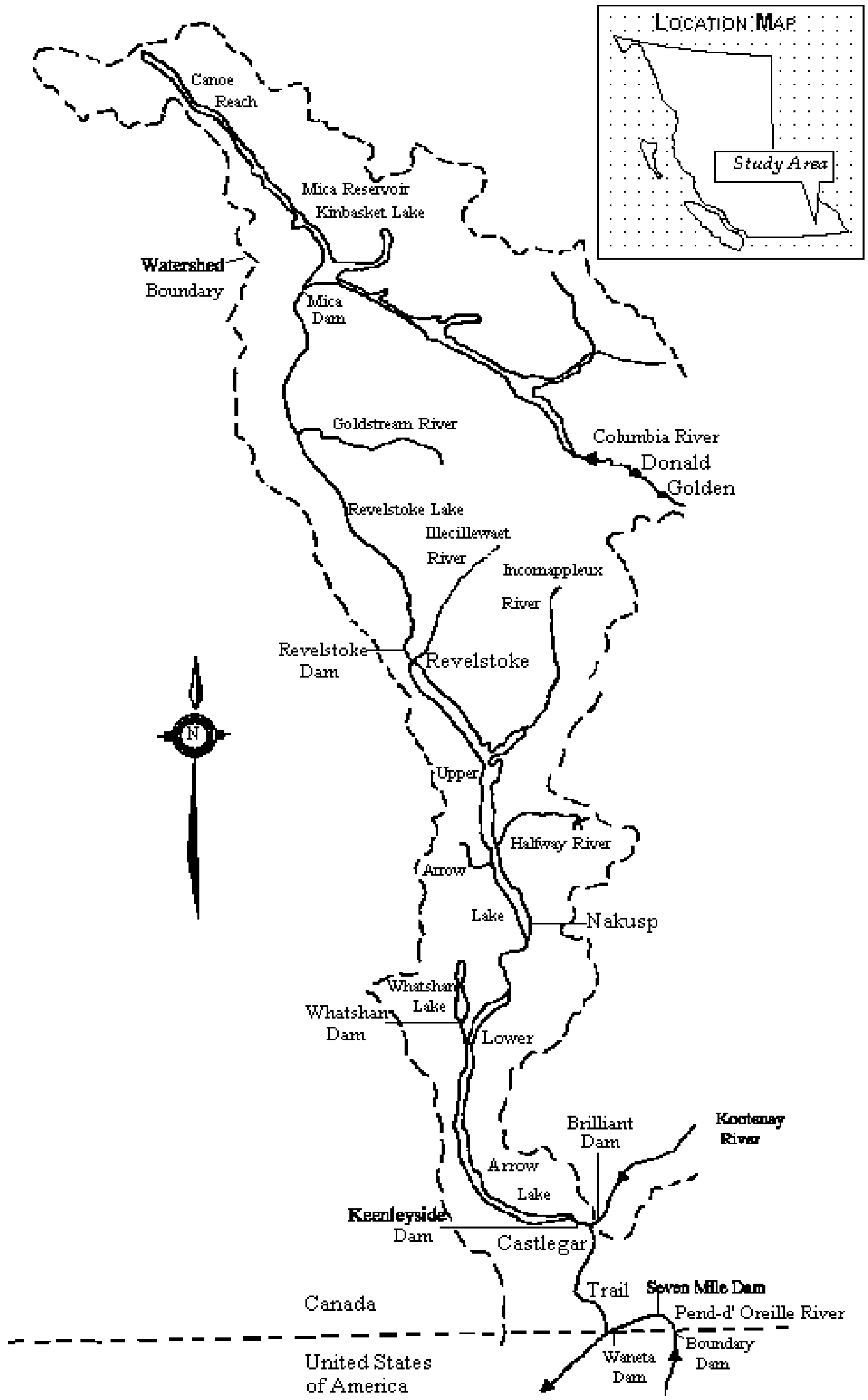
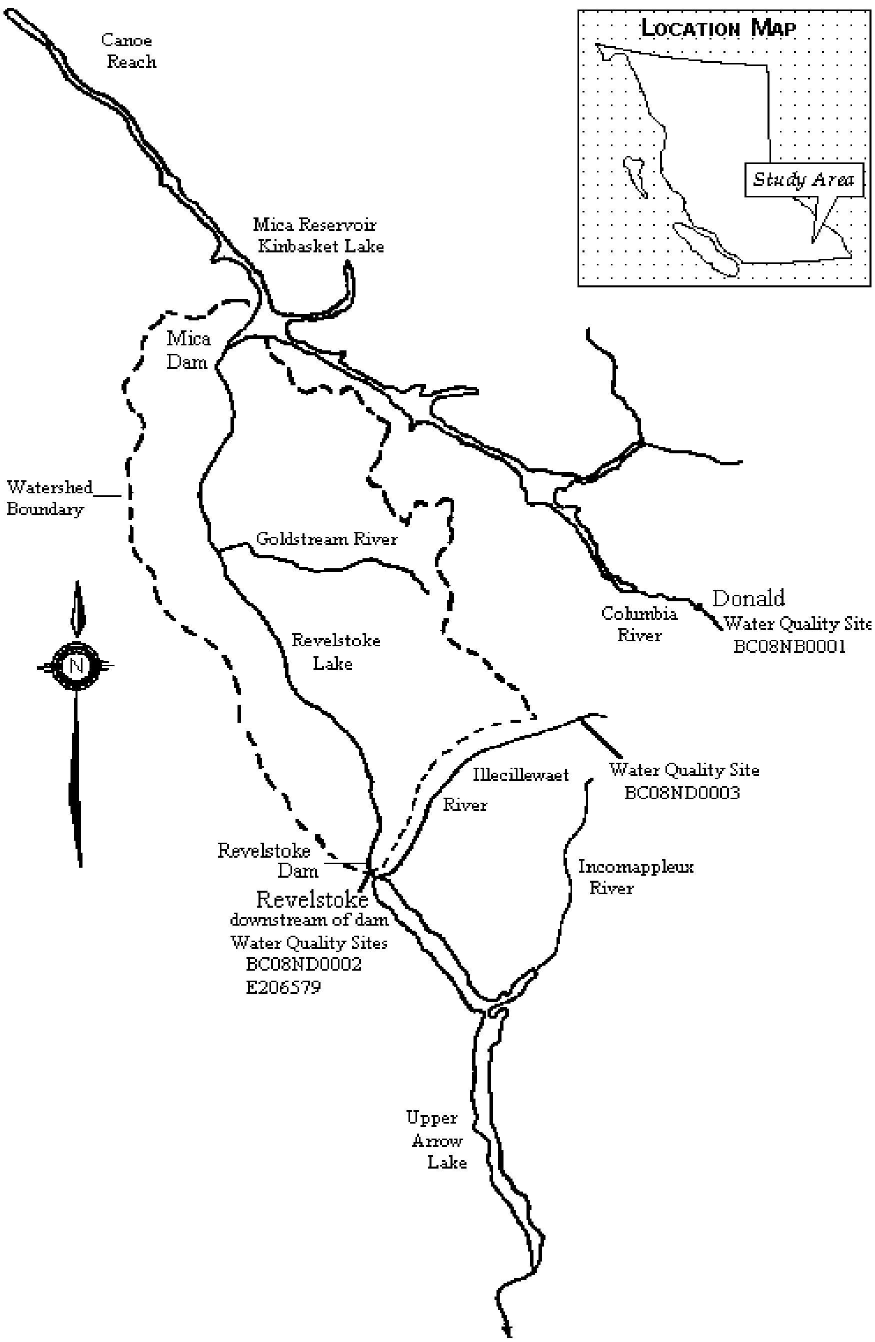


Figure 2 Columbia River at Revelstoke Watershed



Scale: 1 cm : 18 km

Introduction

The City of Revelstoke and surrounding regions are located in the interior of eastern British Columbia, approximately 220 km north from the Canadian - American international boundary. The drainage area for the Columbia River at Revelstoke is approximately 26,700 km^2 (Figure 1).

The Revelstoke Dam, located five km upstream from the City, was completed in 1984. The result is a reservoir called Lake Revelstoke and the ability to produce more electrical energy for the province of British Columbia. The Mica Dam is located 130 km north from the Revelstoke Dam, and is the tallest dam in B.C. at 196.6 m. It became operational in 1973 and regulates the majority of the flow into Lake Revelstoke. The drainage area for the reservoir (Kinbasket Lake - volume of 24,423,000 m^3) behind Mica Dam is approximately 21,000 km^2.

There are no major tributaries to the Columbia River between Mica and Revelstoke dams. Several smaller tributaries and the Goldstream River drain approximately 6,000 km^2, representing 22% of the drainage area of the Columbia River at Revelstoke.

There are three permitted sources of wastewater discharges in the Revelstoke area (Figure 2). These smaller discharges include the City of Revelstoke (PE 2147) and Queen Victoria Hospital (PE 250), which discharge downstream from the water quality site at Revelstoke, and Bethlehem Resources Corporation (PE 6168), which operated a copper/zinc mine and milling facility on the Goldstream River, a tributary of the Columbia River above Revelstoke. There were two permitted discharges within this operation, which discharged to a settling pond and a ground water collection system. The permit limited the discharge of dissolved cadmium (0.01 mg/L), dissolved copper (0.05 mg/L), dissolved iron (0.30 mg/L), dissolved lead (0.05 mg/L), dissolved zinc (0.20 mg/L), and total suspended solids (25 mg/L). The mine was closed in January 1996 (McDonald, 1996).

This report assesses nine years of data from the Ministry of Environment, Lands and Parks (1987-95) and twelve years of Environment Canada data (1984-95). The provincial EMS station number is E206579 and the federal ENVIRODAT site number is BC08ND0002 (Figure 2). Water quality data are plotted in Figures 3 to 49.

Quality Assurance

The water quality graphs were inspected and erroneous values were removed. Metals such as chromium, copper, lead and zinc had high values between 1986 and 1991. This contamination was caused by the breakdown of preservation vial liners and lids. Environment Canada reported low pH values between 1986 and 1988 due to laboratory problems. Mercury data were not included in the report because all detectable values are believed to result from contamination during the collection and measurement process (Pommen, 1994). Quality assurance issues are expanded upon in the next section.

State of the Water Quality

The state of the water quality was judged by comparing values to Ministry of Environment, Lands and Parks' Approved and Working Criteria for Water Quality (Nagpal *et al.*, 1997). Site-specific water quality objectives have not been set for the Columbia River upstream from the Keenleyside Dam.

MacLeod and Whitfield (1996) analyzed six years (1986-91) of water quality data from the Columbia River at Revelstoke to determine the processes controlling water quality and the presence of environmentally significant trends. No trends over time were found for water quality variables. However, upstream reservoirs had altered the natural seasonal patterns for most water quality indicators, and had removed the normal relationship between flow and sediment-related water quality indicators (e.g., total metals).

Variables plotted but not discussed below showed no clear trends over time and met all criteria. These variables are:

total arsenic, total barium, total beryllium, dissolved chloride, total chromium, dissolved fluoride, hardness, total lead, total lithium, magnesium, total molybdenum, total nickel, ammonia-N, nitrogen (nitrate/nitrite), total dissolved nitrogen, pH, total dissolved phosphorus, potassium, filterable residue, silica, sodium, specific conductivity, total strontium, dissolved sulphate, water temperature, and total vanadium.

Variables which exceeded criteria, exhibited trends over time, or were significant in some regard were:

Total alkalinity (Figure 3) and **calcium** (Figure 9) show that the river had a low sensitivity to acid inputs (the river was well buffered). Lower values were reported in July and August.

Total aluminum (Figure 4) values were collected between 1990 and 1996. One value exceeded the aesthetic criterion (0.2 mg/L) for drinking water in 1995. At least 89% of the values met the maximum criterion (0.1 mg/L dissolved) for aquatic life, and at least 48% of the values met the average criterion (0.05 mg/L dissolved) for aquatic life. However, total aluminum values are not directly comparable to dissolved criteria because dissolved aluminum values in the water column are much lower than total aluminum. Dissolved aluminum should be measured in any future monitoring to provide a direct comparison to the criteria.

Total cadmium (Figure 8) values were high between 1986 and 1991 due to preservative vial contamination. Since that time, all total cadmium values were less than the minimum detectable limit (0.0001 mg/L). The minimum detectable limits for cadmium (0.001 and 0.0001 mg/L) were 3 to 33 times above the aquatic life criterion (0.00003 mg/L). To compare the cadmium levels to criteria for aquatic life more effectively, the minimum detectable limit should be lowered to at most one-tenth of the criterion value, and dissolved cadmium should also be measured if high total cadmium values are found.

Total chromium (Figure 11) values were high due to suspected preservative vial contamination between 1986 and 1991. Since that time, all values met the aquatic life criterion (0.02 mg/L) for fish and the drinking water criterion (0.05 mg /L). Three values exceeded the criterion (0.002 mg/L) for plankton. Suspended sediments (non-filterable residues or turbidity) were low on these occasions, indicating that the chromium may have been biologically available. Total chromium values in excess of the 0.002 mg/L criterion have been observed at many of the Canada-B.C. water quality monitoring stations throughout the province. These occurrences may have been natural phenomena or due to network-wide artificial contamination (Pommen, 1996).

Total cobalt (Figure 12) exceeded the aquatic life criterion (0.0009 mg/L) in one sample collected in April, 1990. This sample had an elevated non-filterable residue value (55 mg/L), indicating that the cobalt was in a particulate form and probably not biologically available. Since 1990, all values have been near or below the detection limit of 0.0001 mg/L.

Total copper (Figure 14) had high values due to preservative vial contamination between 1986 and 1991. Since that time, two values exceeded the average criteria to protect aquatic life (0.002 mg/L to 0.003 mg/L, depending on hardness values) in 1991. The criteria levels have not been exceeded since then. However, these values were collected less frequently (less than five samples in 30 days) than required to evaluate the attainment of the criteria rigorously. There was no apparent relationship between copper and suspended sediments (non-filterable residues or turbidity) in samples collected after the period of vial contamination (Figure 15), suggesting that copper was not associated with particulate matter and may have been biologically available.

Hardness (Figure 17) values were lower than the optimum range (80 -100 mg/L) for drinking water at the Revelstoke site, but were still quite acceptable.

Total iron (Figure 18) values exceeded the 5 mg/L irrigation criterion on one occasion and the 0.3 mg/L drinking water (aesthetics) and aquatic life criterion in 8% of the samples between 1984 and 1996. Higher iron and non-filterable residue values occurred together (Figure 19), indicating that the iron was in a particulate form and probably not biologically available. Also, high iron values would be reduced by drinking water treatment to remove turbidity.

Total lead (Figure 20) had high values due to preservative vial contamination between 1986 and 1991. Since that time, all total lead values met the 30-day average criteria to protect aquatic life (0.004-0.006 mg/L).

Total manganese (Figure 24) exceeded the criterion for aquatic life (0.1 mg/L) once and two values exceeded the aesthetic criterion for drinking water (0.05 mg/L). High manganese and non-filterable residues or turbidity were reported in these samples collected in 1989 and 1990, indicating that the manganese was in a particulate form and probably not biologically available. Also, high manganese values would be reduced by drinking water treatment needed to remove turbidity. Annual average total manganese values decreased between 1986 and 1995 due to two factors:
· detection limits were lowered from 0.01 mg/L to 0.001 mg/L in 1986, and
· higher manganese values in 1989 and 1990 due to higher non-filterable residues or turbidity.
Consequently, the apparent decrease is deemed to be a measurement artifact, rather than an environmentally significant trend.

Dissolved Ortho-phosphorus (Figure 33) values were less than the minimum detectable limit (0.003 mg/L) before 1992. Since that time, 15% of the values were greater than the minimum detectable limit.

Total phosphorus (Figure 34) data were examined for trends using statistical methods due to concerns that upstream dams and reservoirs were reducing phosphorus input to the Arrow Lakes. Non-parametric tests indicated that there was strong evidence of a linearly decreasing trend in total phosphorus concentration data for 1986-96 (Regnier, 1998). B.C. Ministry of Environment Kootenay Region Fisheries has recommended beginning phosphorus fertilization in the Upper Arrow Lake Reservoir in the spring of 1999 (Columbia Basin Fish & Wildlife Compensation Program, 1999).

Non-filterable residue (Figure 37) values were greater than the minimum detectable limits (1 mg/L and 4 mg/L) in 14% of the samples collected between 1987 and 1995. Two values exceeded the criterion (25 mg/L) for good fisheries. The values were lower than would be expected for an unregulated river due to the settling out of non-filterable residues in Kinbasket Lake and Lake Revelstoke reservoirs upstream from the sample site.

Total selenium (Figure 38) values were greater than the minimum detectable limit (0.0001 mg/L) in 11% of the samples collected between 1984 and 1995. One value in 1995 slightly exceeded the maximum criterion (0.001 mg/L) for aquatic life. The low non-filterable residues and turbidity values for this sample indicate that the selenium was not in a particulate form and may have been biologically available. Bethlehem Resources Corporation's zinc mine in the Goldstream River Valley, which closed in January 1996, may have been a source of the elevated selenium. The mine was discharging selenium to the Goldstream River in 1995-96, resulting in levels of up to 0.01 mg/L in the Goldstream River (McDonald, 1996), and given the dilution for the Goldstream River in the Columbia River (about 22:1), it could have contributed significantly to the levels at Revelstoke.

Water temperature (Figure 46) values met the drinking water (aesthetics) criterion (15 °C) and the maximum criteria (22-24 ^{0}C) for adult and juvenile salmonids. All values were less than the optimum range (15-35 ^{0}C) for recreational use (swimming) between 1983 and 1995, and thus the water at this site was too cold for swimming.

Turbidity (Figure 47) values exceeded the 5 NTU aesthetics objective for drinking water (with disinfection only) in one sample collected in May 1989. The health-based drinking water criterion (1 NTU) was exceeded 29% of the time. Turbidity values were lower than in other natural rivers in the Kootenay area during freshet because of settling in the Kinbasket Lake and Lake Revelstoke reservoirs. The turbidity levels in the Columbia River water at Revelstoke are such that treatment processes to remove it are required prior to drinking.

Total zinc (Figure 49) had high values due to preservative vial contamination between 1986 and 1991. Since that time, all values met the maximum criterion for aquatic life (0.03 mg/L for fish and invertebrates), while one value in 1991 exceeded the criterion to protect algae (0.015 mg/L). This value was in a sample with low non-filterable residues or turbidity, indicating that the zinc was not in a particulate form, and may have been biologically available (Figure 50). All zinc values have met all criteria since 1991.

Conclusions - State of Water Quality

· There was a declining trend in total phosphorus, probably due to the trapping effect of upstream dams and reservoirs.
· The river had a low sensitivity to acid inputs.
· Water hardness was lower than the optimum range for drinking water, but was still quite acceptable.

· Iron and manganese values that exceeded the aquatic life criterion were probably in a particulate form, not biologically available, and would be removed by the drinking water treatment needed to remove turbidity.
· Turbidity values were lower than other natural rivers in the Kootenay area during freshet because of settling in the Kinbasket Lake and Lake Revelstoke reservoirs.
· Columbia River water at Revelstoke must be treated to remove turbidity and disinfected prior to drinking.
· One selenium value exceeded the maximum criterion for aquatic life in 1995. This value was collected in a sample with low suspended sediments, indicating that the selenium was not in a particulate form, and may have been biologically available. The Bethlehem Resources Corporation's zinc mine in the Goldstream River Valley (now closed) may have been a source of the selenium.
· Water temperature met the criteria for aquatic life and drinking water aesthetics, but was too cold for water-contact recreation(e.g., swimming).
· One zinc value exceeded the maximum criterion for aquatic life (algae) in 1991. This value was collected in a sample with low suspended sediments, indicating that the zinc was not in a particulate form, and may have been biologically available.

Recommendations for Water Quality Management

Remediation

· B.C. Ministry of Environment Kootenay Region Fisheries has recommended beginning phosphorus fertilization in the Upper Arrow Lake Reservoir in the spring of 1999.

Monitoring

We recommend that routine monitoring be discontinued on the Columbia River at Revelstoke with the exception of total phosphorus.

