Water Quality Trends in the Fraser River Basin, 1985-1995

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Abstract:

Water quality data have been collected at nine river sites in the middle and upper Fraser River Basin on a monthly or biweekly basis since 1985 under a joint program conducted by both Environment Canada and the British Columbia Ministry of Environment, Lands and Parks. Statistical analysis of this data set for the period 1985 to 1990 was reported by Shaw and El Shaarawi (1995). The present work uses statistical techniques applied in this previous study to an additional 5 years of data.

Techniques applied included a range of graphical and statistical methods, including a variety of commonly used non-parametric methods, parametric regression modelling and intervention analysis. After careful screening of the data for completeness and errors, a set of 8 stations and upwards of 43 were analysed. The suite of variables covered routinely measured chemical and physical parameters, such as physicals, dissolved ions, dissolved nutrients, microbials, total metals and, at a few localities, adsorbable organohalogens.

Both increasing and decreasing trends in constituent concentrations were found throughout the basin, and in many cases these would seem to be related to natural phenomena. Anthropogenic influences were, however, clearly implicated in some of the strongest trends. Bleaching process changes implemented in the early 1990s had an immediate and dramatic effect in reducing levels of dissolved chloride. Other more subtle trends were perhaps related to human activity. Analyses of data from the one small-basin monitoring site, the Salmon River at Salmon Arm, identified trends in turbidity and dissolved ions may be related to development patterns in the watershed.

Résumé

Depuis 1985, des données sur la qualité de l'eau, provenant de neuf stations dans des cours d'eau situés à l'intérieur des tronçons moyen et supérieur du bassin hydrographique du Fraser, ont été recueillies sur une base mensuelle ou bimensuelle en vertu d'un programme appliqué de concert par Environnement Canada et par le ministère de l'Environnement, des Terres et des Parcs de la Colombie-Britannique. L'analyse statistique de l'ensemble de données recueillies entre 1985 et 1990 a été présentée par Shaw et El Shaarawi (1995). Dans la présente étude, les chercheurs appliquent à une nouvelle période de 5 ans les techniques statistiques appliquées antérieurement.

Il s'agit de différentes méthodes graphiques et statistiques, notamment des méthodes non paramétriques communément employées, la modélisation par régression paramétrique et l'analyse par intervention. Après un examen préliminaire attentif, pour s'assurer qu'elles sont complètes et exemptes d'erreurs, les chercheurs ont analysé les données provenant de 8 stations et portant sur 43 variables. La série de variables couvrait des paramètres physico-chimiques courants, p. ex., les conditions physiques, les ions en solution, les nutriments en solution, les microorganismes, le total des métaux et, à quelques endroits, les composés organohalogénés adsorbables.

Quant à la concentration des constituants, des tendances à la hausse comme à la baisse sont observées partout dans le bassin. Dans de nombreux cas, elles semblent dépendre de phénomènes naturels. Toutefois, des influences anthropiques se manifestent clairement au niveau des tendances les plus fortes. Les changements apportés au procédé de blanchiment, au commencement des années 1990, ont eu un effet immédiat et très prononcé sur la baisse de la teneur en chlorure en solution dans l'eau. D'autres tendances plus fines étaient peut-être reliées également à l'activité humaine. L'analyse des données en provenance de la seule station située dans un petit sous-bassin, celui de la rivière Salmon à Salmon Arm, a mis en évidence des tendances des paramètres que sont la turbidité et les ions en solution, peut-être associées à l'utilisation du territoire à l'intérieur de ce sous-bassin.

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1 Introduction

The Fraser River originates high in the Rocky Mountains along the British Columbia - Alberta border and flows approximately 1,400 km to the Pacific Ocean near Vancouver. The drainage basin covers a total area of 233,000 km^2, or almost one quarter of the total B.C landmass (Dorcey and Griggs 1991), and supports about 80 percent of the total economic production for the province. Contained within the basin is approximately 44 percent of the farmland and almost half of the total harvestable forest area of B.C. About two-thirds of the province's total population, or 2.5 million people, presently reside within the basin's boundaries (1997 BC Facts from Statistics Canada).