Figure 3 Total Alkalinity

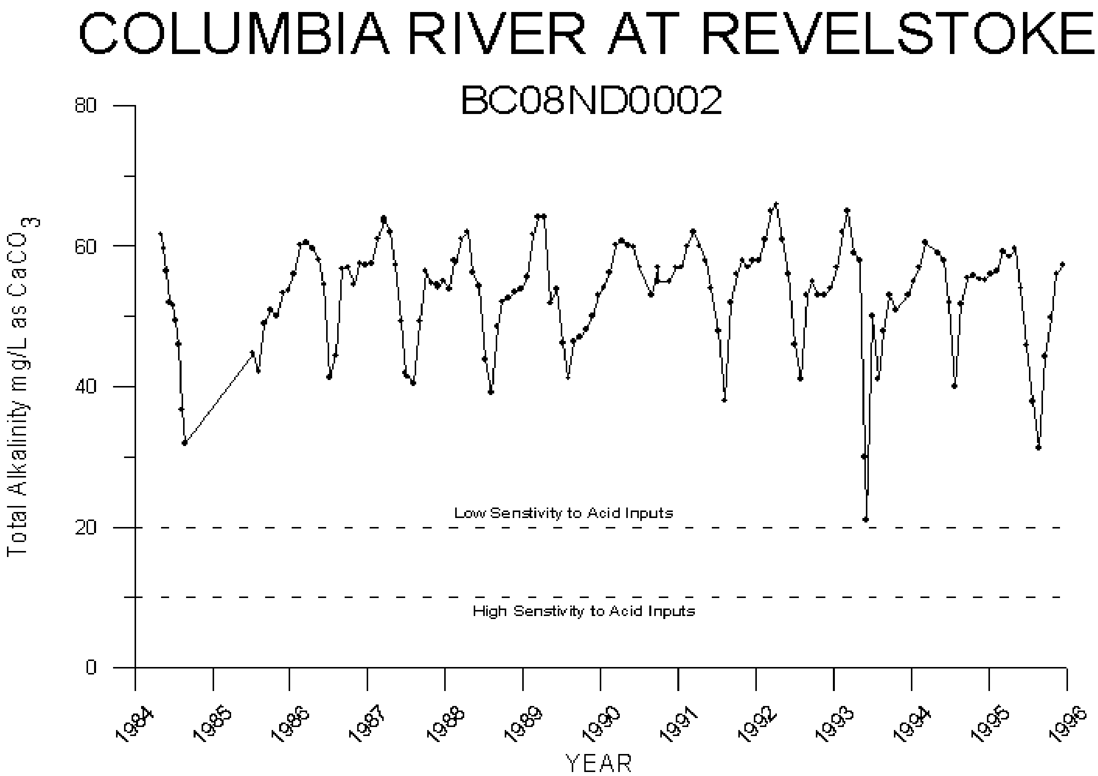


Figure 4 Total Aluminum

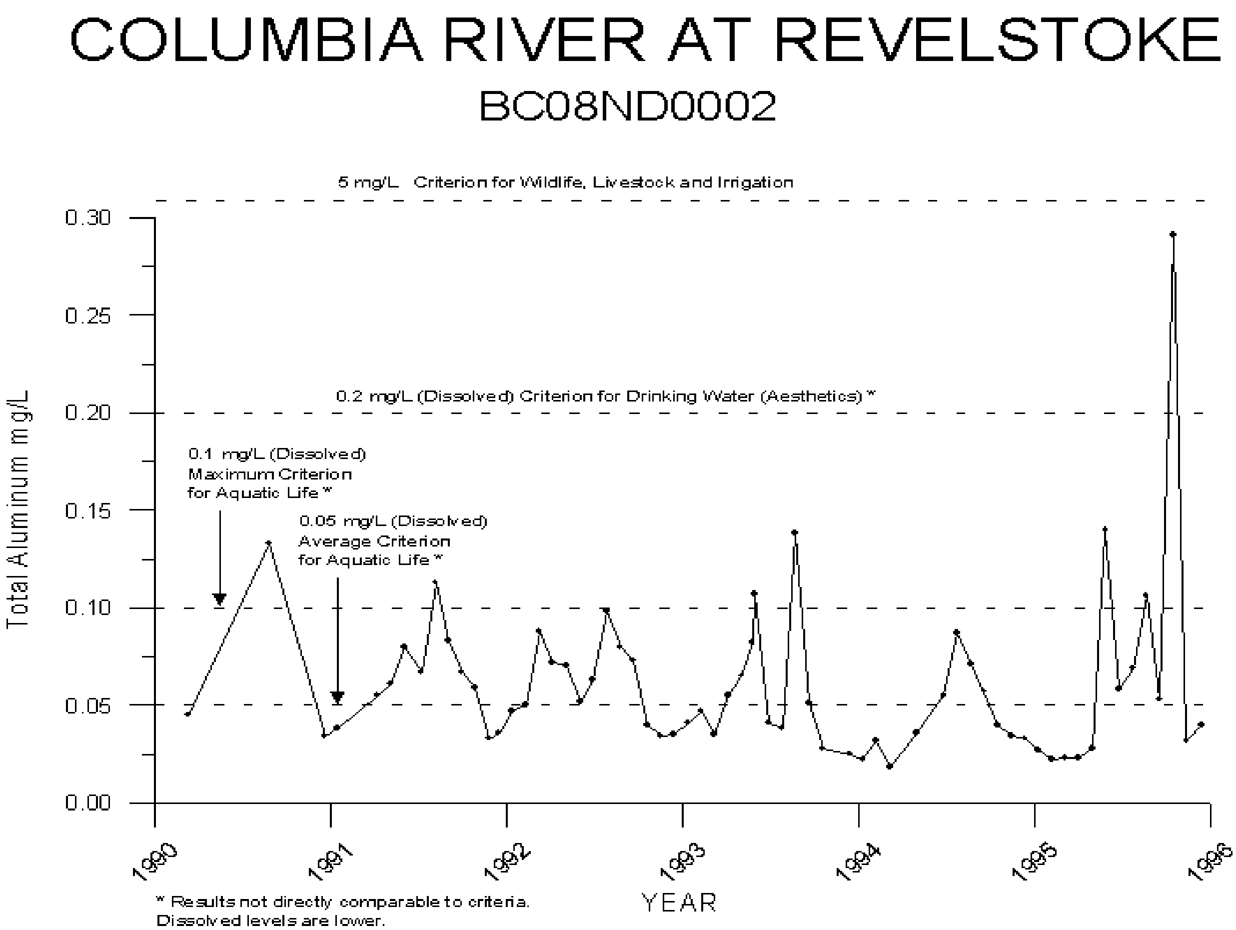


Figure 5 Total Arsenic

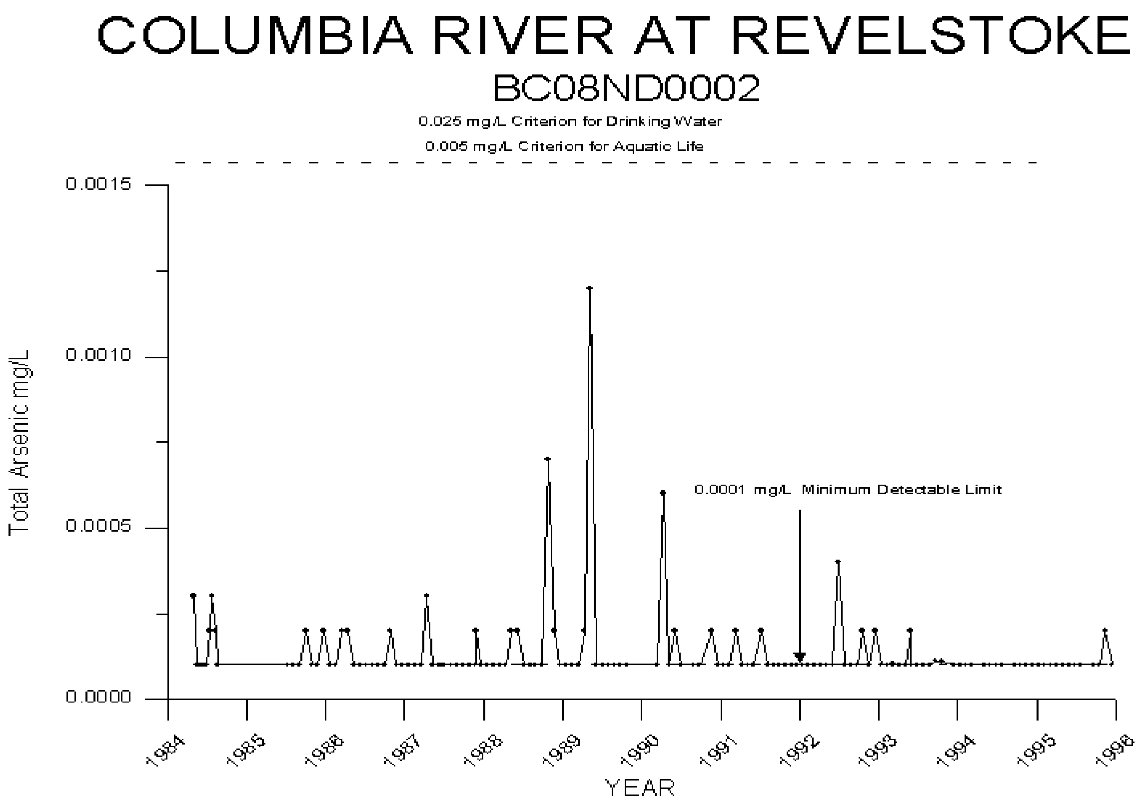


Figure 6 Total Barium

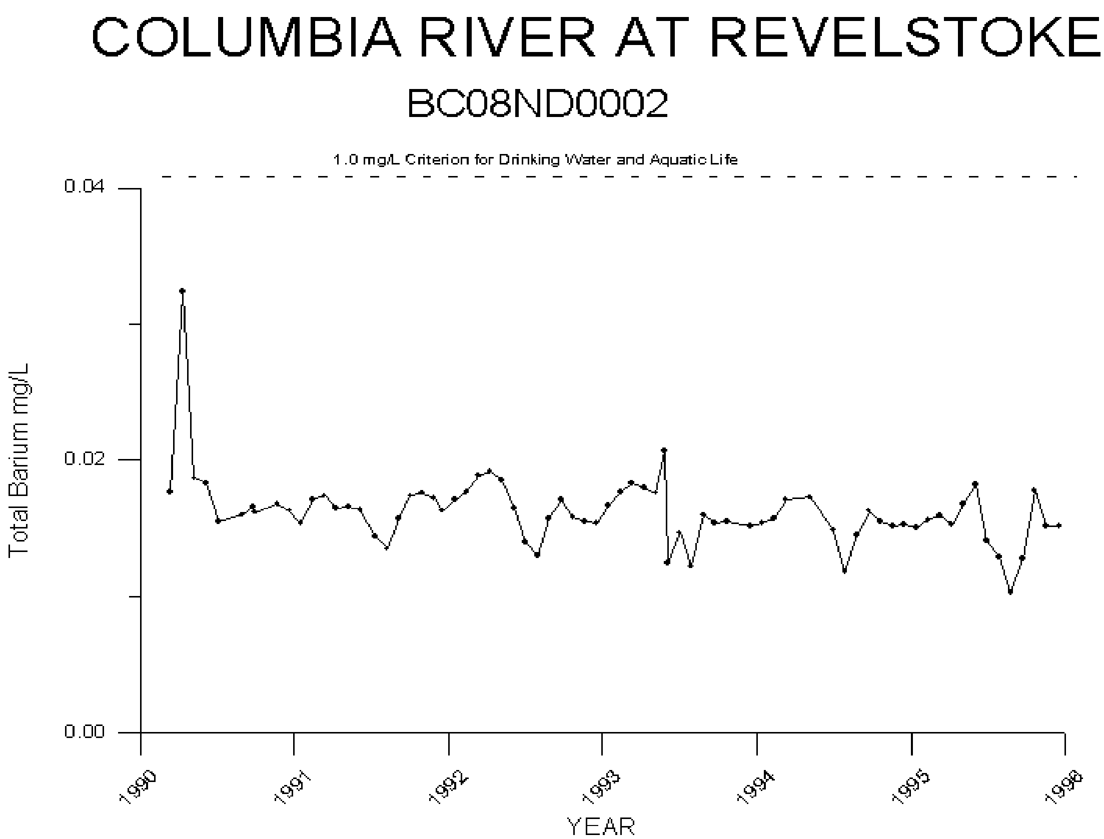


Figure 7 Total Beryllium

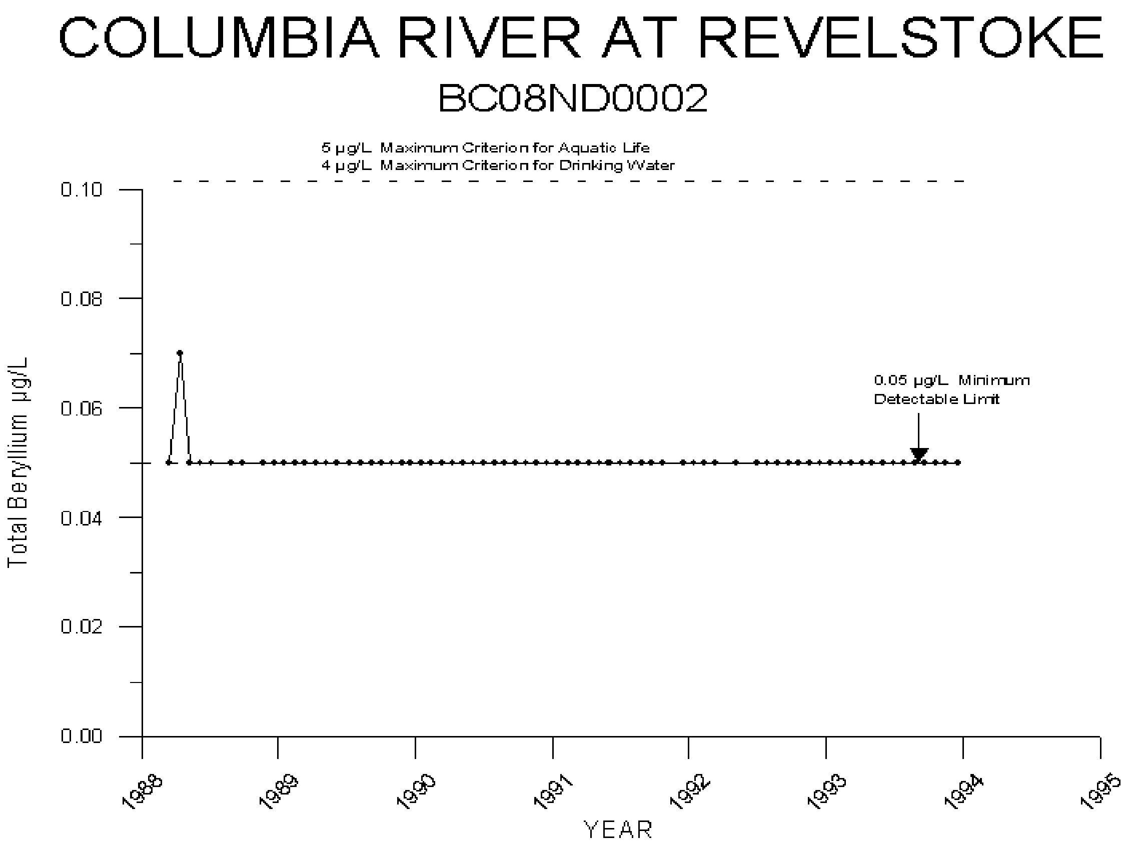


Figure 8 Total Cadmium

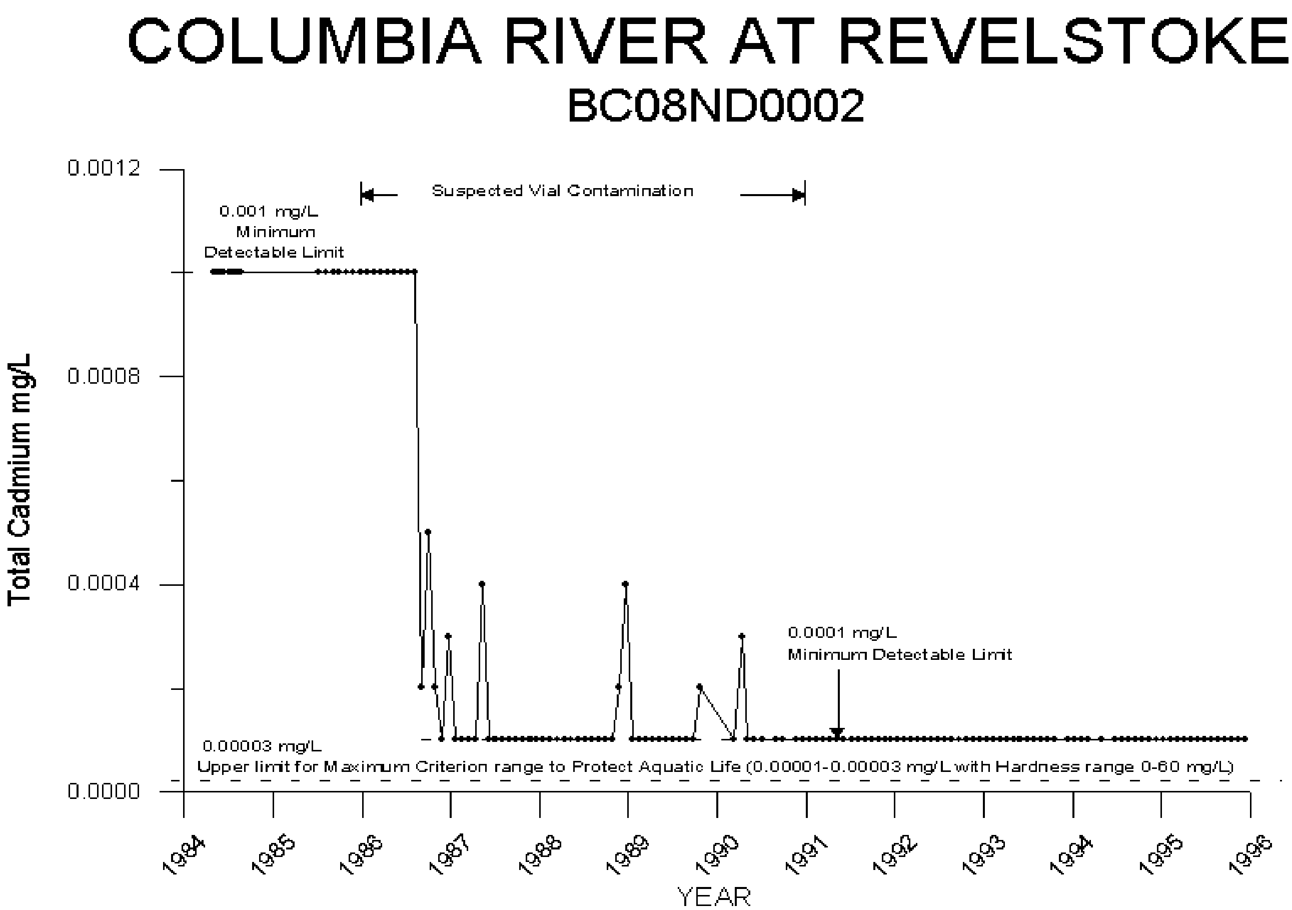


Figure 9 Calcium

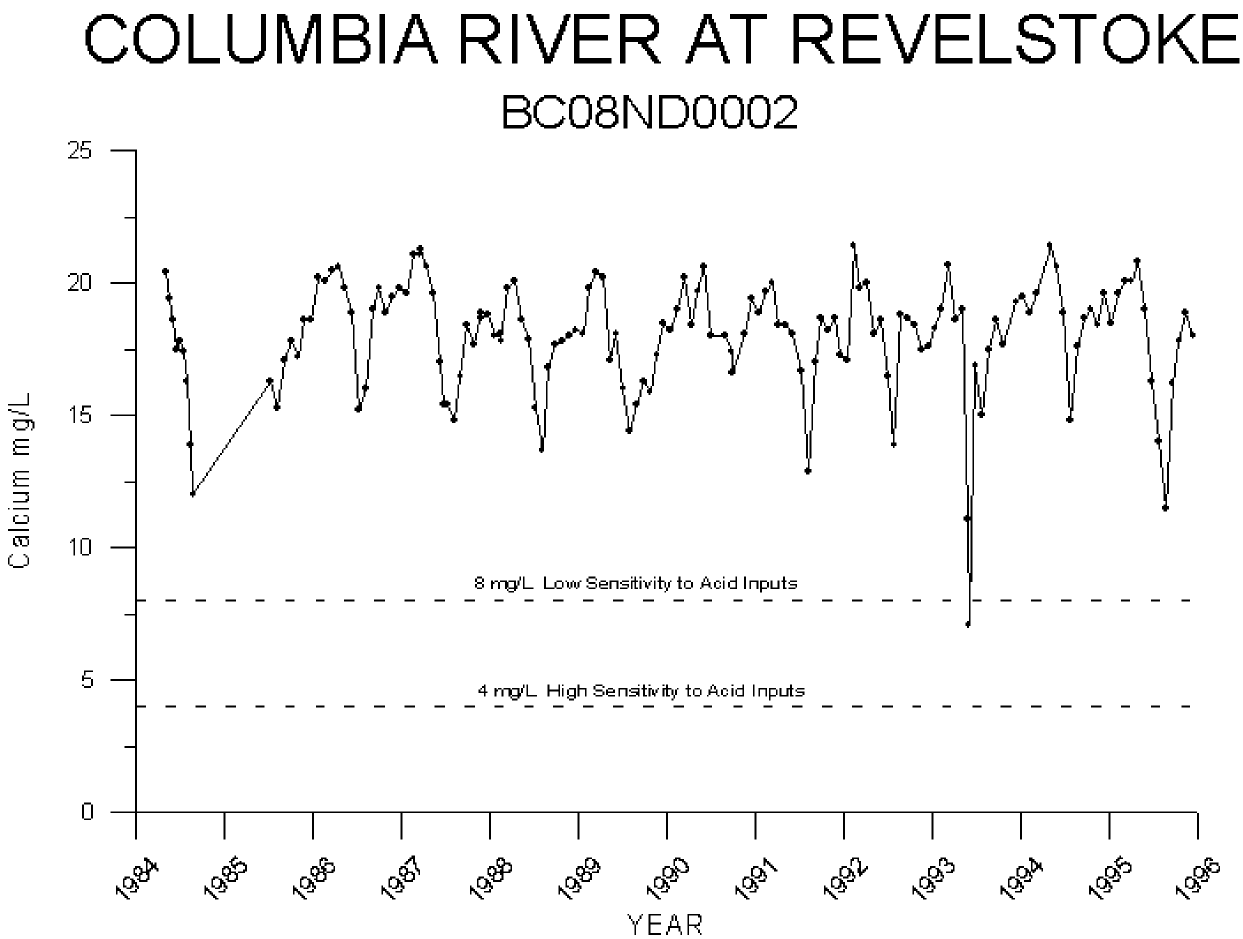


Figure 10 Dissolved Chloride

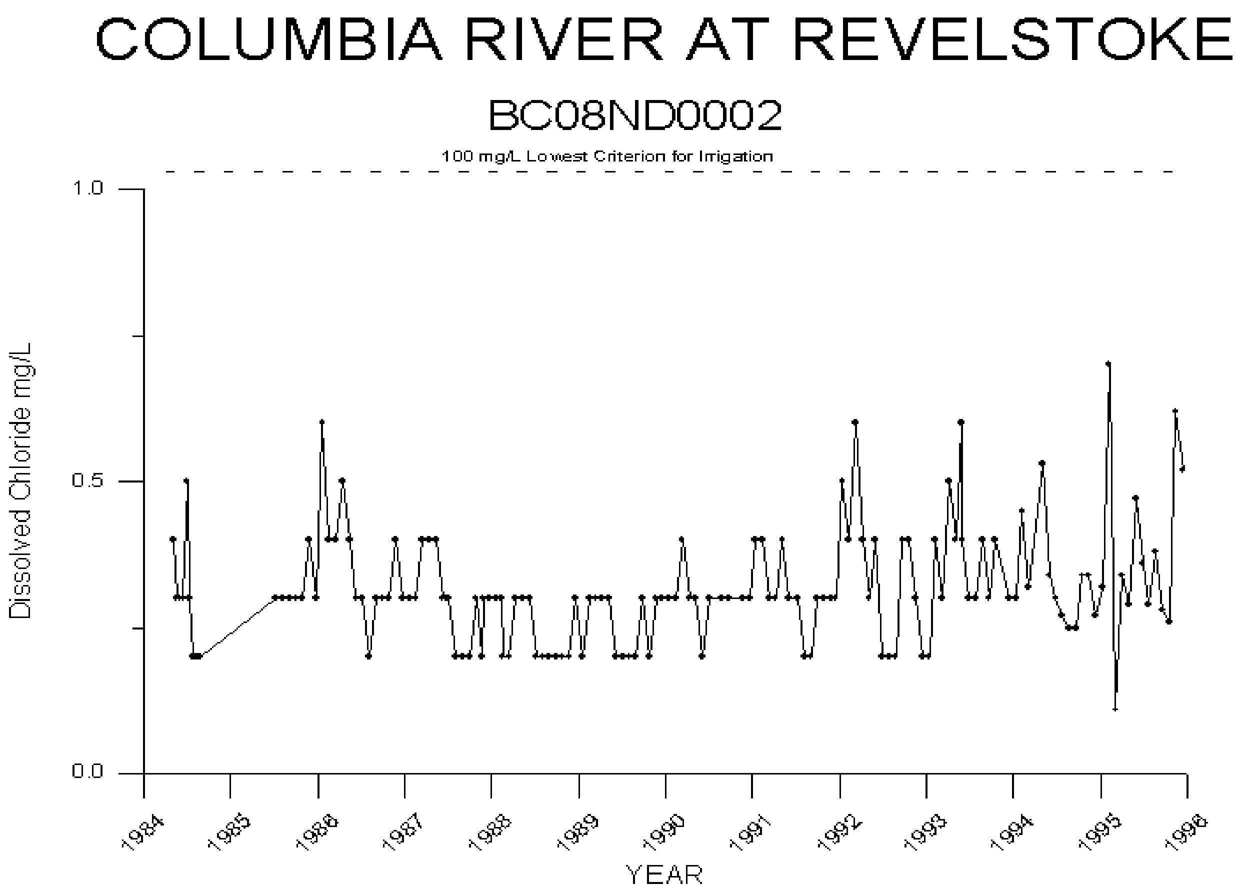


Figure 11 Total Chromium

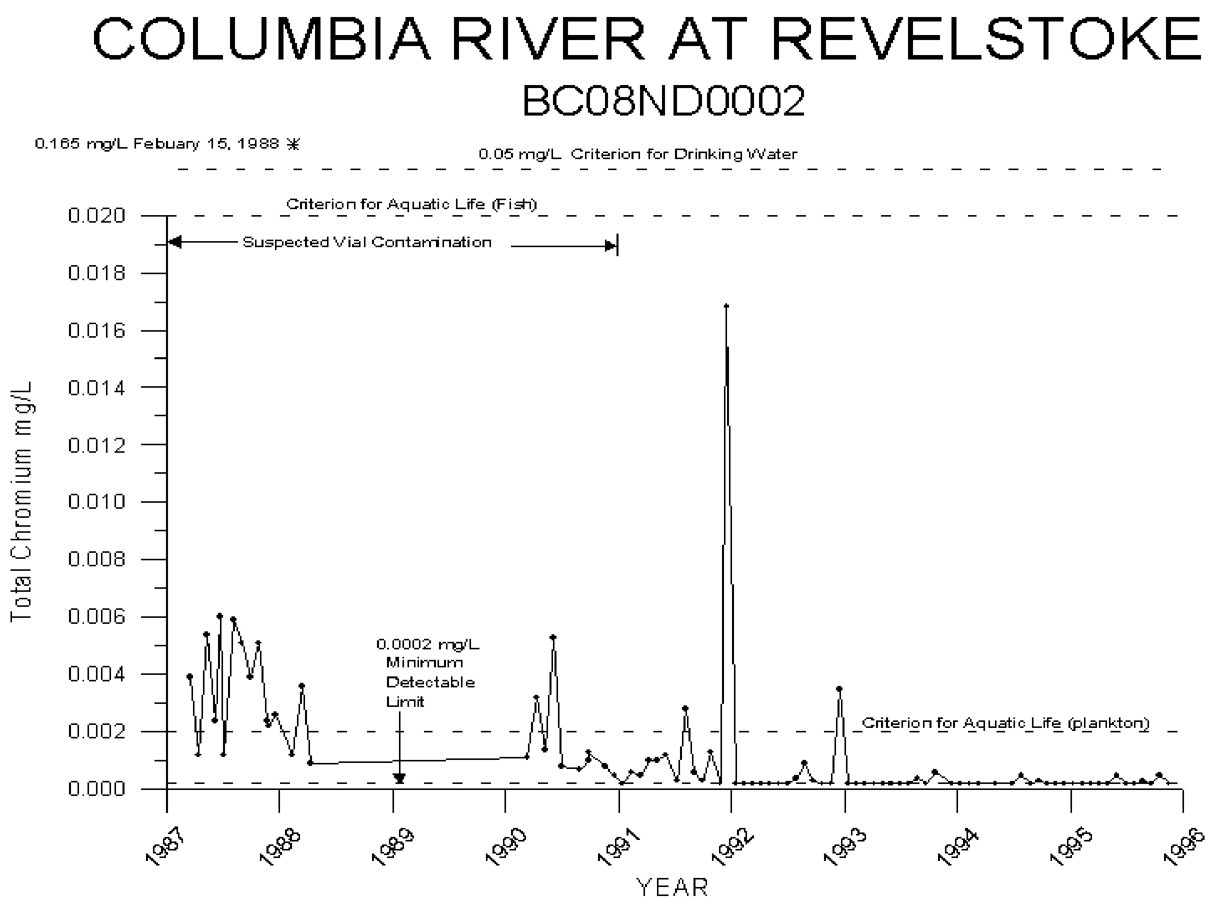


Figure 12 Total Cobalt

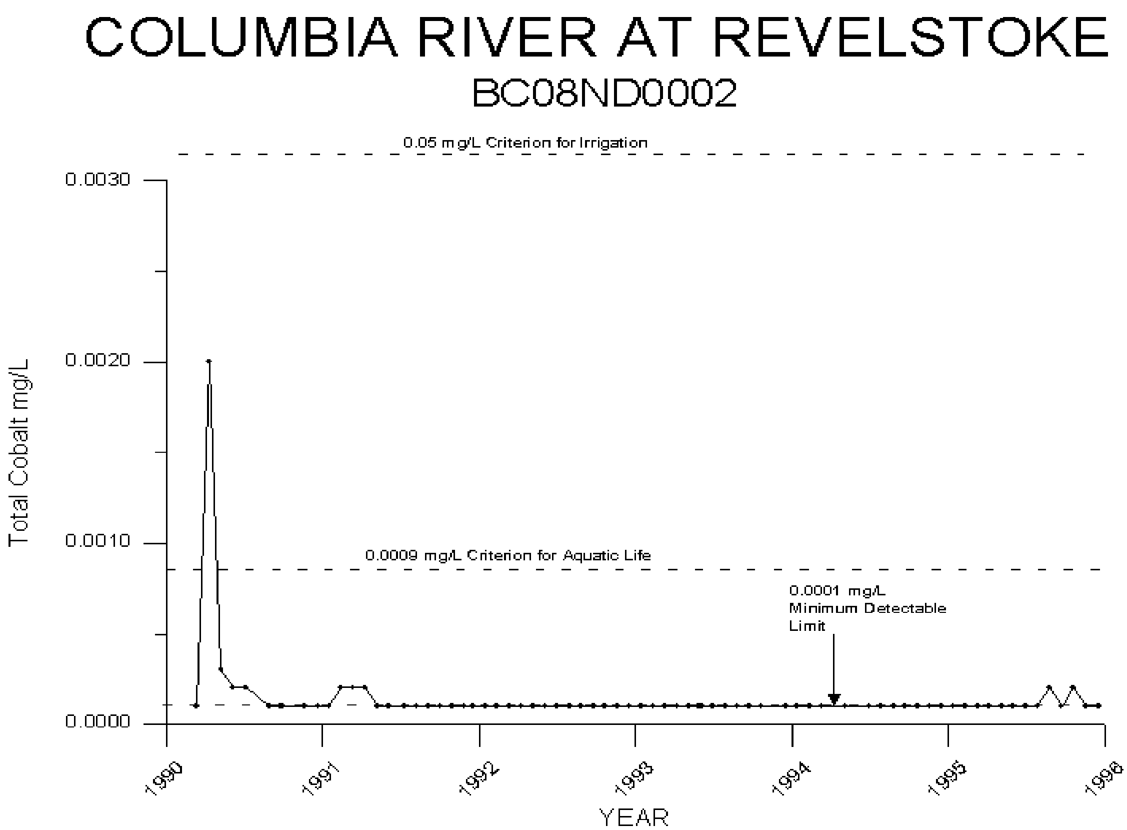


Figure 13 Apparent Colour

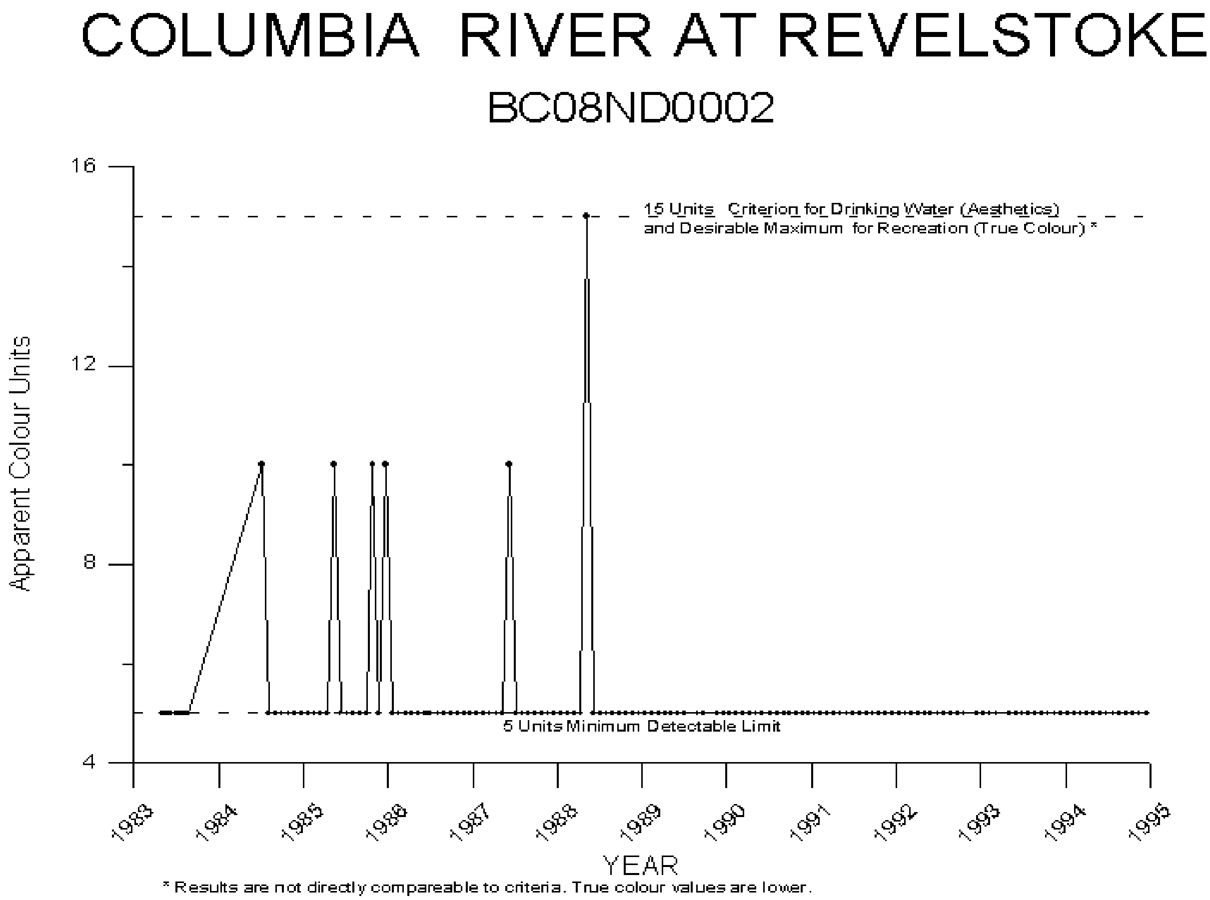


Figure 14 Total Copper

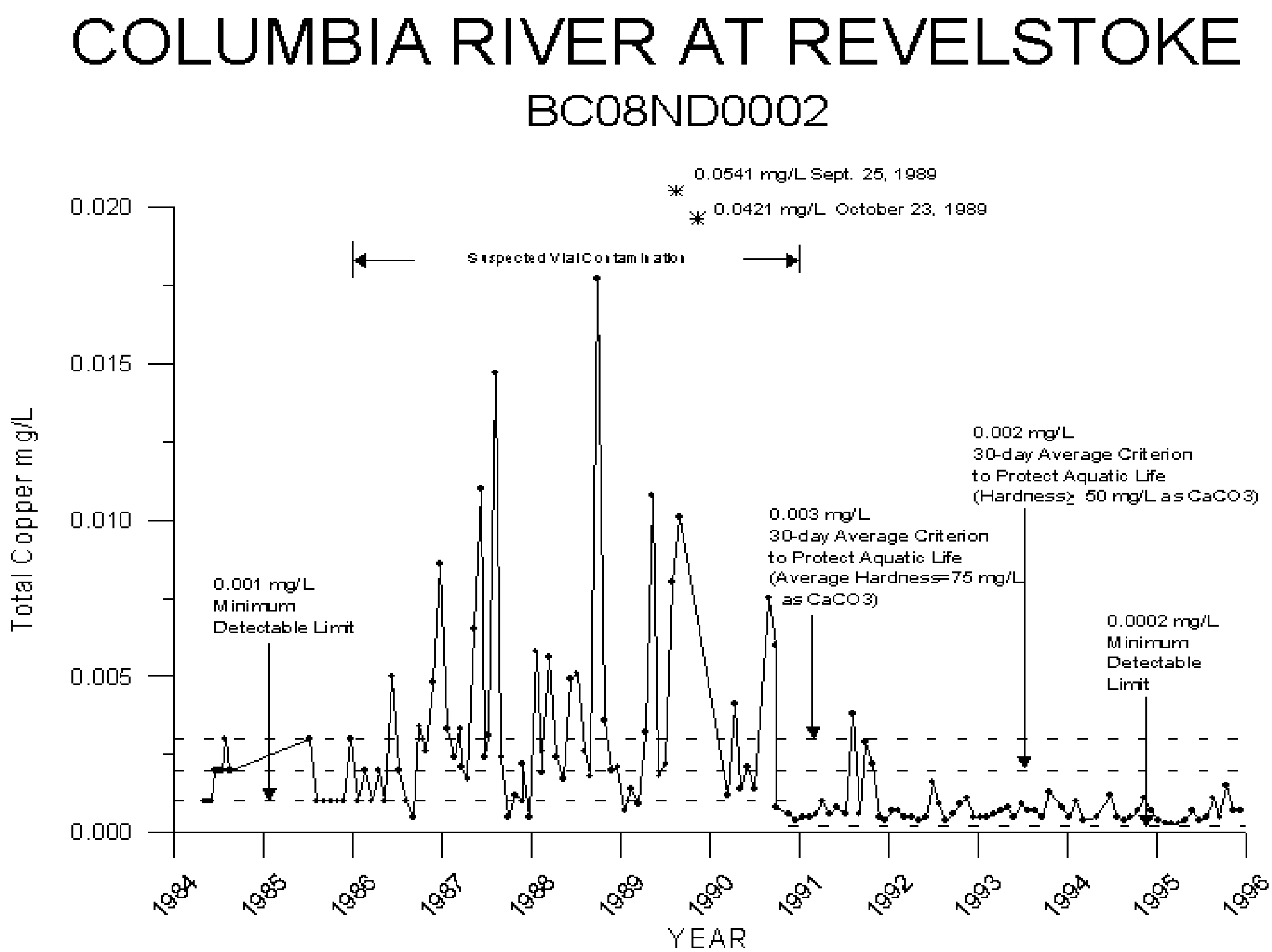


Figure 15 Total Copper and Non-filterable Residue

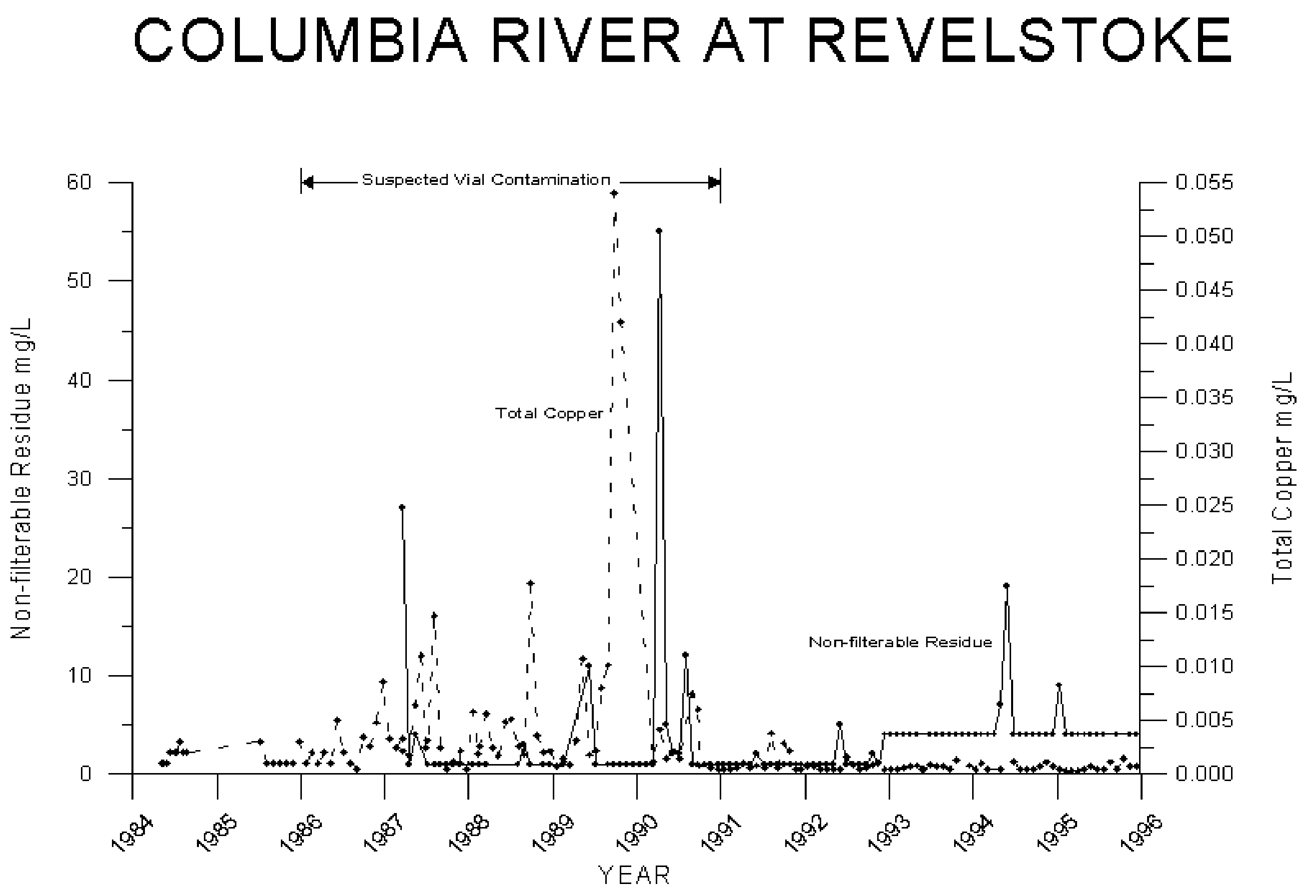


Figure 16 Dissolved Fluoride

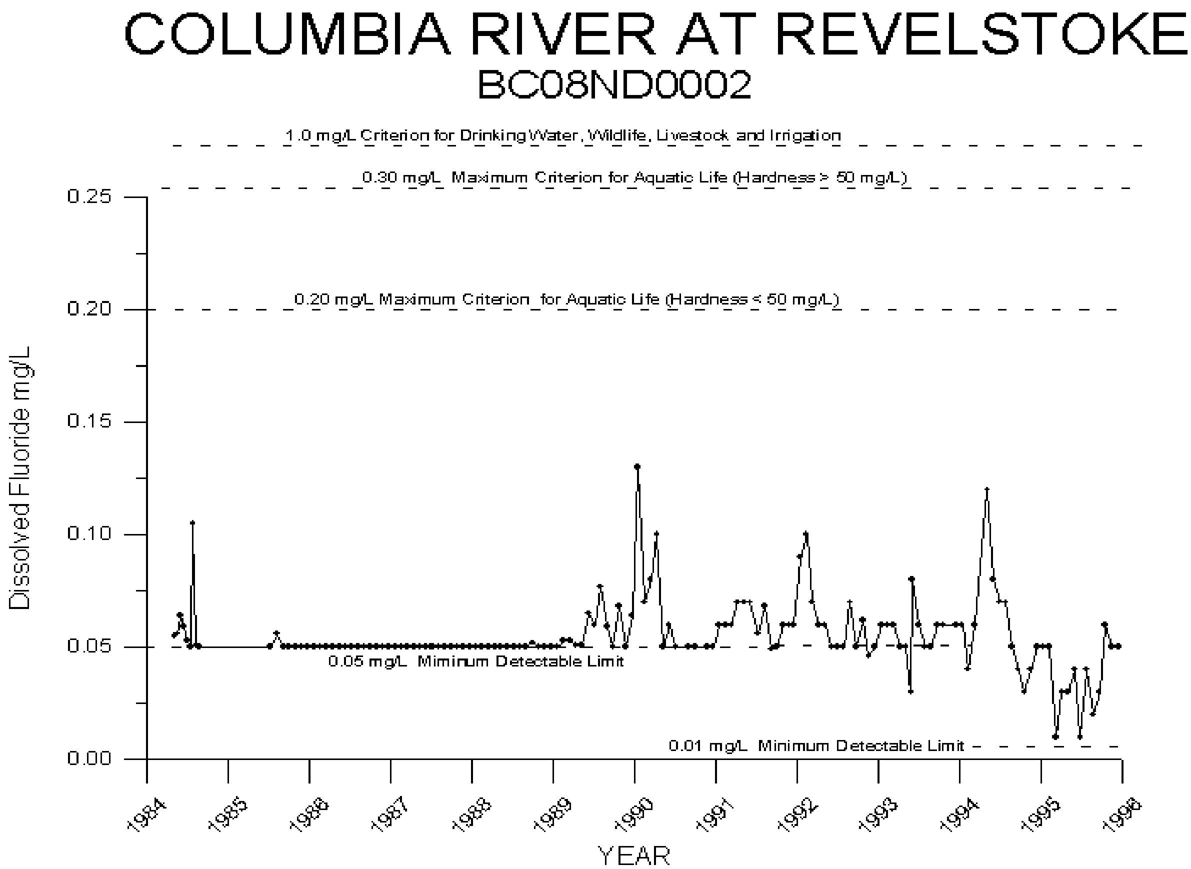