Renowned for supporting the world's largest salmon run (Northcote and Larkin 1989), six different species of salmon spawn and return to the basin. Over 60 percent of the provincial sockeye and pink salmon catch come from the Fraser River and tributaries. The basin is also home to 21 different waterfowl species, easily surpassing all other basins in the province in terms of both waterfowl diversity and population.

Maintenance of water quality as a fundamental component of the aquatic environment is crucial to the productivity of the Fraser Basin. Synoptic studies of patterns in water quality in the upper basin have been conducted by a number of researchers (Cameron 1996; Cameron *et al.* 1995; Schreier *et al.* 1991; Whitfield 1983; Whitfield and Schreier 1981). These studies have provided a valuable "snap-shot" of regional and longitudinal trends in water quality from the headwaters to the Fraser Valley and identified important factors determining constituent composition in the Fraser River and tributaries.

Temporal studies have been conducted recently using data available from long-term water monitoring data. Water quality in the Fraser River and significant tributaries has been monitored under the Canada-BC Water Quality Monitoring Agreement. At most sites, the data series of monthly or biweekly samples extends to 1985. Preliminary statistical analysis of this data set from 1985 to 1990 was conducted through the Fraser River Action Plan by Shaw and El-Shaarawi (1995). The analysis included application of a variety of parametric and non-parametric statistical methods for investigation of trends in five years of data available at the time. The data series was relatively short for robust analysis of trends, and a key recommendation was for further study using the same methods when additional data became available, probably at five year intervals.

The present report addresses this recommendation, applying statistical and graphical methods used by Shaw and El-Shaarawi (1995) on a full 10 years of water quality data from the Fraser River sites.

2 Influences on Water Quality in the Fraser River

2.1 Natural Processes

Both natural and anthropogenic factors influence water quality in the Fraser River Basin. The principal natural factor affecting Fraser basin water quality is the character of the underlying bedrock (Hem 1992; Wetzel 1983; Muir and Johnson 1979).

A simplified map of the bedrock geology in the Fraser River Basin is presented in Figure 1. Groundwater infiltration, rainfall runoff, snowmelt, glacial-melt and the rivers themselves interact with these soils and bedrock, producing water containing solutes and sediments. These interactions are driven primarily by river discharge. Periods of high stream discharge increase streambed erosion, contributing to an increase in sediment-related constituents such as turbidity, residues, and total metals. Other constituents, such as dissolved ions, generally show inverse relationships with discharge due to dilution of groundwater flows.

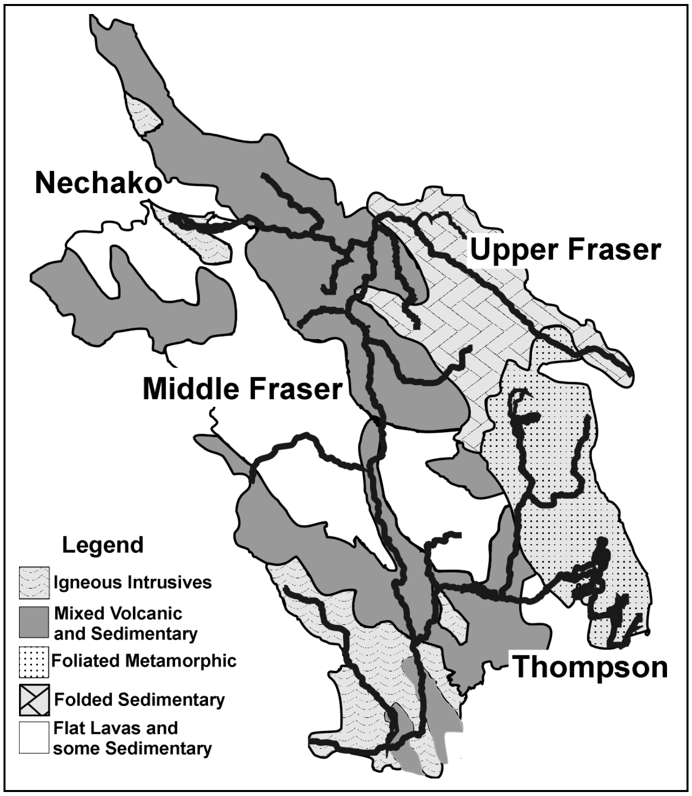


Figure 1. Bedrock geology of the Fraser River Basin (after Schreier *et al.* 1991).