Figure 17 Hardness

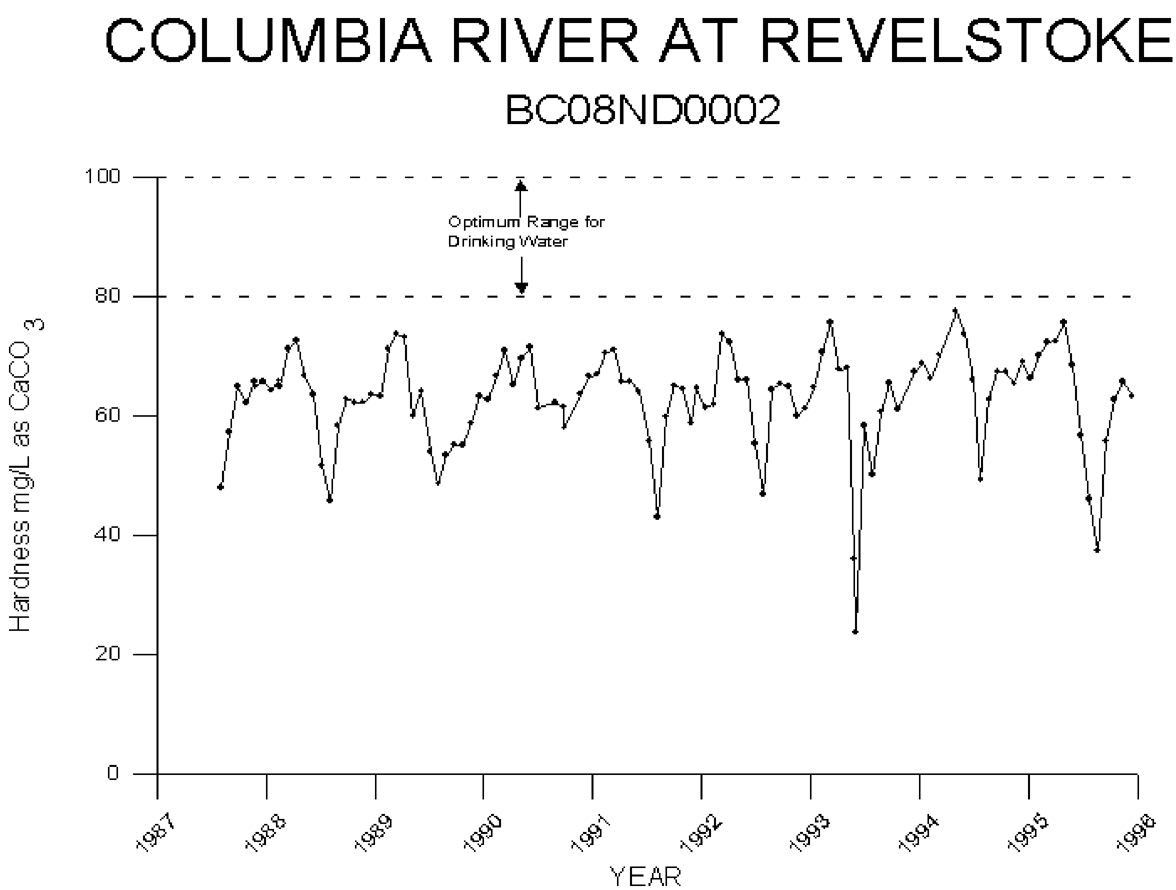


Figure 18 Total Iron

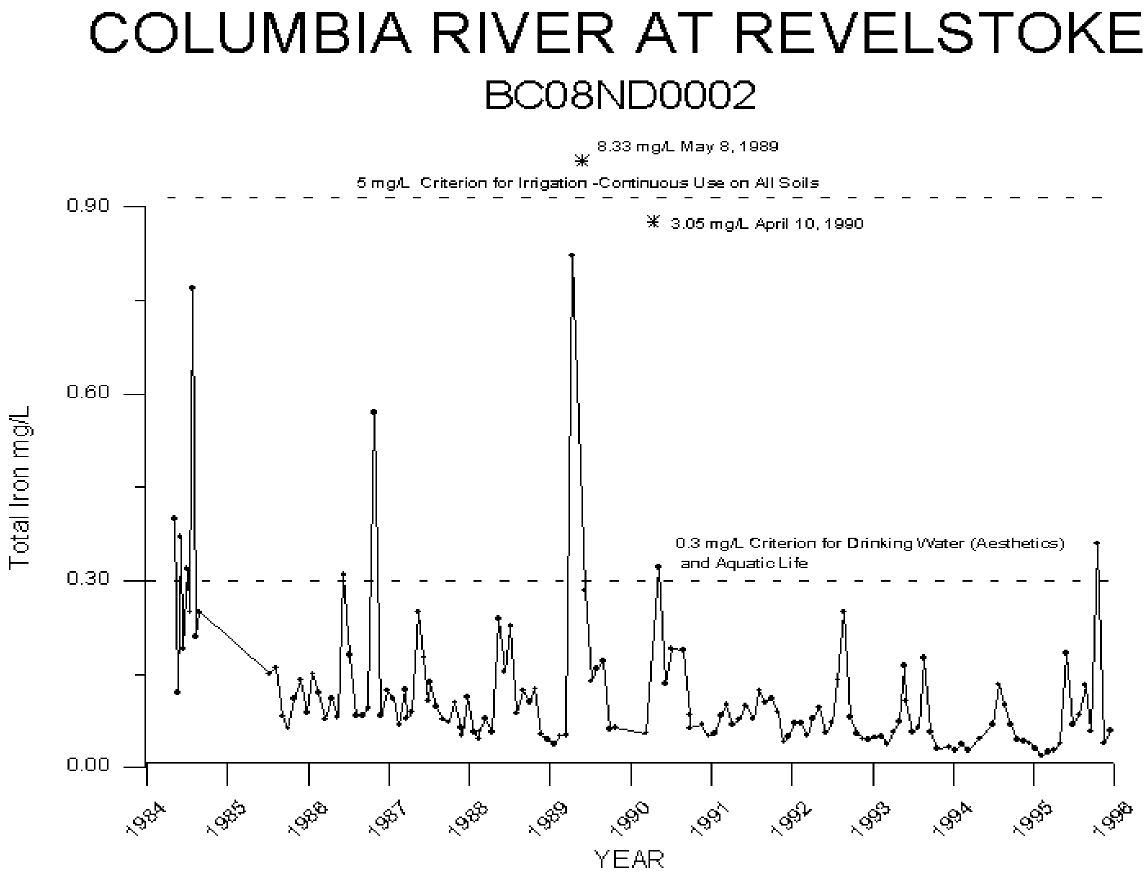


Figure 19 Total Iron and Non-filterable Residue

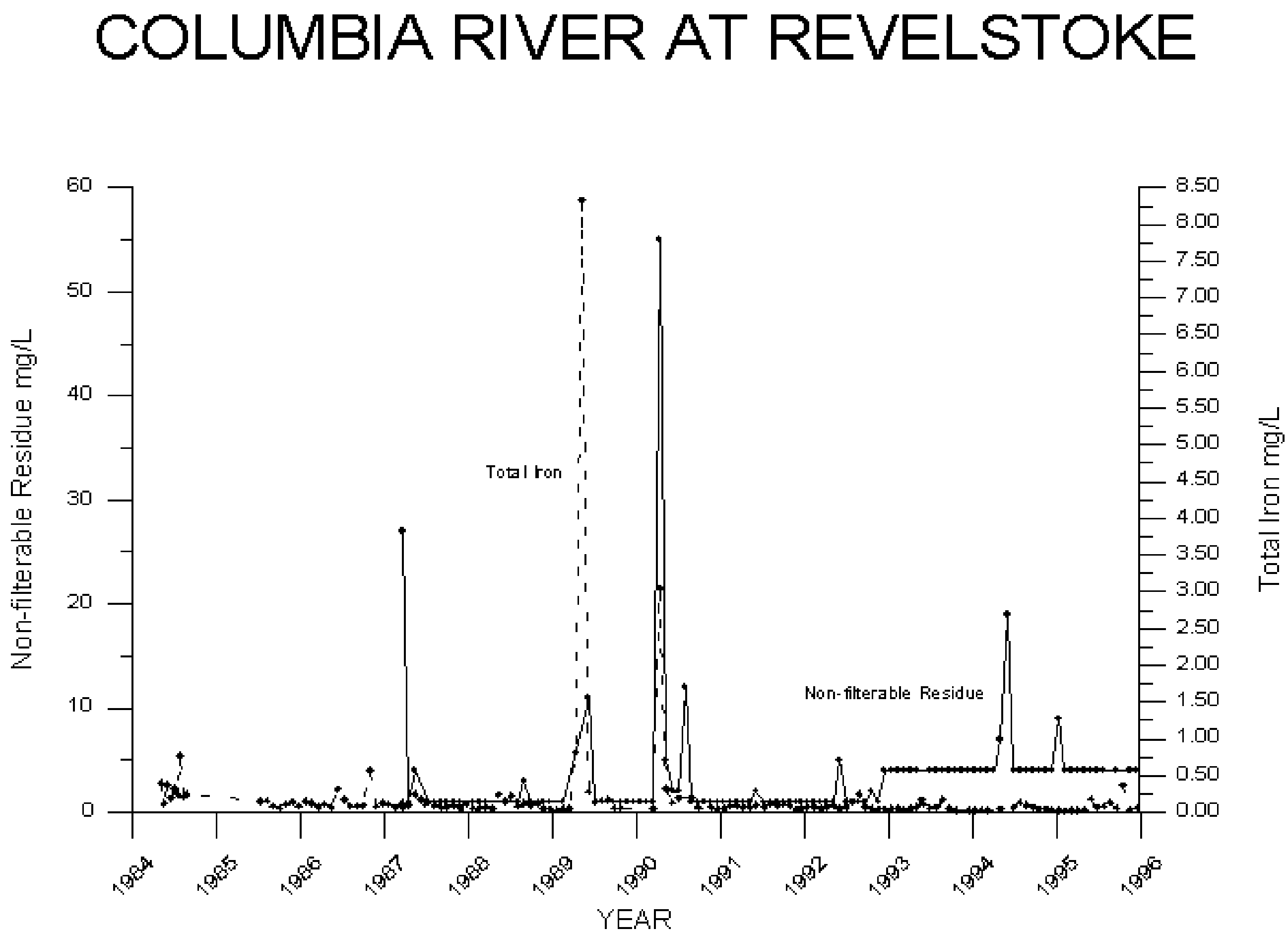


Figure 20 Total Lead

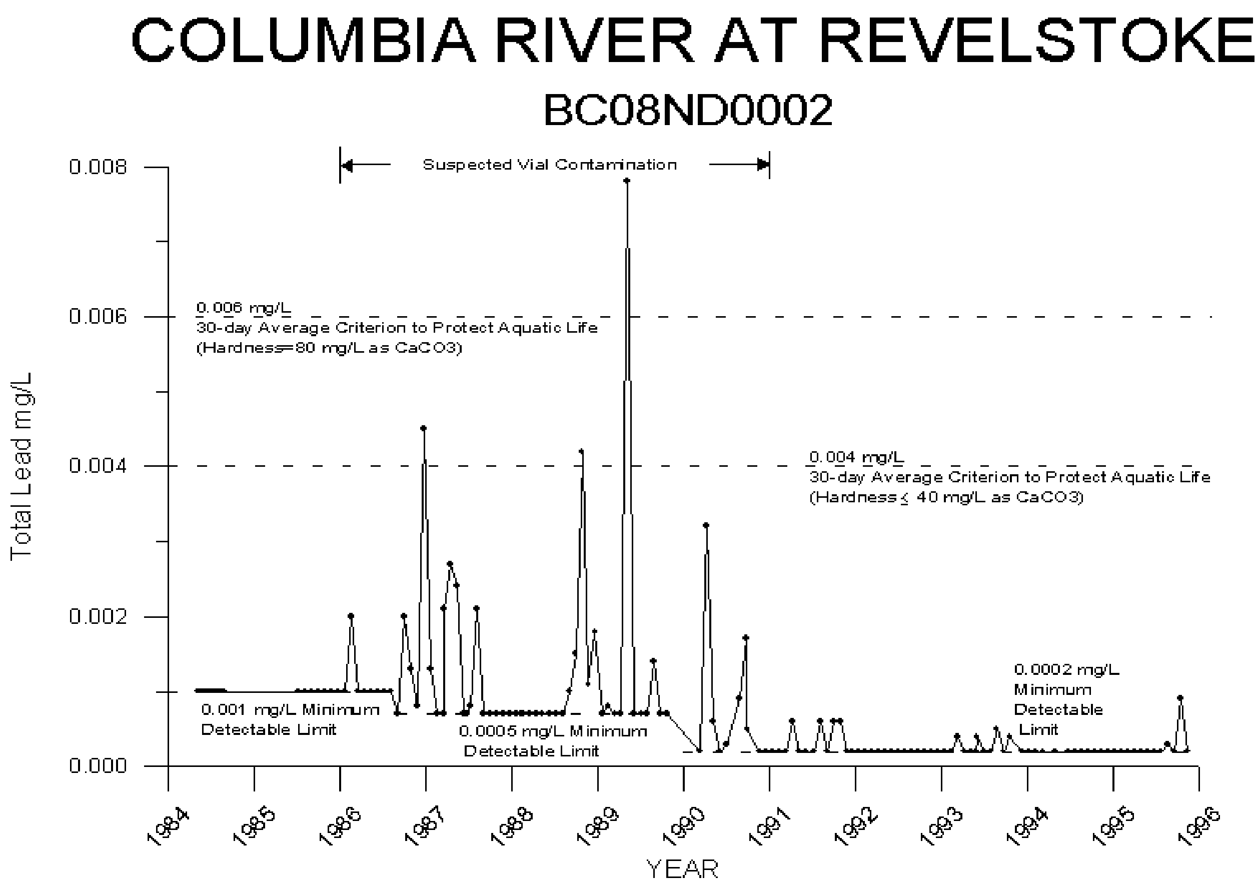


Figure 21 Total Lead and Non-filterable Residue

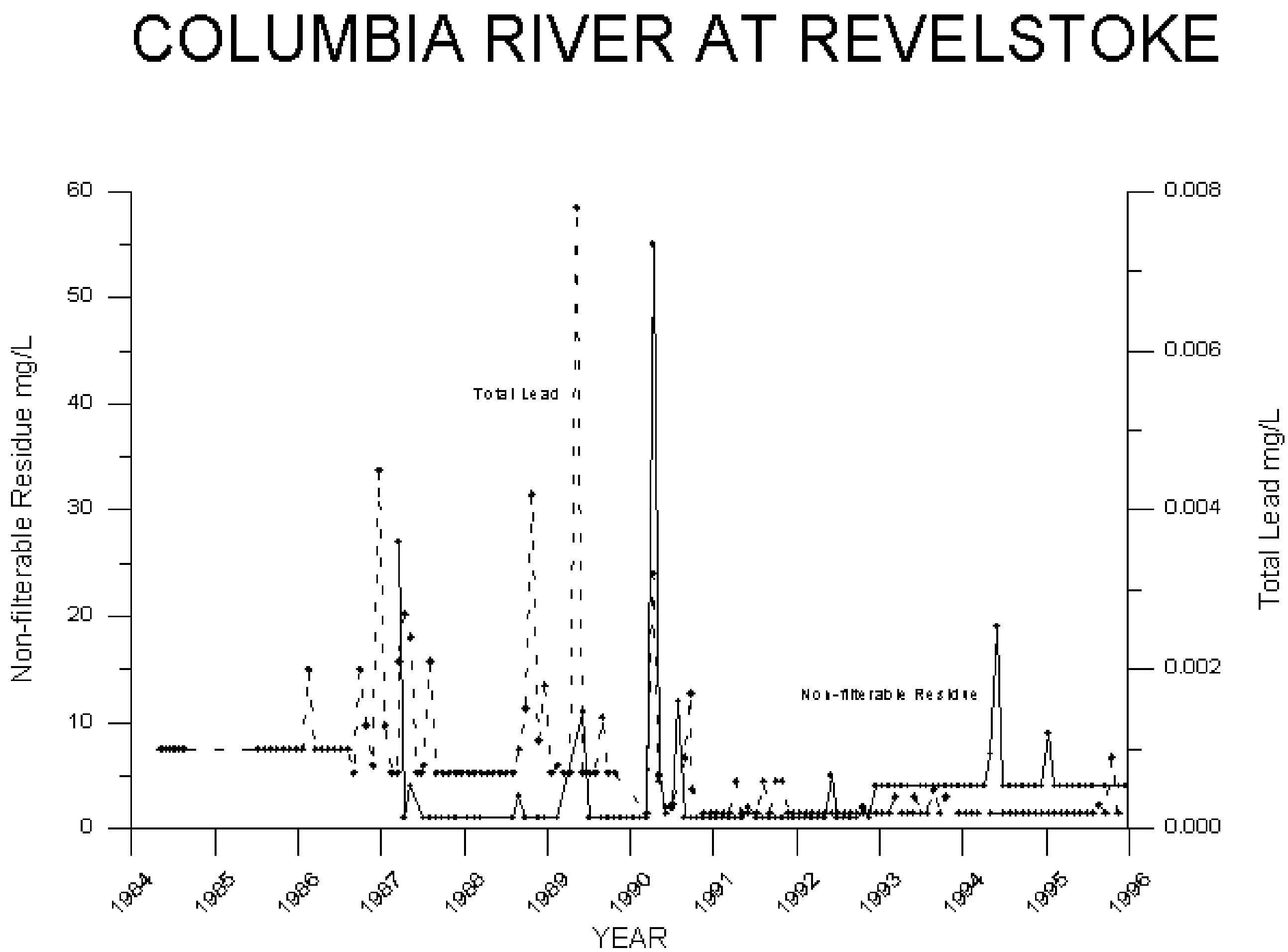


Figure 22 Total Lithium

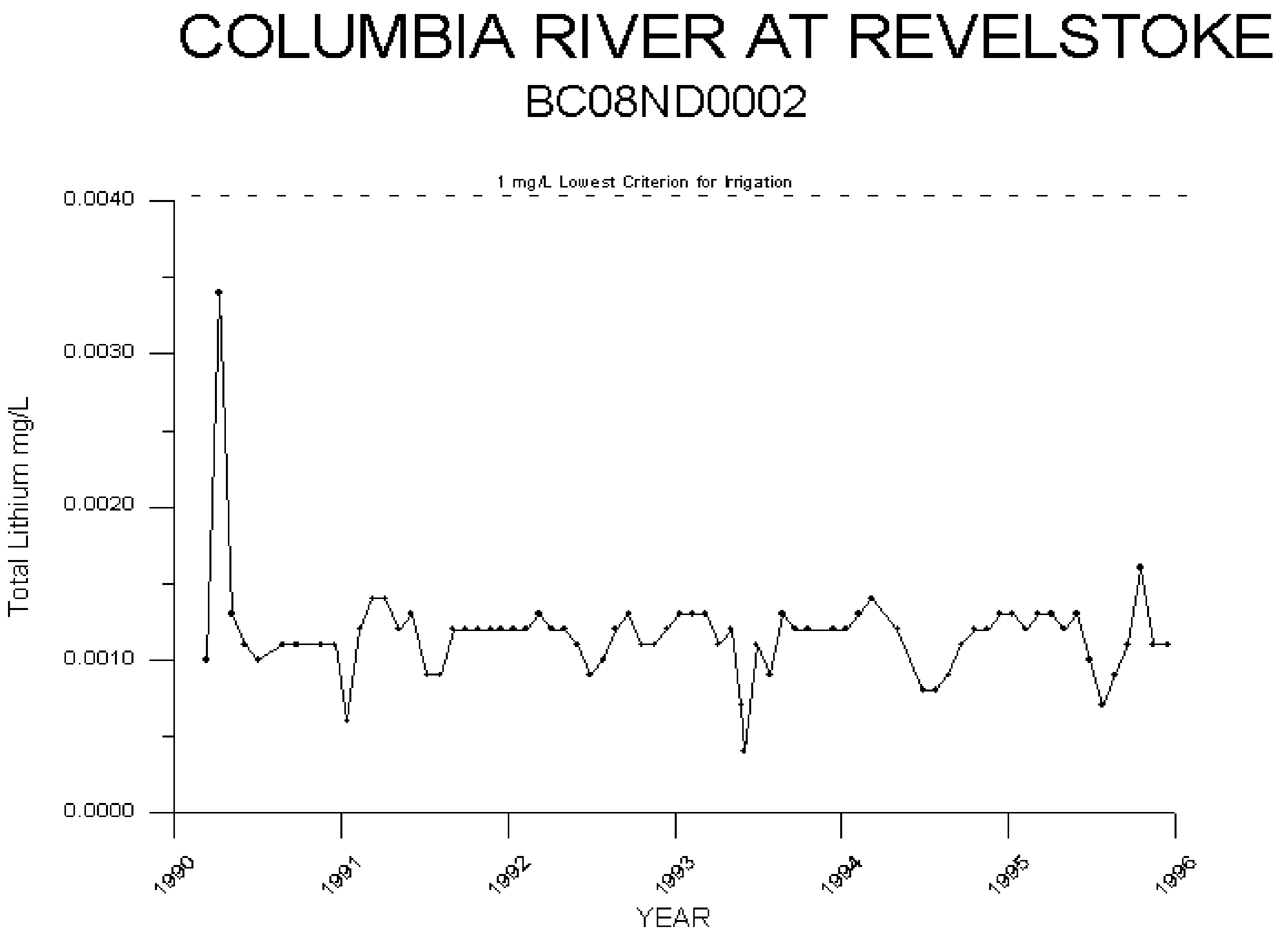


Figure 23 Magnesium

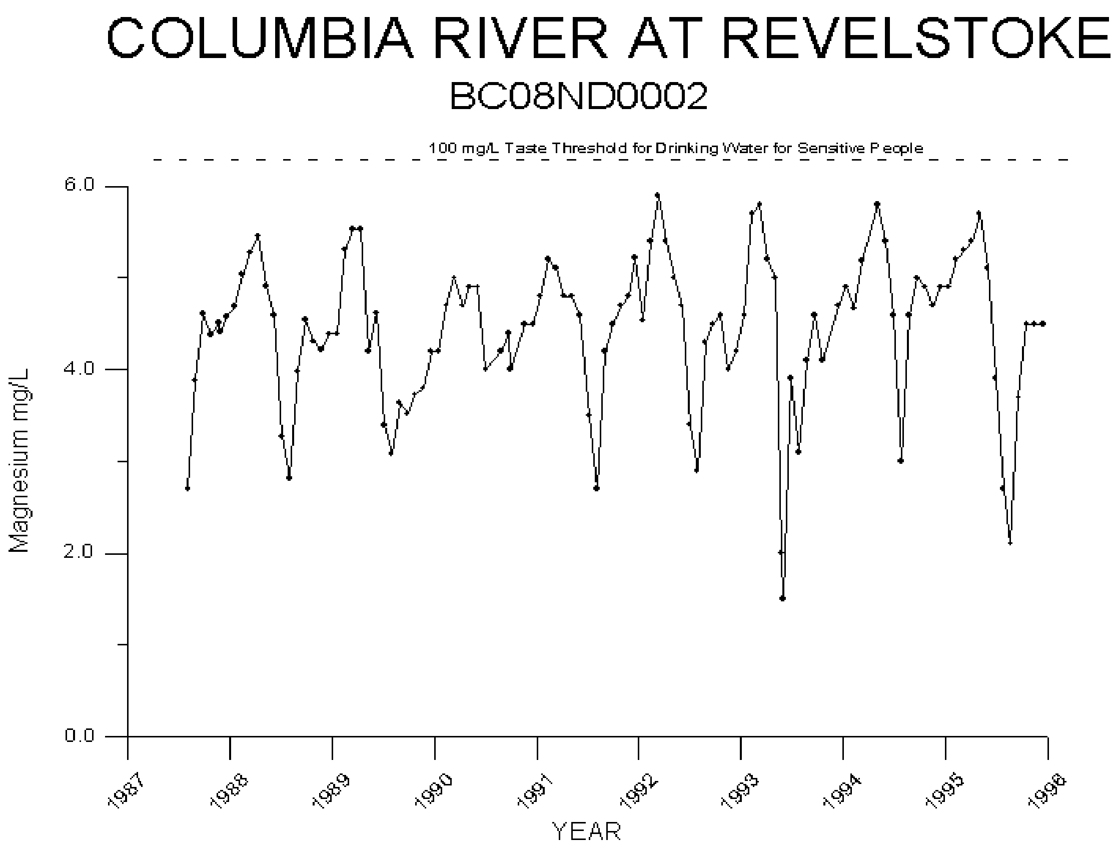


Figure 24 Total Manganese

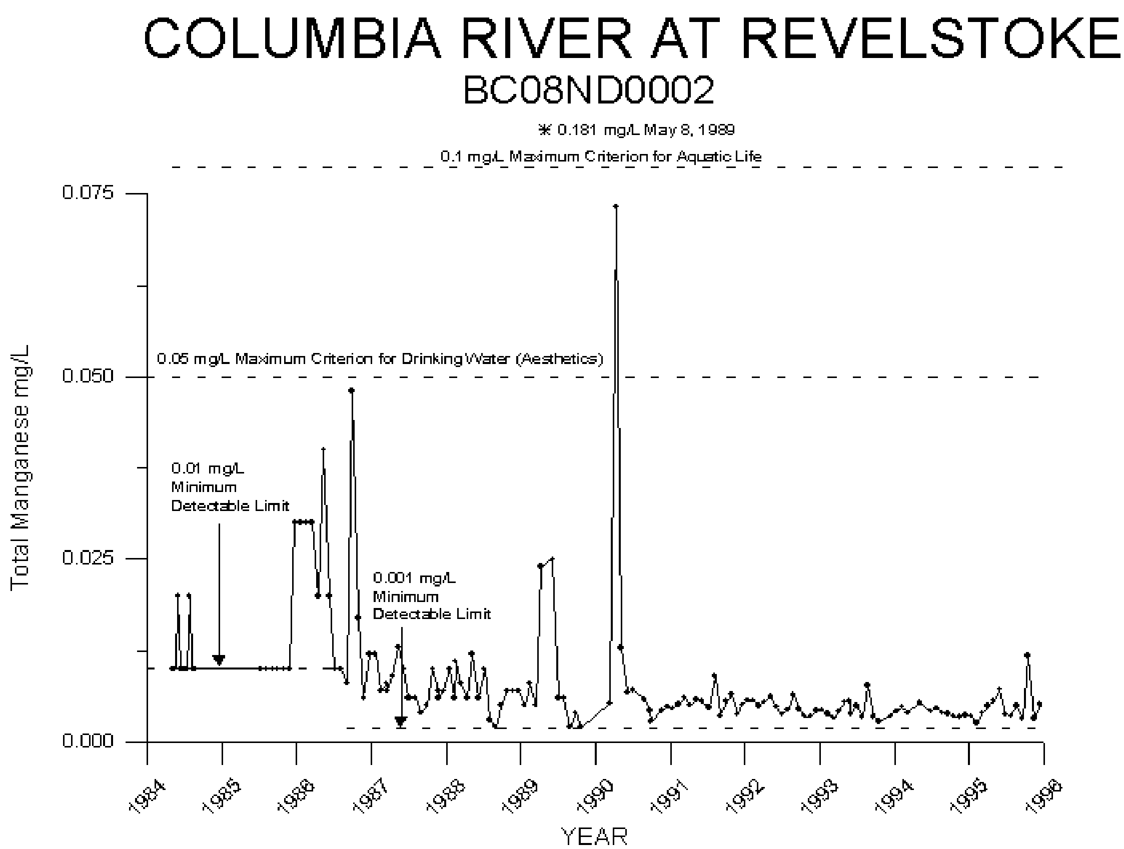


Figure 25 Total Molybdenum

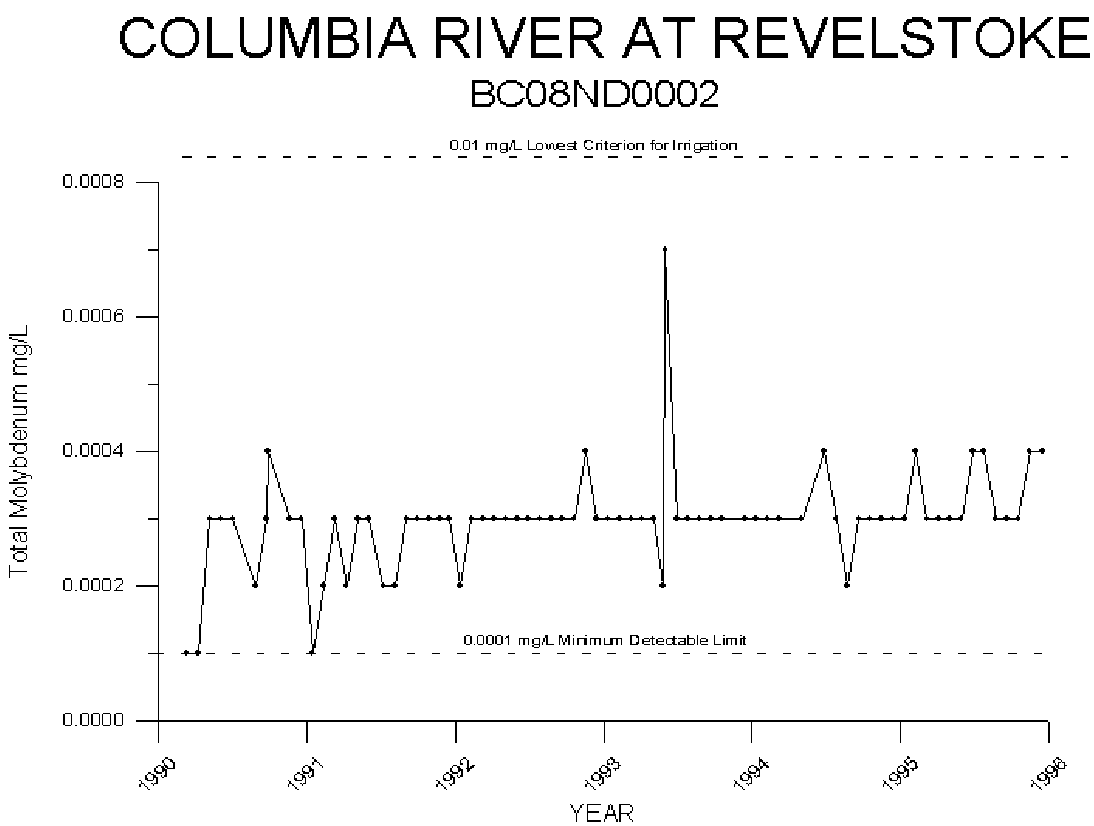


Figure 26 Total Nickel

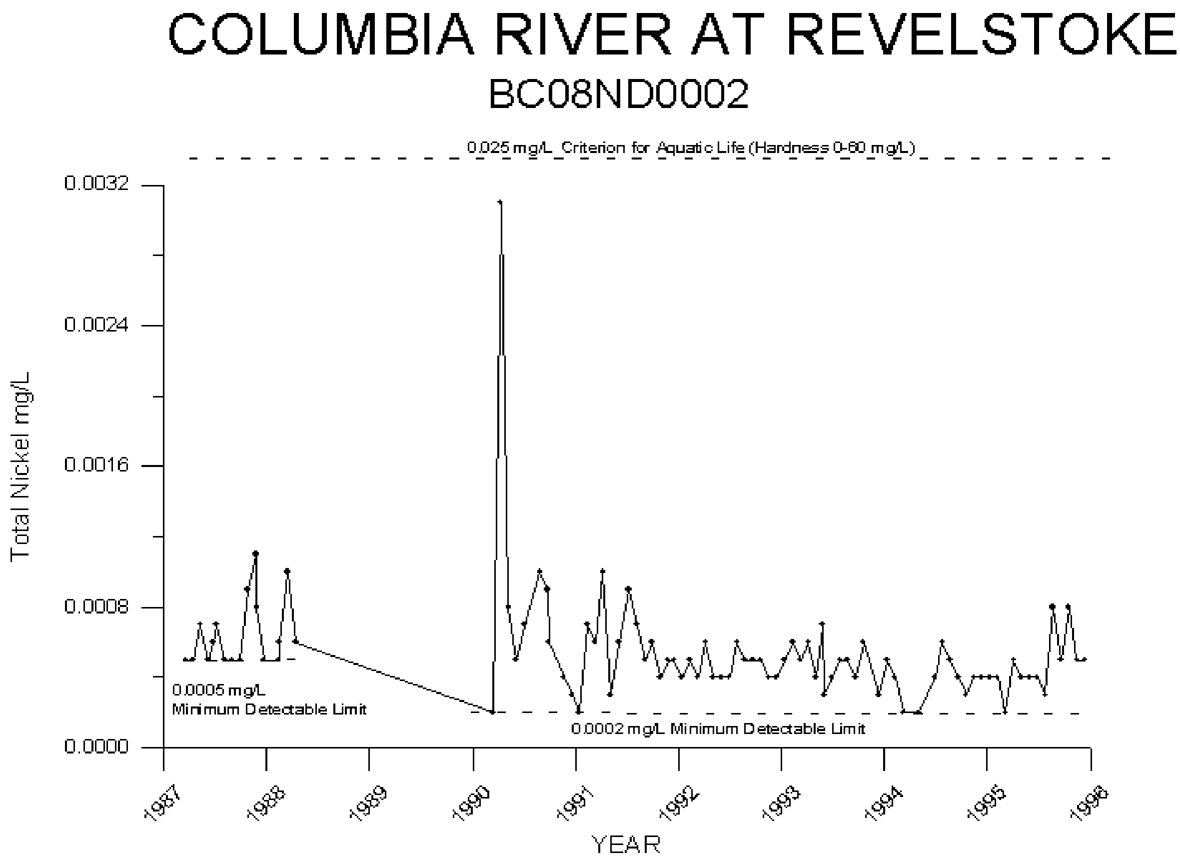


Figure 27 Ammonia-N

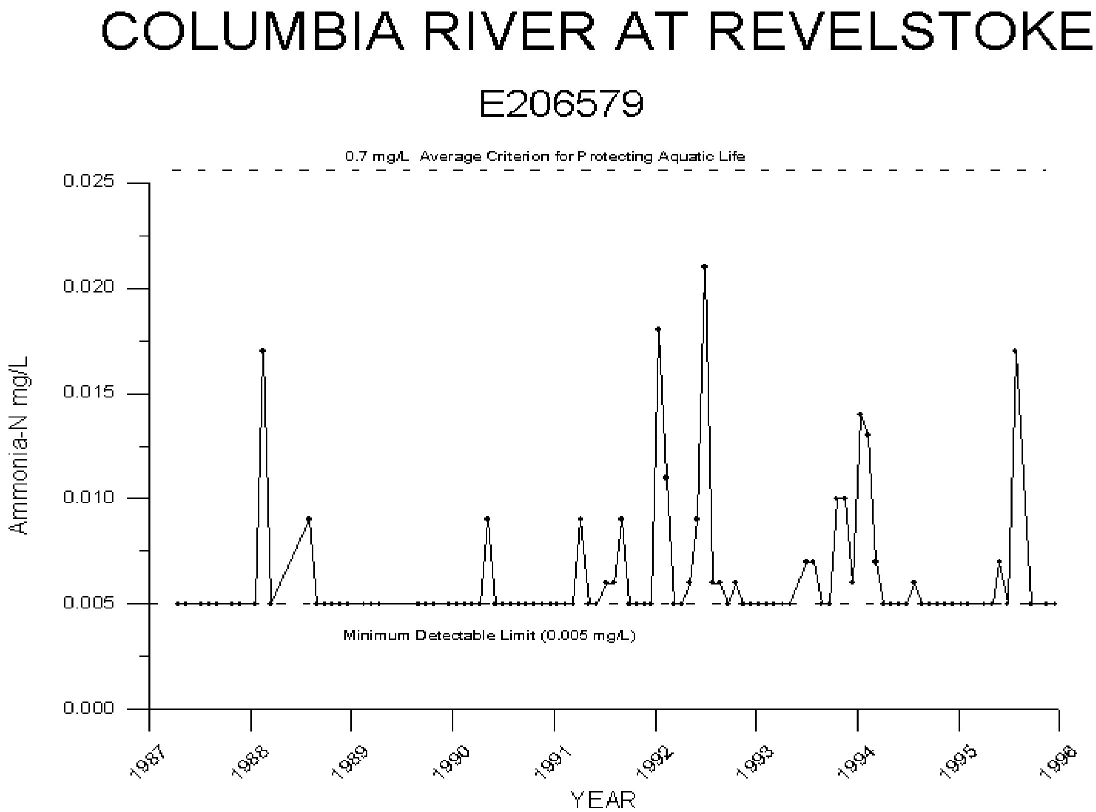


Figure 28 Nitrogen (Nitrate/Nitrite)

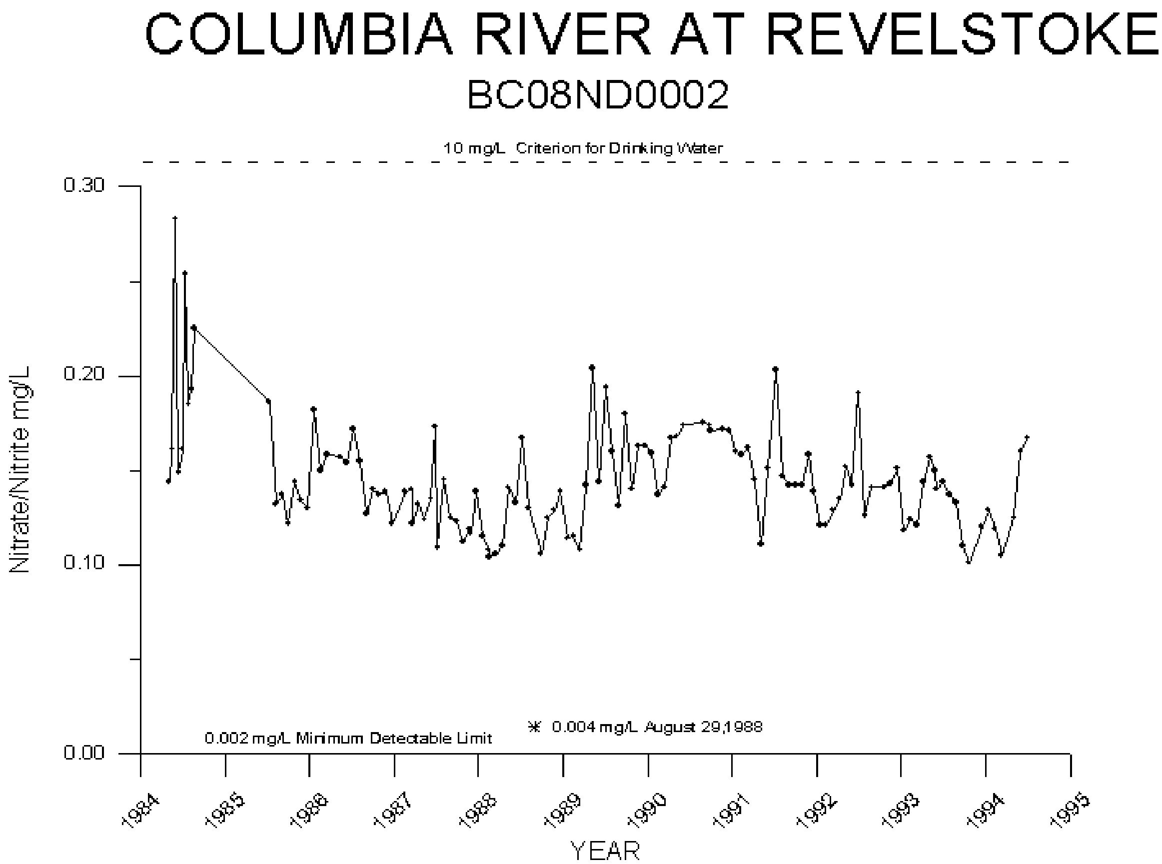


Figure 29 Total Dissolved Nitrogen

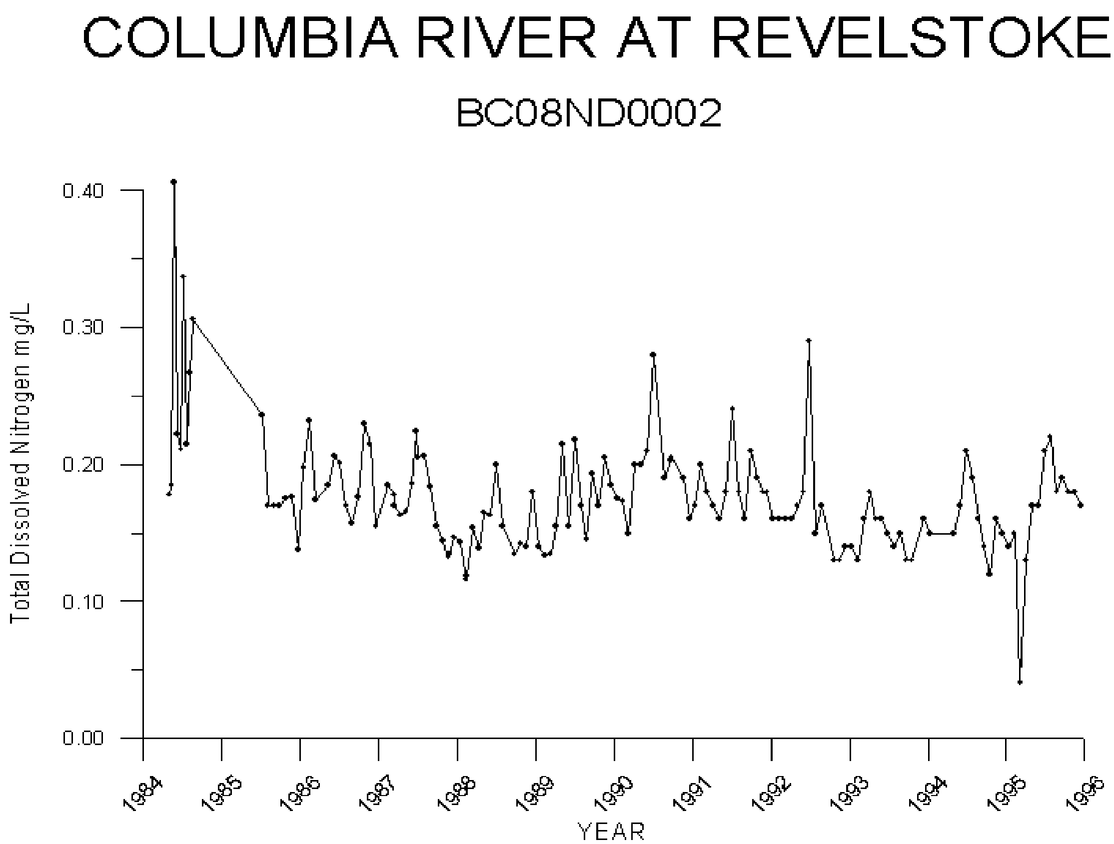


Figure 30 pH (federal)