2.2 Anthropogenic Activities

Land use for activities such as agriculture, forestry, urban development, and industrial manufacturing and processing are some of the anthropogenic factors affecting the water chemistry in the basin (Shaw and El-Shaarawi 1995).

Agricultural effects include the use of chemical fertilizers, pesticides and cattle manure which can contribute to nutrient pollution in surrounding streams and groundwater (Dorcey and Griggs 1991). Runoff from cattle feeding and holding areas can also result in local increases of bacteriological variables, such as the fecal coliforms.

Forestry-related land uses have these three main issues of concern:

1) loss of riparian margins, resulting in elevated water temperatures;
2) sediment load increases from soil destabilization, and;
3) nutrient leaching (Dorcey and Griggs 1991).

Direct discharges to the river are also of concern. There are at least 27 major permitted waste discharges in the upper Fraser River Basin (see summary Table 1). The majority of these are sewage discharges, either from municipal treatment plants or private residences (Norecol 1993). Water quality variables which would be affected by sewage discharges

Table 1. Major permitted waste discharges in the Upper Fraser River Basin (summarized from Shaw & El Shaarawi 1995).

Effluent Type	Total Permitted Volume (m^3/day)	Downstream WQ site	Expected effluent constituents (summarized from Norecol 1993)
Sewage	1,923	Hansard	Metals, fecal coliforms, nutrients, Cl, suspended sediments
Sewage	10,570	Nechako	
Wastewater	182	Nechako	Metals, fecal coliforms, nutrients, Cl
Chemical Plant	14,200	Marguerite	Wide range of metals
Kraft Mill	548,200	Marguerite	Chlorinated compounds, nitrate, suspended sediments
Pulp Mill	28,000	Marguerite	Chlorinated compounds, absorbable organohalides, colour, nitrate, suspended sediments
Sewage	48,826.5	Marguerite	Metals, fecal coliforms, nutrients, Cl

are coliforms, dissolved nutrients (particularly phosphorus), some dissolved ions (such as dissolved chloride), and a wide range of water-borne metals.

In terms of total effluent discharge volumes, pulp and paper production is by far the most significant industrial activity in the upper Fraser River Basin. In a reach of about 150km on the mainstem Fraser River are five pulp and paper mills which together contribute about 75 percent of the total effluent discharged to the Fraser River Basin above Hope (Schreier *et al.* 1991).

Chlorinated compounds found in bleached kraft mill effluents (BKME) have received particular attention due to their persistence and potential for bioaccumulation in tissues. Process changes by B.C. pulp and paper mills over the past decade have resulted in dramatic declines in most chlorinated effluent components. Defoamers and other chemicals in the brownstock process have been changed, the use of chlorophenol-treated wood chips has ceased, and mills have also implemented a program of progressive substitution of chlorine dioxide for elemental chlorine in the bleaching process (Schreier *et al.* 1991).

3 Water Quality Monitoring in the Fraser River Basin

Within the Fraser River Basin are nine long-term water quality monitoring sites; five on the Fraser River mainstem (Red Pass, Hansard, Stoner, Marguerite, Hope) and four on tributaries of the Fraser mainstem (Nechako, Thompson, Salmon, Sumas). Locations and details of the sites are summarized in Table 2. Water samples have been collected from these sites on a bi-weekly or monthly basis since the mid 1980s under a Federal-Provincial Water Quality Monitoring Agreement. Occasional breaks in monitoring at some sites have occurred, such as extended periods when field personnel were not available (Ryan, personal communication 1997).

Water samples collected at each site are field-preserved as needed and shipped to analytical laboratories for determinations. Analytical results are entered into electronic databases (EC - ENVIRODAT; BCMoELP - EMS). A detailed quality assurance program at each stage from sampling to data entry ensures minimal error in the final archived data set (McNaughton *et al.* 1990), and suspect data are included but flagged as such in the database.