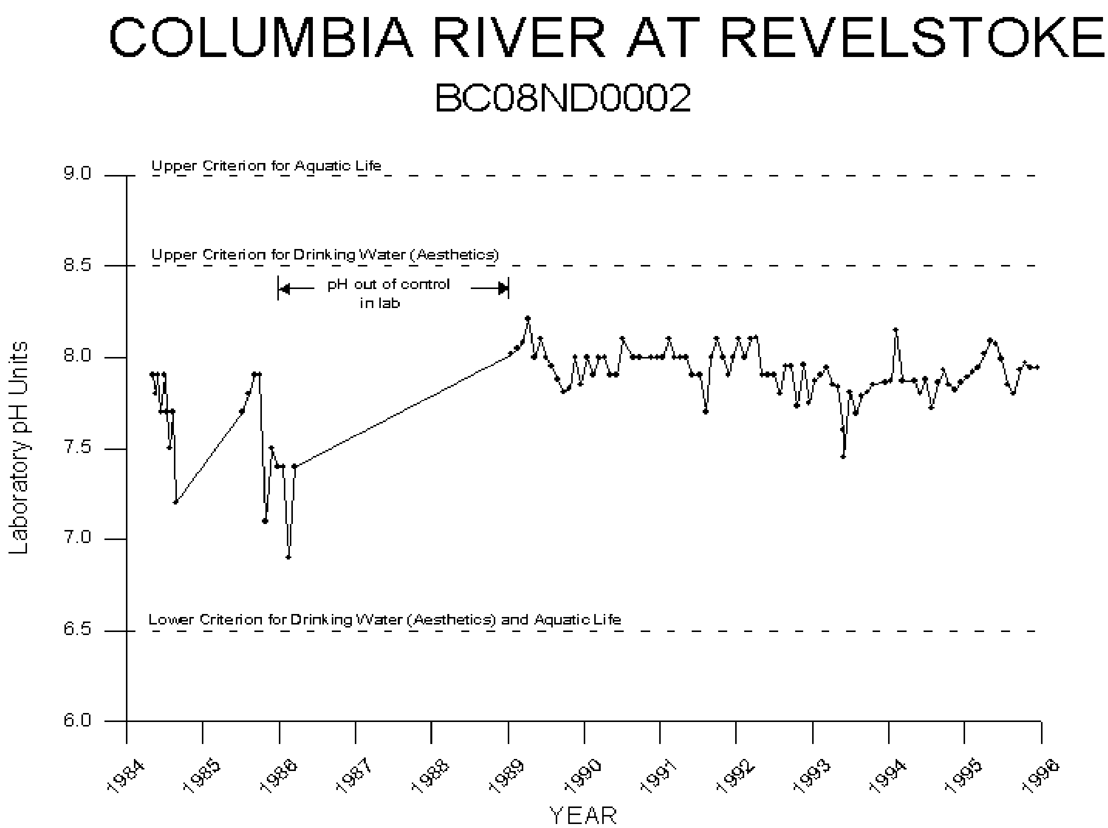


Figure 31 pH (provincial)