An extensive suite of water quality constituents are measured by EC and BCMoELP. For convenience, constituents are divided into the following groupings:

- **Physical Parameters**: general characteristics not attributable to a particular constituent; e.g. temperature, pH, specific conductivity, colour, and sediment-related parameters such as turbidity and non-filterable residue (NFR).
- **Dissolved Ions**: dissolved ion concentrations such as calcium, magnesium, and chloride.
- **Nutrients**: dissolved nitrogen and phosphorus.
- **Trace Metals**: total concentrations of metals such as aluminum, copper, lead, and zinc.
- **Organics and microbials**: adsorbable organohalides (AOX) and fecal coliforms.

The water quality monitoring sites are located in the vicinity of Water Survey of Canada gauging stations, and these data are also available for modelling and interpretation of chemical constituent patterns.

Table 2. Locations and brief site descriptions for monitoring sites analyzed in this report.

Location	EC Envirodat Number	BC EMS Number	Site Description
Fraser River @ Red Pass Latitude: 52° 59' 17" Longitude: 119° 00' 33"	BC08KA0007	-N/M-	- at the outlet of Moose Lake; represents the water quality in the upper basin.
Fraser River @ Hansard Latitude: 54° 04' 39" Longitude: 121° 50' 48"	BC08KA0001	E206580	-reference water quality in the Fraser mainstem before the first major population centre at Prince George.
Fraser River @ Stoner Latitude: 53° 38' 18" Longitude: 122° 39' 58"	-N/M-	E206182	-reflects the influence of effluent discharges to the Fraser mainstem at Prince George.
Fraser River @ Marguerite Latitude: 52° 31' 48" Longitude: 122° 26' 33"	BC08MC0001	0600011	- isolates the effect of effluent discharges into the Fraser mainstem at Quesnel from that monitored at Stoner.
Fraser River @ Hope Latitude: 49° 23' 14" Longitude: 121° 27' 03"	BC08MF0001	E206581	-data collected here integrates effects of upper Fraser effluents; provides a background for the Lower Fraser Valley.
Nechako River near Prince George Latitude: 53° 55' 38" Longitude: 122° 45' 54"	BC08KE0010	E206583	- measures the effects of upstream flow regulation and indicator of water quality of a major tributary to the Fraser.
Salmon River @ Hwy. 1 crossing Latitude: 50° 41' 29" Longitude: 118° 19' 44"	BC08LE0004	E206092	- established in 1988 in response to concerns of declining water quality in the basin
Thompson River @ Spences Bridge Latitude: 50° 25' 15" Longitude: 121° 20' 29"	BC08LF0001	E206586	- measure of water quality of the largest tributary of the Fraser River and influence of industrial discharges at Kamloops.
Sumas River @ Internat. Boundary Latitude: 49° 00' 10" Longitude: 122° 13' 50"	BC08MH0027	N/M	- transboundary site; monitoring to measure effect of agricultural activity and Sumas water treatment.

N/M – The site is **N**ot **M**onitored by this agency.

4 Methods

4.1 Exploratory Data Analysis

Exploratory data analysis (EDA) procedures were employed in an initial screening of the dataset. EDA procedures screen data for evidence of contamination, extent of censoring (records below detection limits), and any obvious outliers and inconsistencies. Apart from computing basic summary statistics (such as means, medians, minima, maxima, number of observations) EDA procedures are best represented by graphical displays of the data. Time series and box and whisker plots (Tukey 1977), blocked by month and by year, were used in the initial data explorations.

The data series was further screened for selection of variables for trend analysis. The following criteria were employed:

(1) series with >80% of observations present;
(2) series with >80% of observations above detection limit