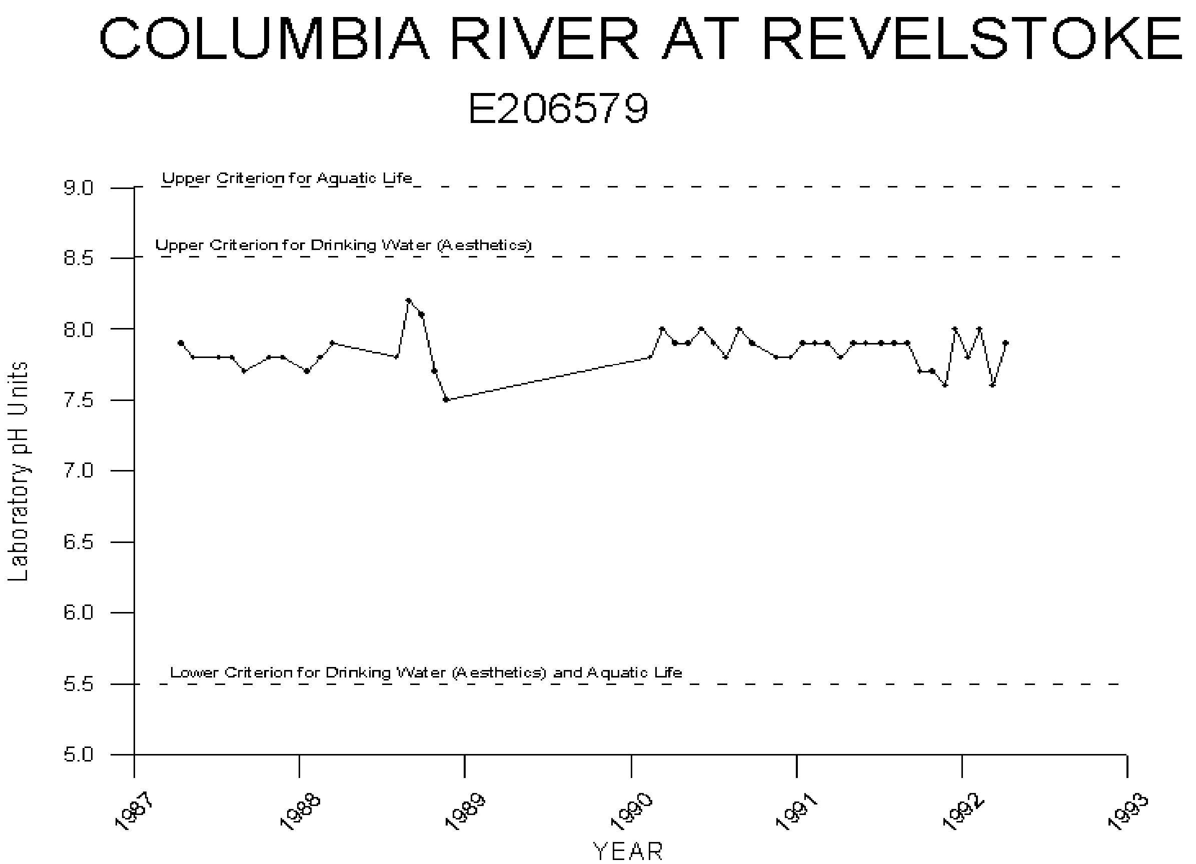


Figure 32 Total dissolved phosphorus

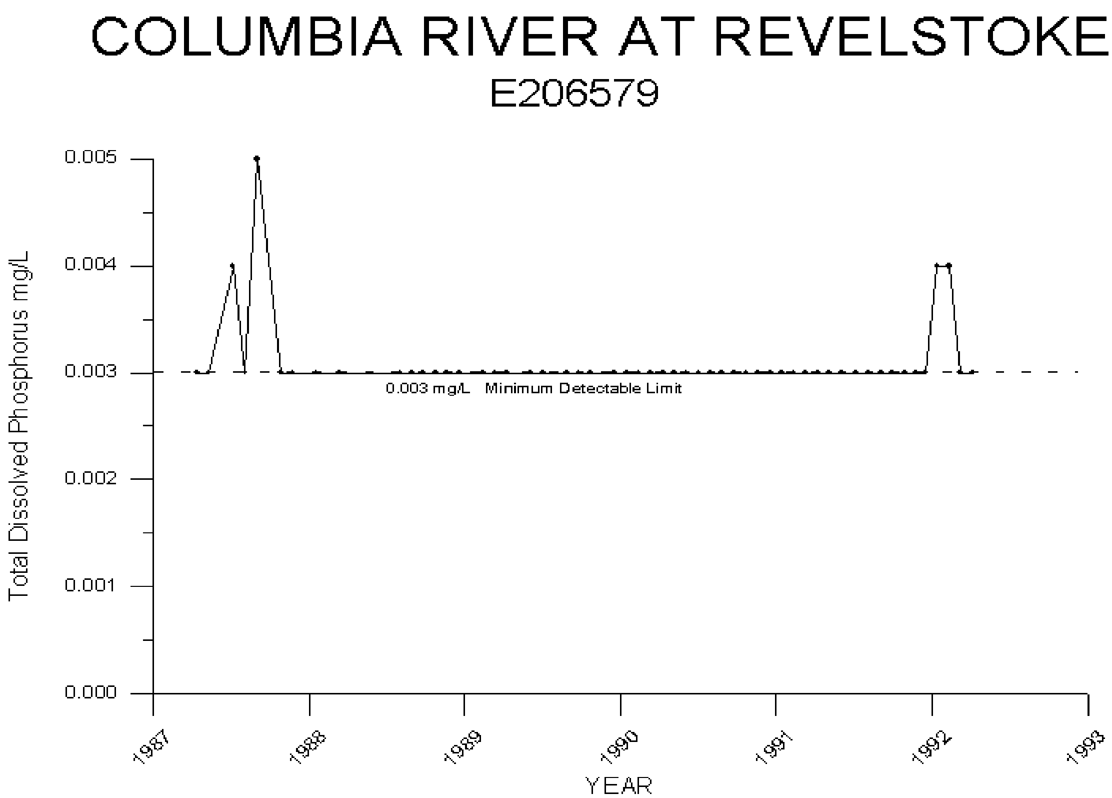


Figure 33 Dissolved Ortho-Phosphorous

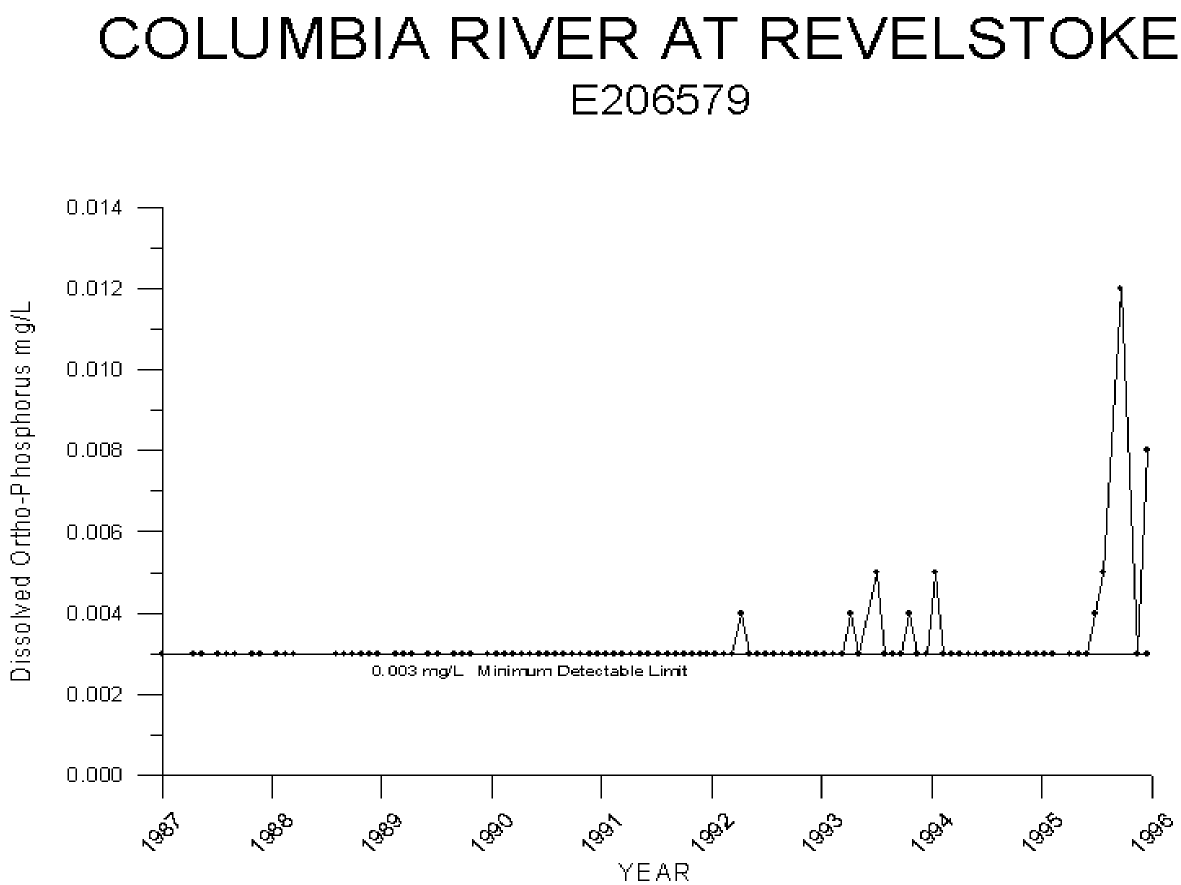


Figure 34 Total Phosphorus

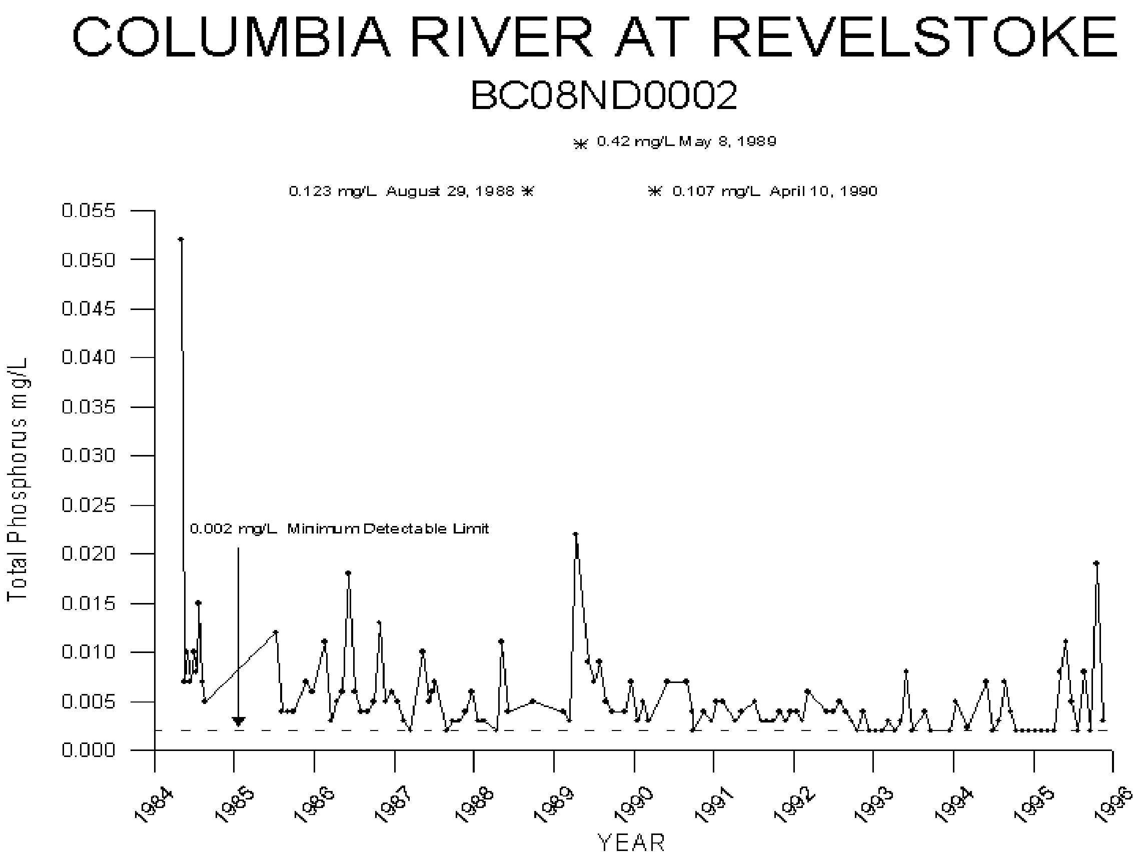


Figure 35 Potassium

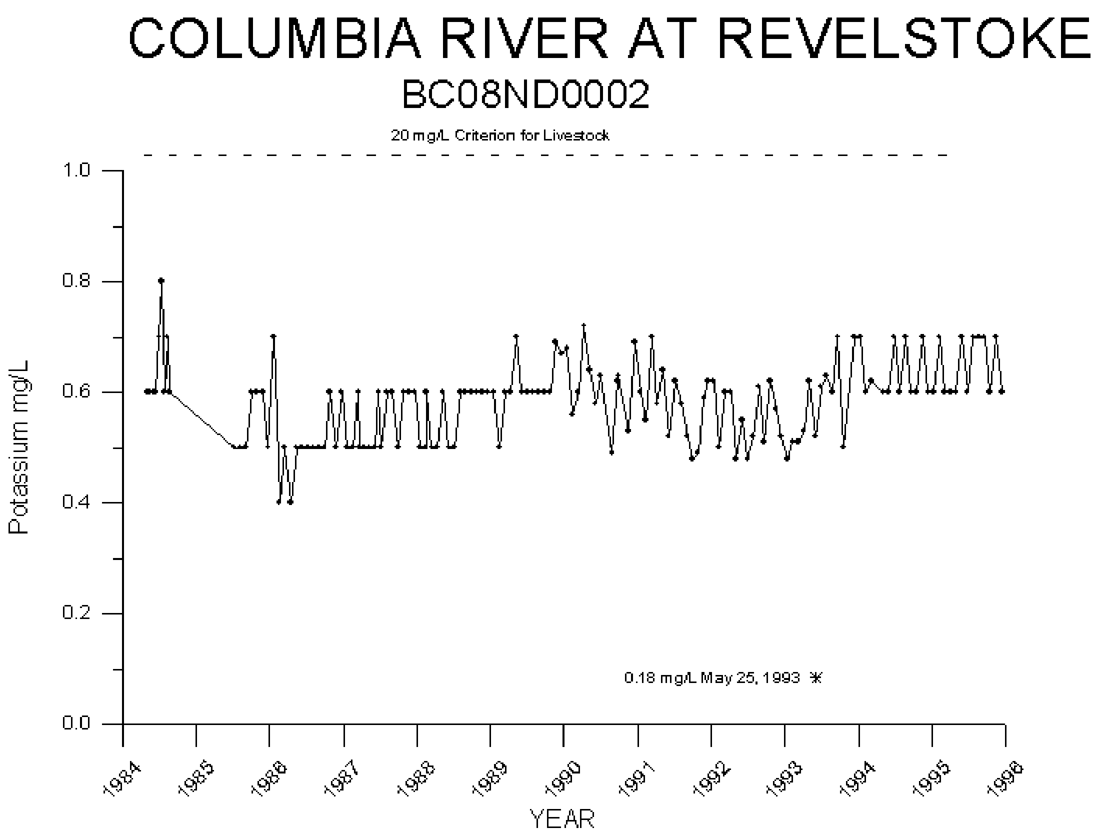


Figure 36 Filterable Residue

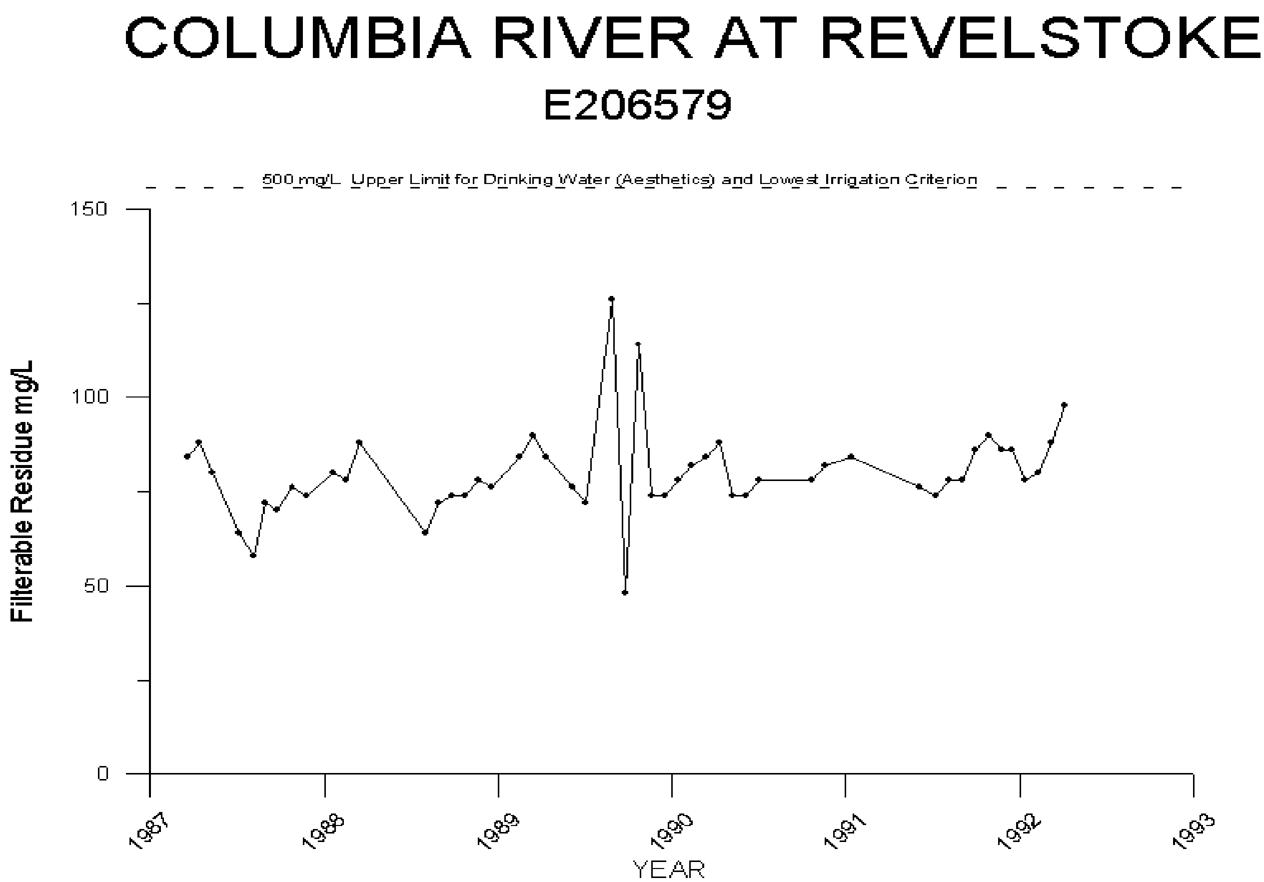


Figure 37 Non-Filterable Residue

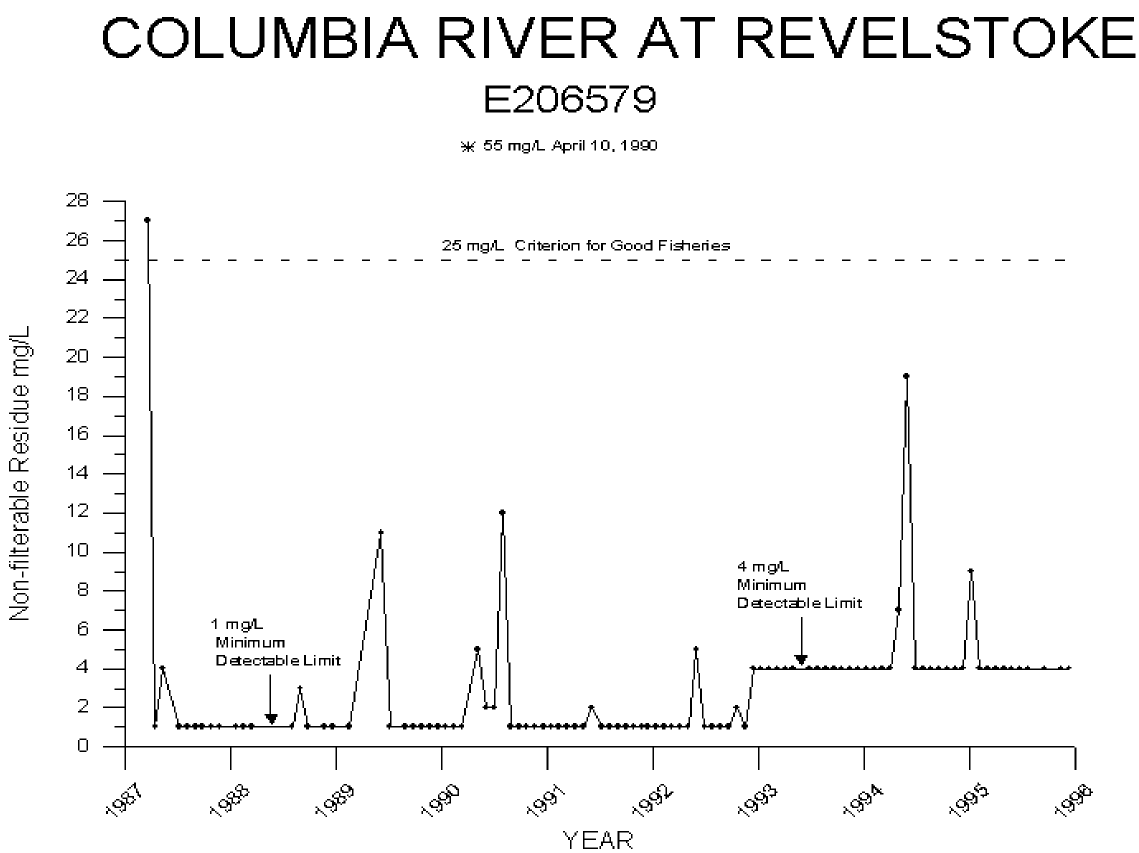


Figure 38 Total Selenium

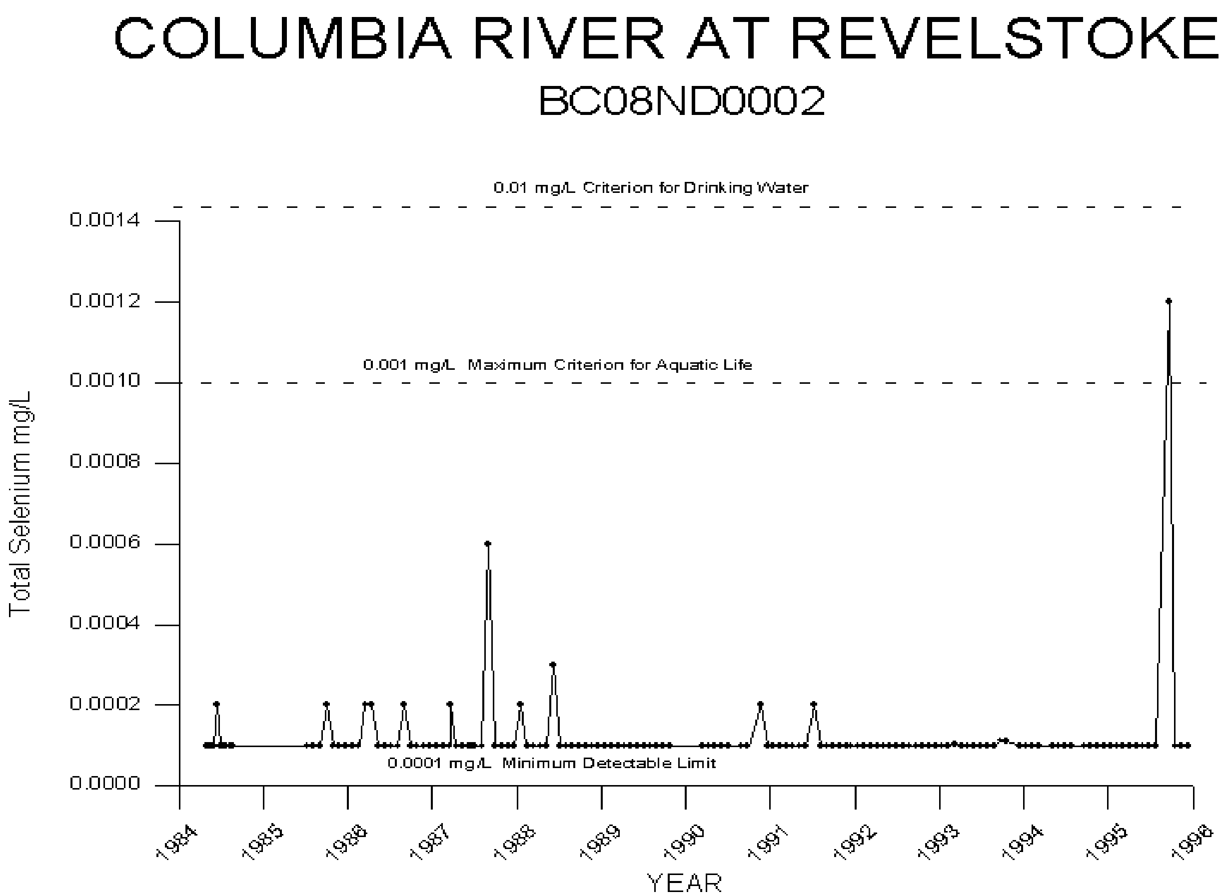


Figure 39 Silica

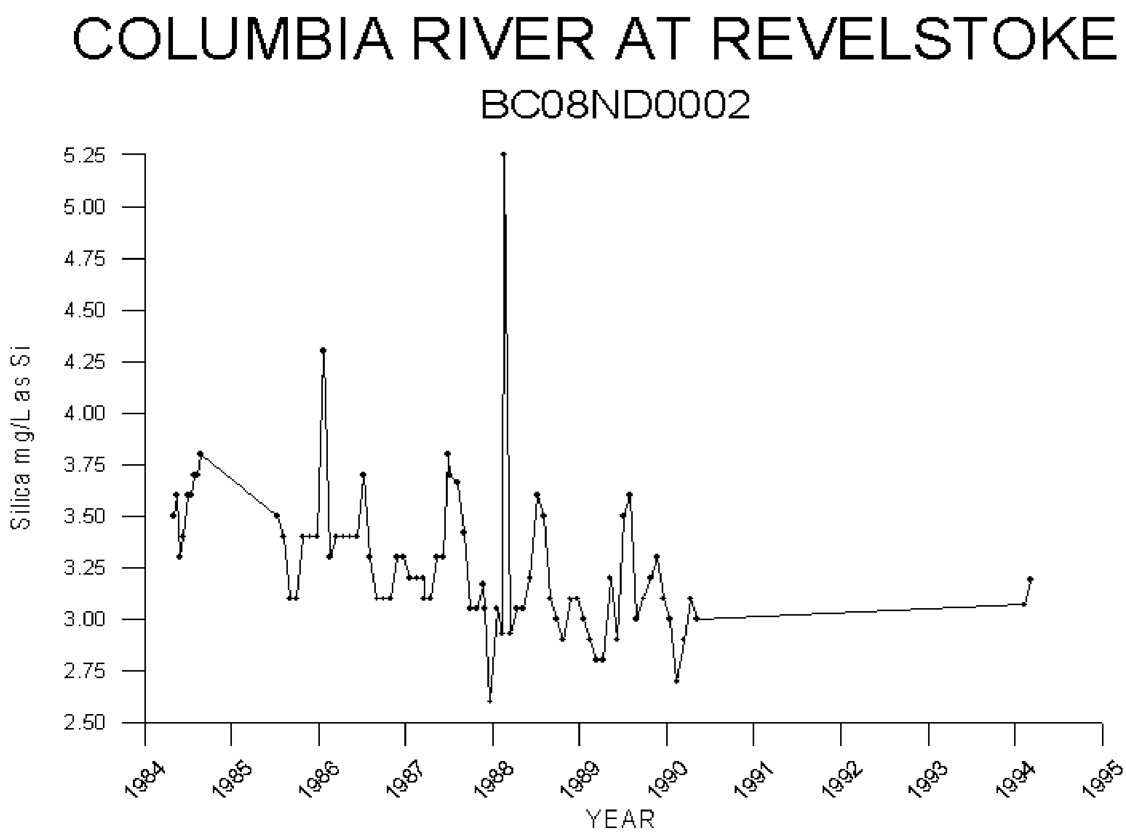


Figure 40 Sodium

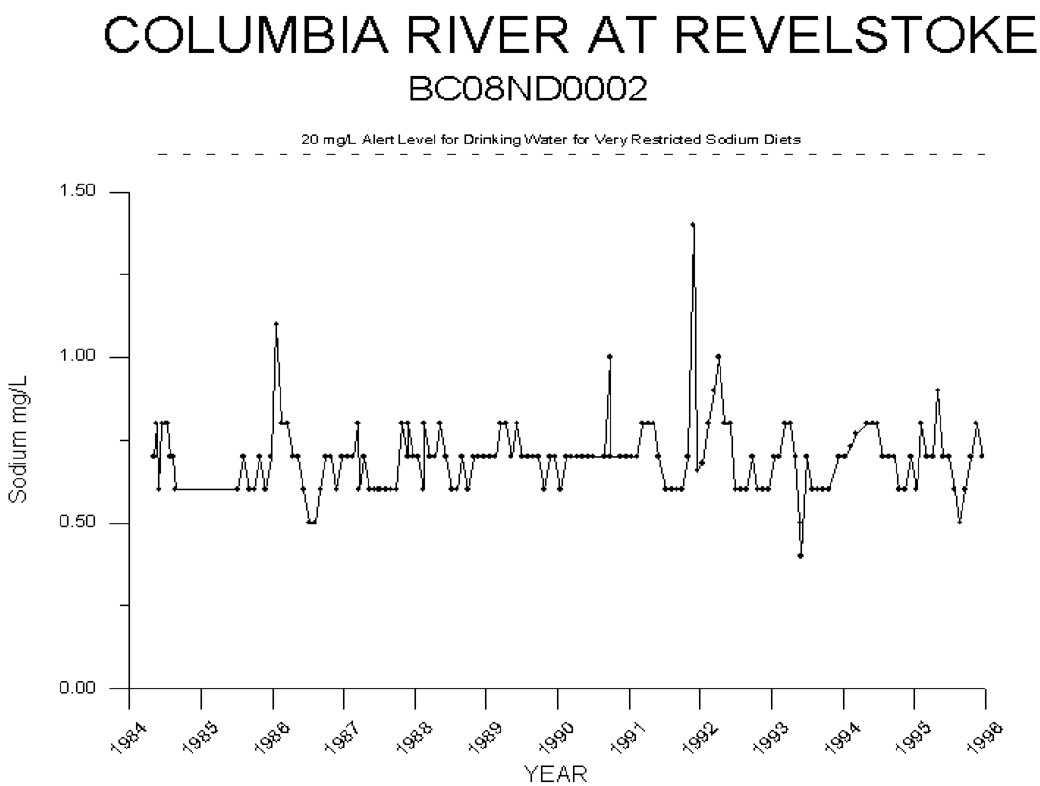


Figure 41 Specific Conductivity (federal)

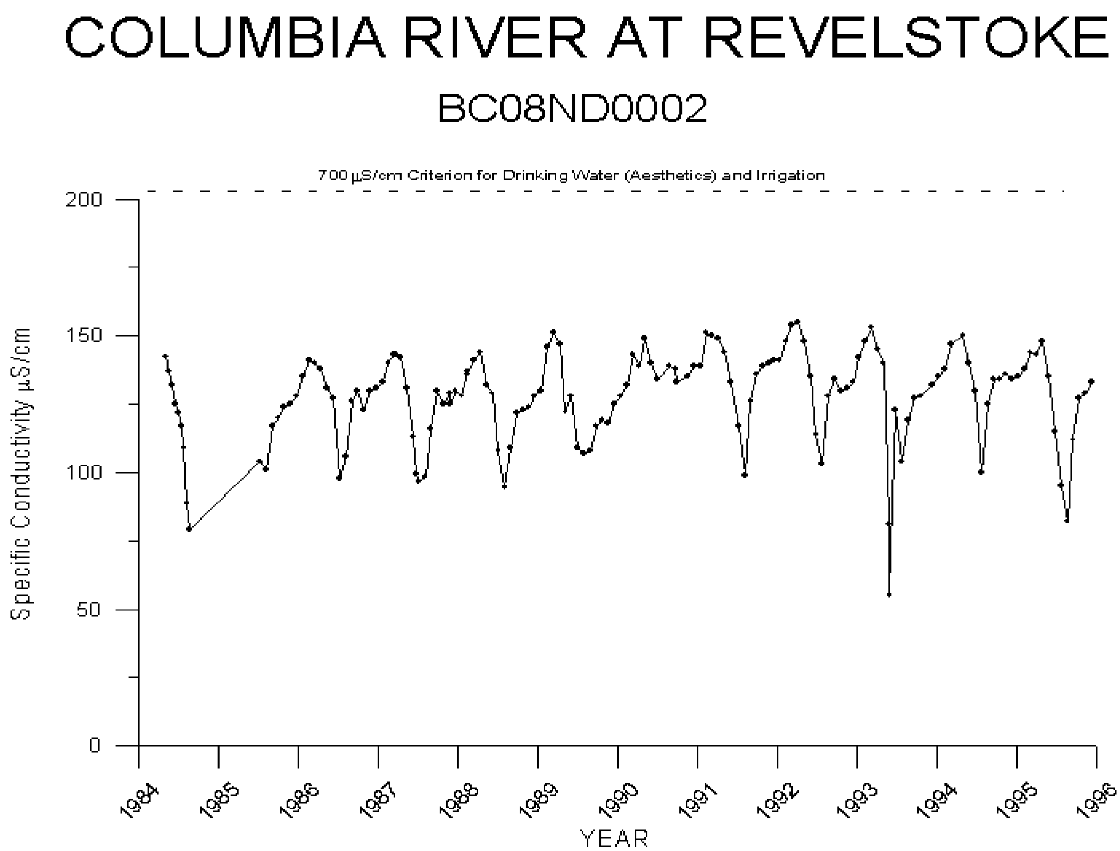


Figure 42 Specific Conductivity (provincial)

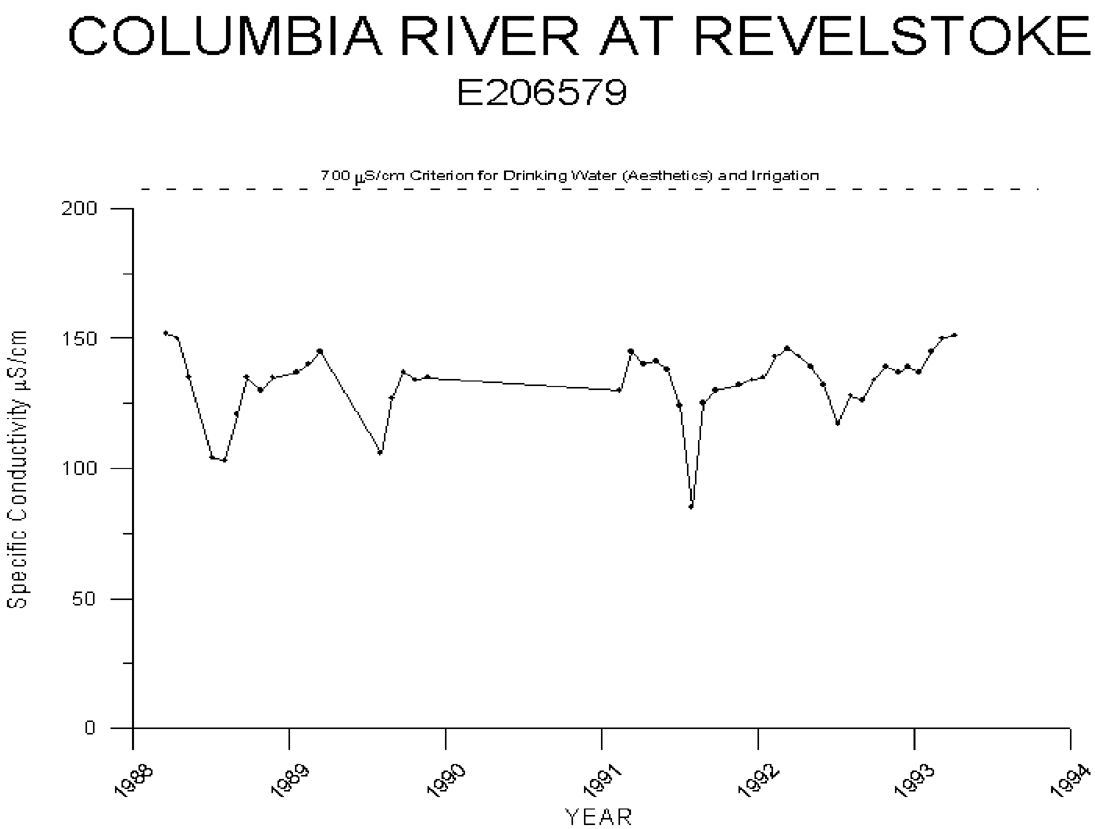


Figure 43 Total Strontium

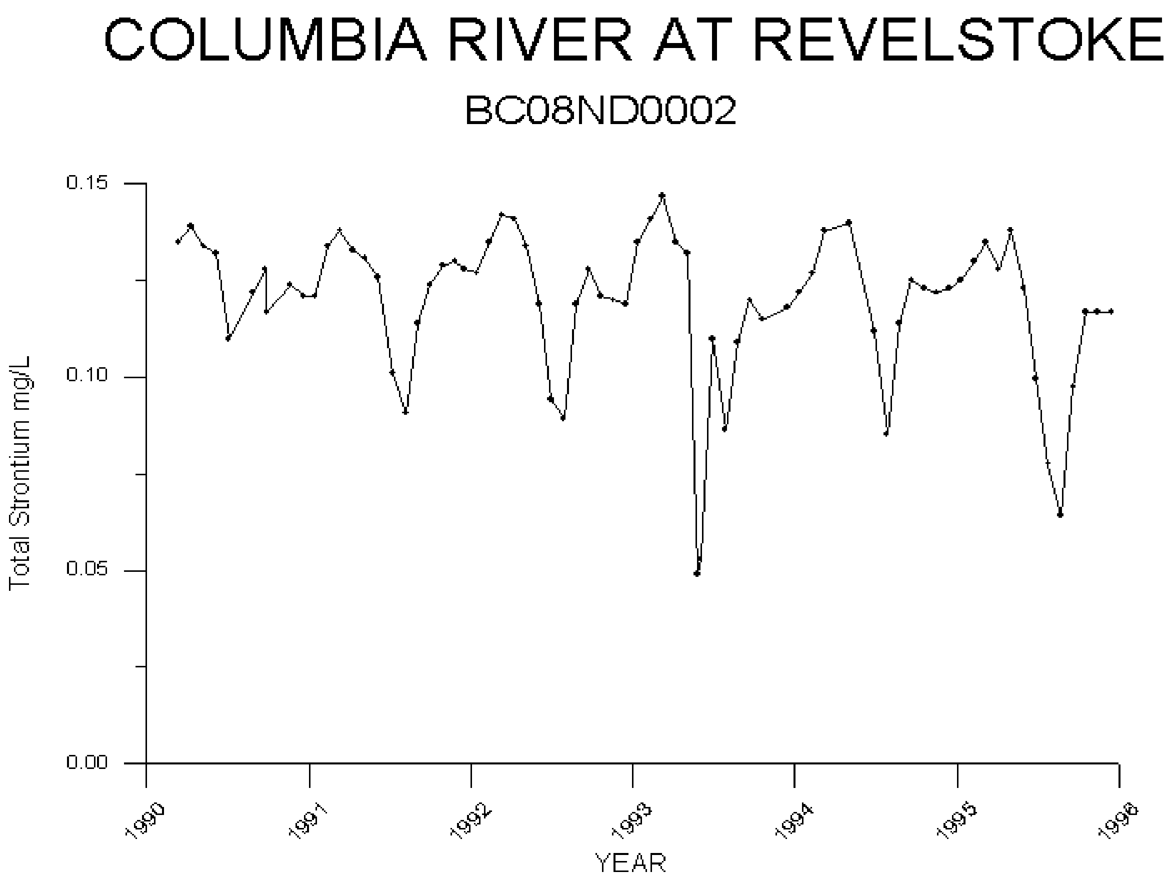


Figure 44 Dissolved Sulphate

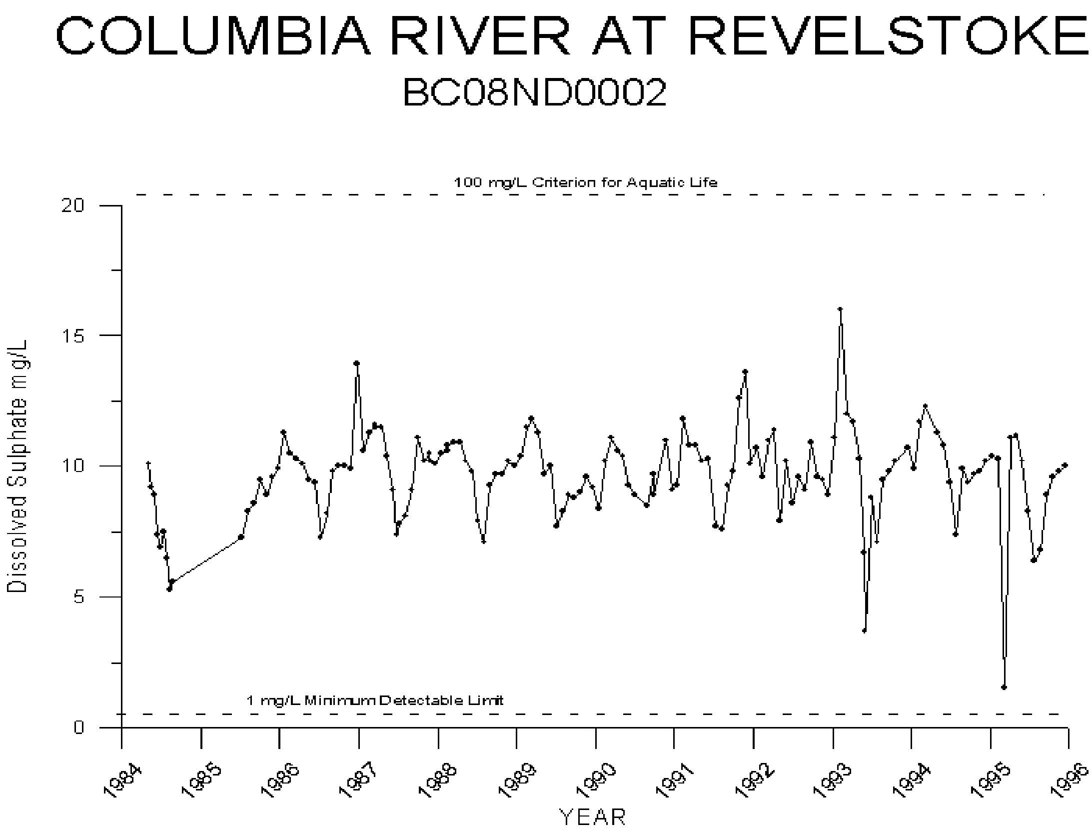


Figure 45 Air Temperature

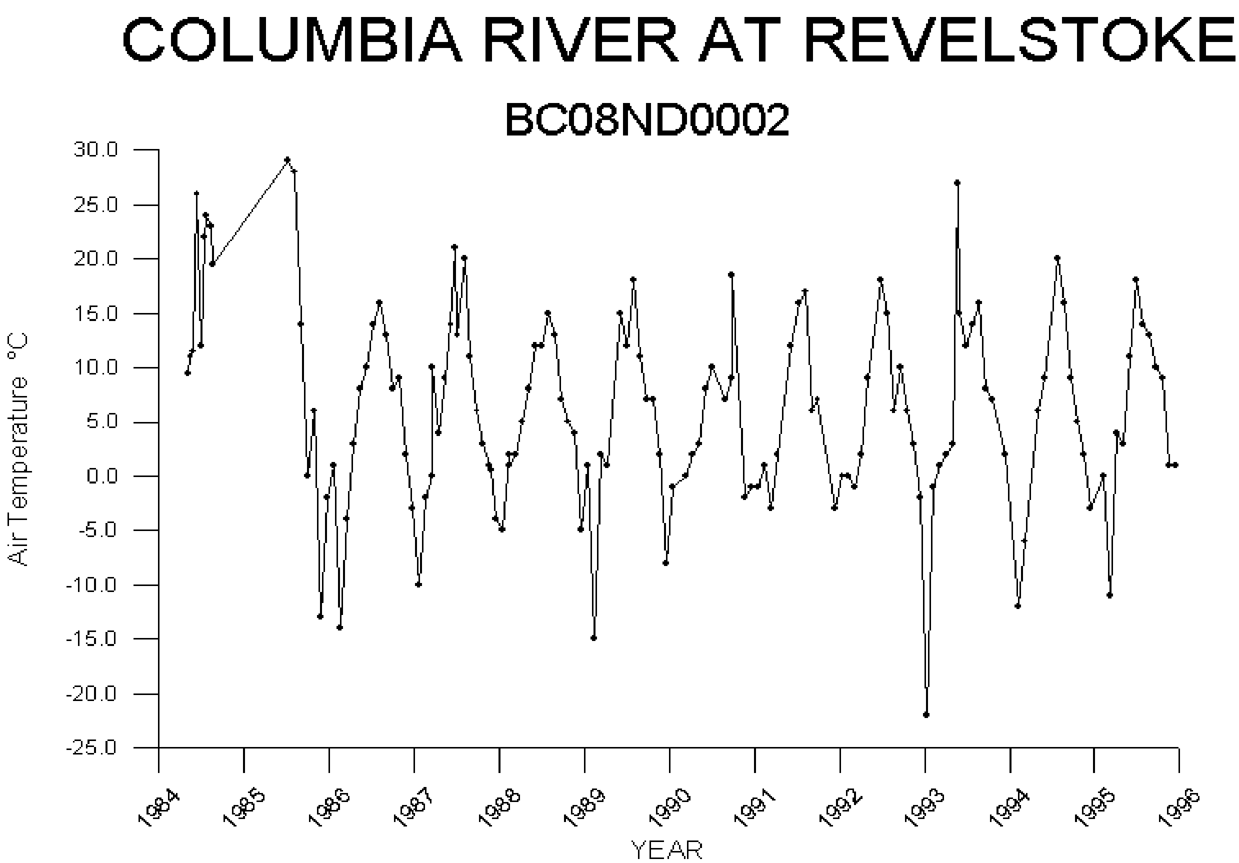


Figure 46 Water Temperature

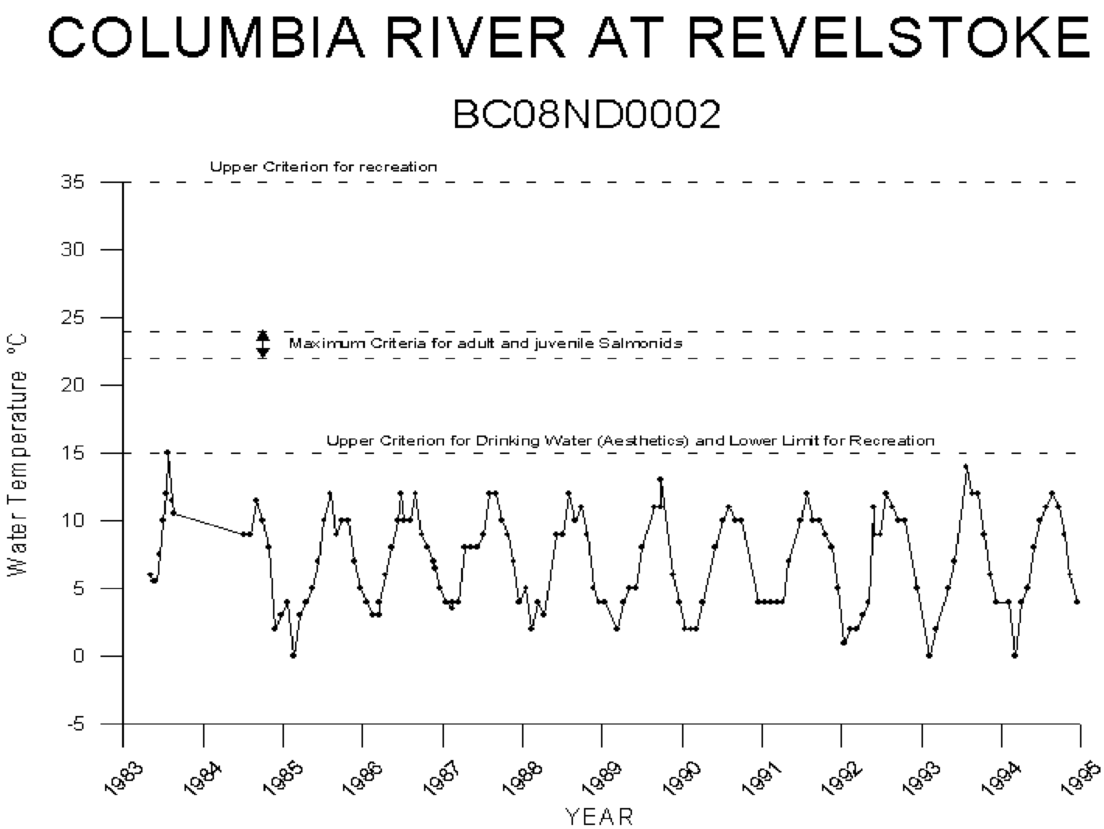


Figure 47 Turbidity

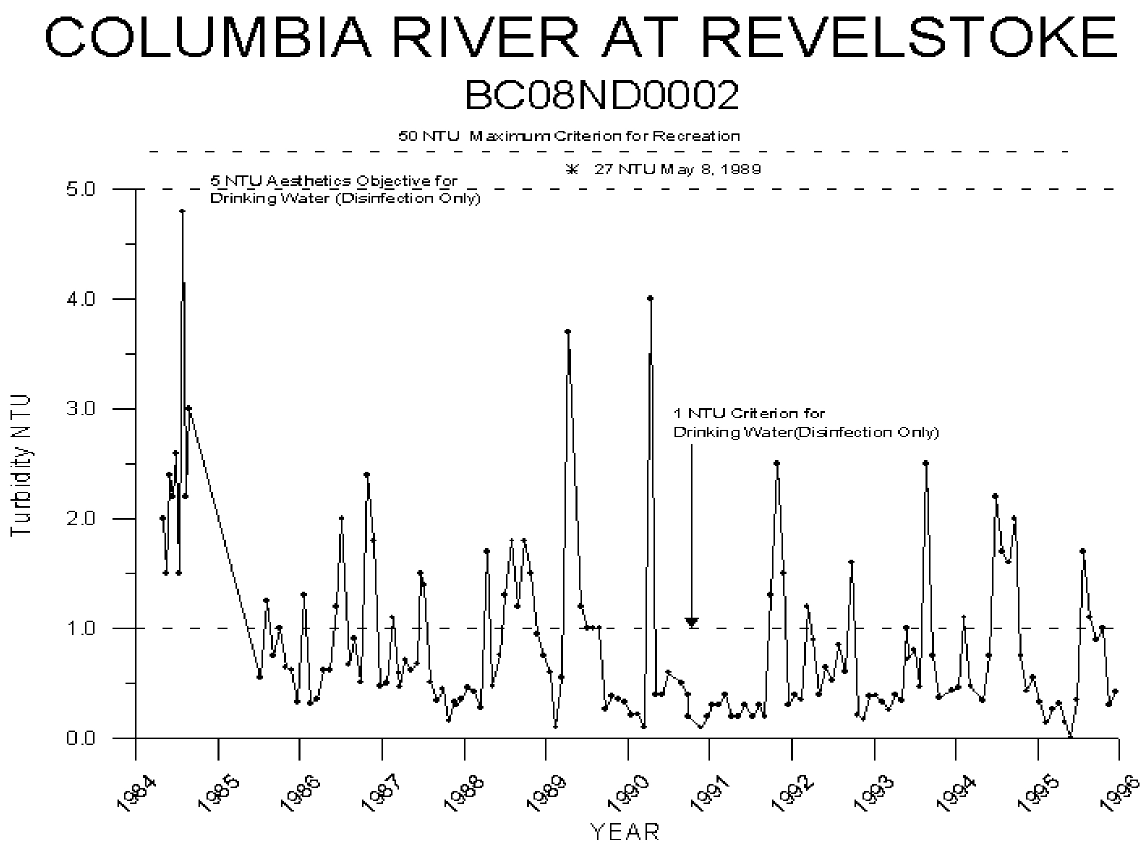


Figure 48 Total Vanadium

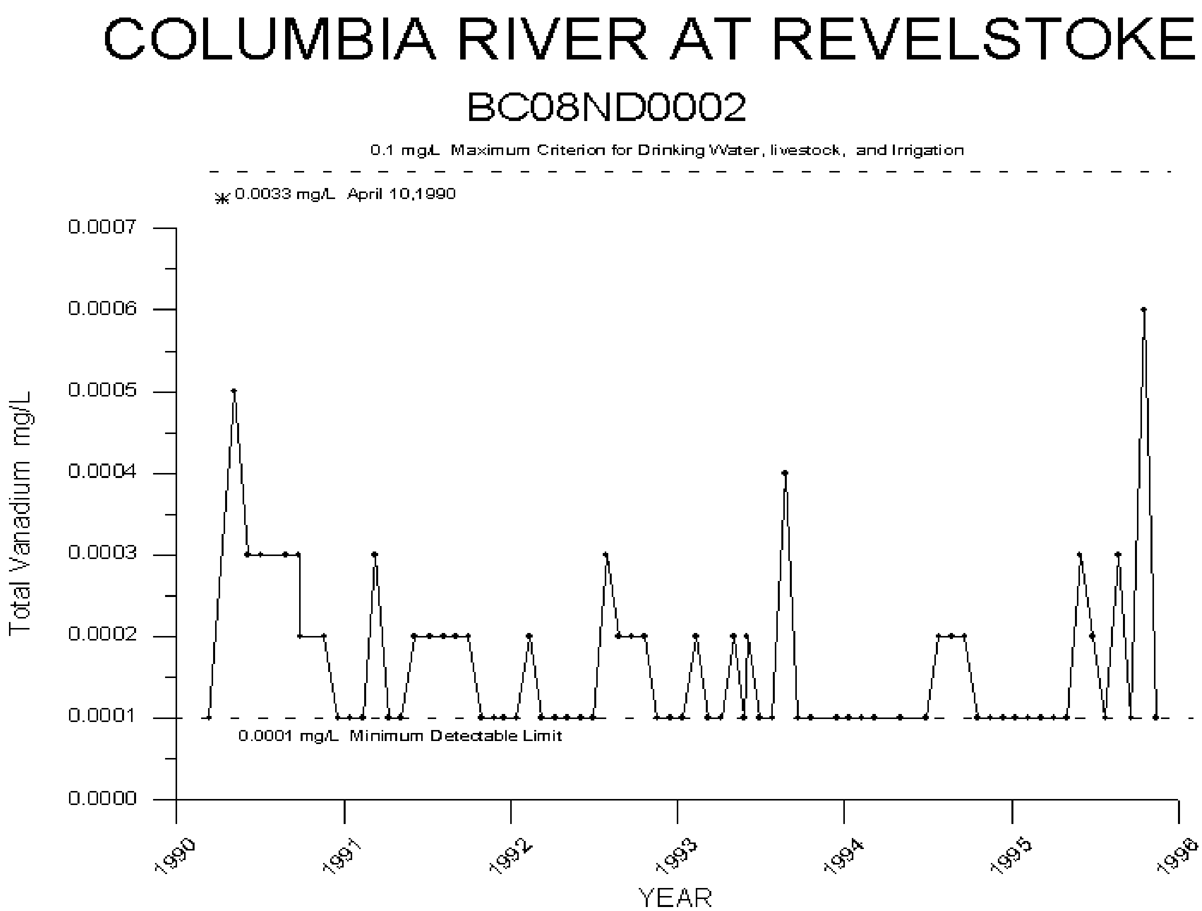


Figure 49 Total Zinc

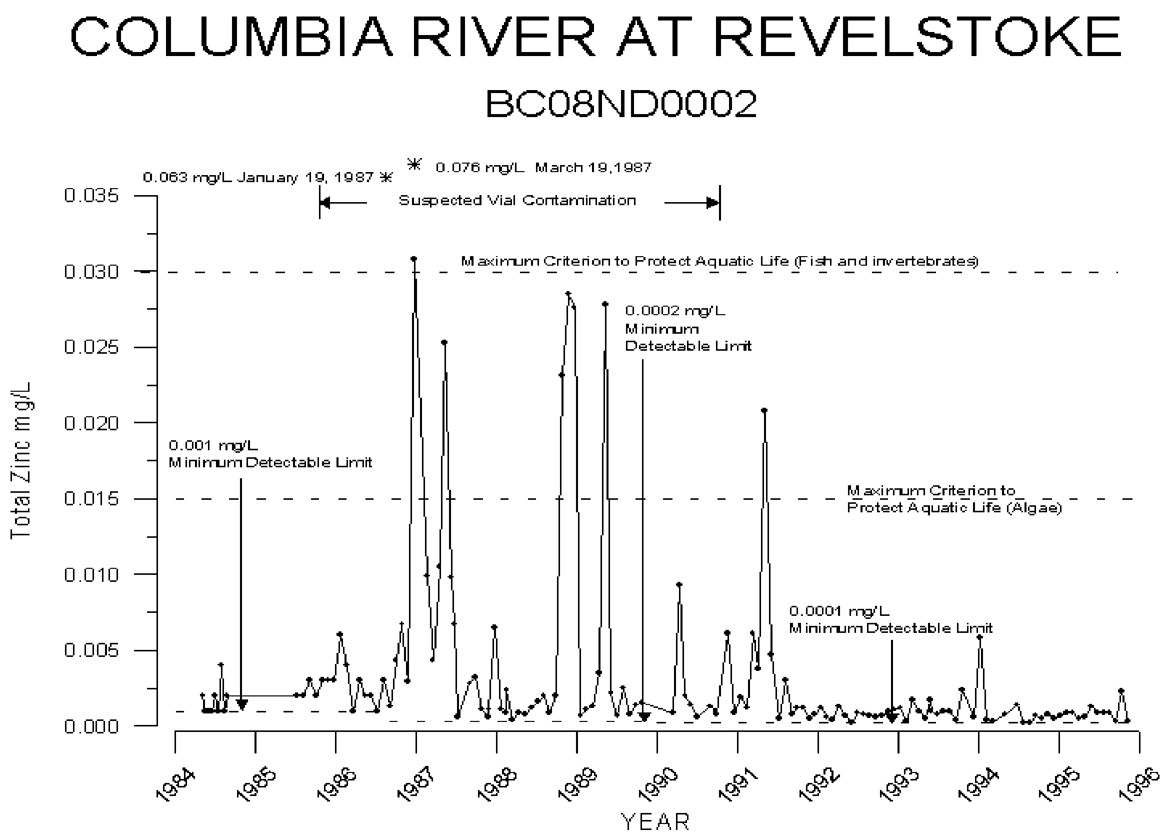
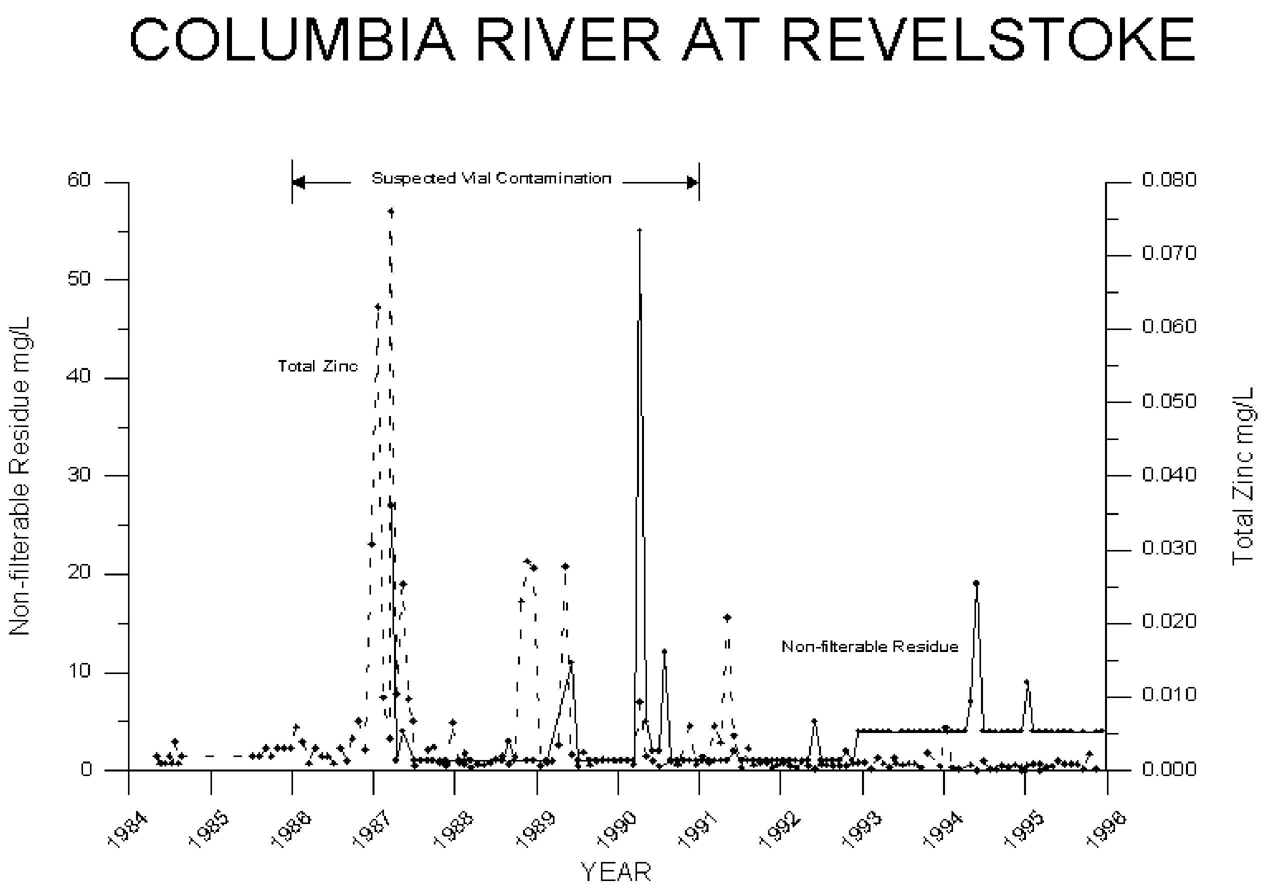


Figure 50 Total Zinc and Non-filterable Residue



References

Columbia Basin Fish & Wildlife Compensation Program. 1999. Program Update Newsletter, Winter 1999, Number 6.

EC-INFO for Pacific and Yukon Region. Surface Water Quality Monitoring Data in British Columbia. Environment Canada, Vancouver.

EMS (Environmental Monitoring System). Ministry of Environment, Lands and Parks, Victoria, B.C.

MacLeod C. and P.H. Whitfield. 1996. Seasonal and Long-Term Variations in Water Quality of the Columbia River at Revelstoke, B.C. Northwest Science, Vol. 70, No. 1, p 55-65.

McDonald, L. 1996. Personal Communication. Pollution Prevention and Pesticides, Ministry of Environment, Lands and Parks, Cranbrook, B.C.

Nagpal, N.K., L.W. Pommen, and L.G. Swain. 1997. Approved and Working Criteria for Water Quality - 1997. Water Quality Section, Water Management Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. (In Press).

Pommen, L.W. 1996. Personal Communication. Water Quality Branch, Ministry of Environment, Lands and Parks, Victoria, B.C.

Pommen, L.W. 1994. Mercury Monitoring Issue (Mark II). Presented at the Environmental Impact Biologists' Meeting. February 21-22, 1994. Victoria, B.C. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, B.C.

Regnier, R. 1998. Trend Analyses of Total Phosphorus in the Columbia River at Revelstoke 1986-1996. Unpublished report prepared for B.C. Ministry of Environment, Lands and Parks by Central Limit Statistical Consulting.

Water Survey of Canada. Surface Water and Sediment Data to 1993. Environment Canada, Ottawa.