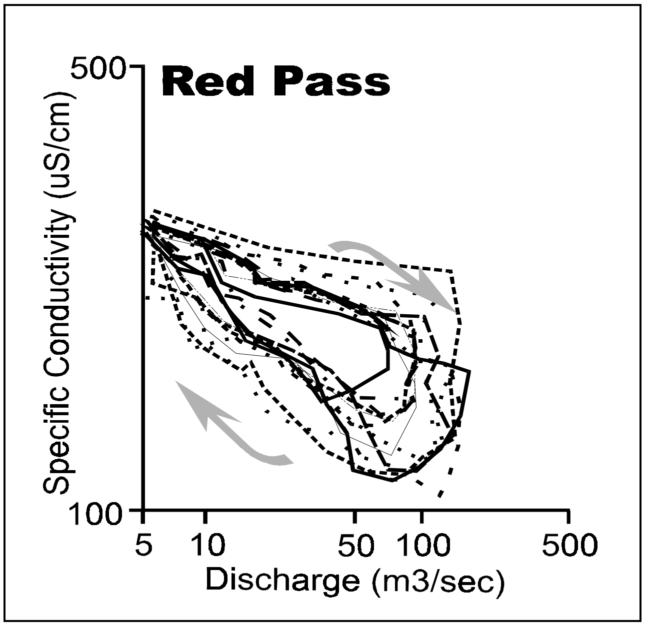


Figure 2. Discharge and specific conductivity relationship in the Fraser River at Red Pass for the years 1985 - 1996. Each loop represents the progress in an January-December cycle in the discharge-conductivity relationship

In some instances where monitoring was either sporadic or disrupted for some reason, a subset of the data series comprising the longest continuous block of observations was selected for analysis.

Plots of discharge-constituent patterns were used to better understand the nature of the observed water quality patterns and extent of hysteresis* in the relationships (*e.g.*: Figure 2). Williams (1989) and Whitfield and Whitley (1986) provided a classification and mechanism for the possible forms arising in these plots (Table 3).

4.2 Statistical Methods: Non-Parametric Analyses

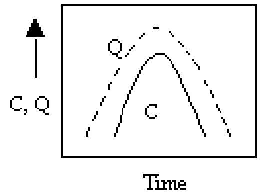
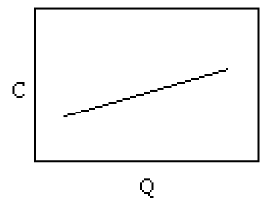
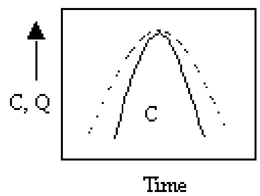
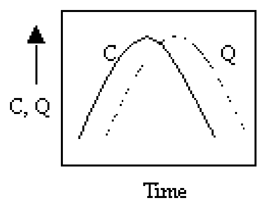
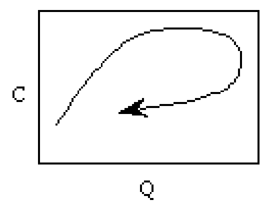
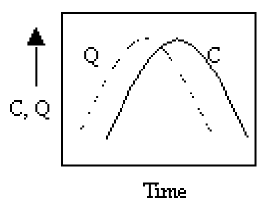
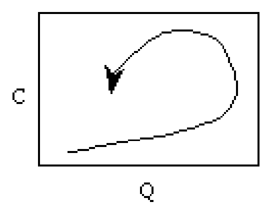
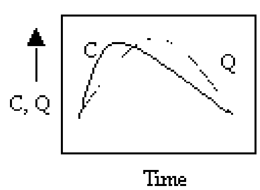
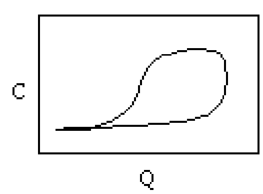
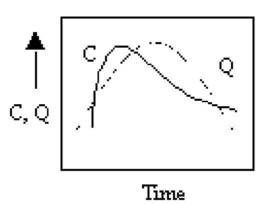
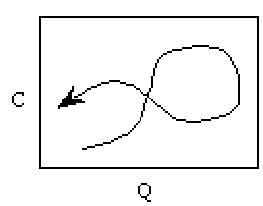
Non-parametric tests to detect trends in water quality have been used in the past (Yu and Zou 1993; Walker 1991; Gilbert 1987; Hirsch and Slack 1984). The relative simplicity and minimal data assumptions of these tests make them a popular choice in analysis of water quality time series. Five different non-parametric tests, the S*easonal Kendall's Tau*, the *modified Seasonal Kendall's Tau*, the *Van Belle and Hughes* tests for homogeneity of trends and for trends across time and the *Sen's Slope estimator* (Gilbert 1987; Helsel 1988) were used to detect and determine magnitude of trends in the Fraser River water quality data. Computational details and background information may be found in El Shaarawi *et al*. (1991); Gilbert (1987); Helsel and Hirsch (1992); Shaw and El Shaarawi (1995).

4.3 Parametric Statistics

Non-parametric statistics test for monotonic changes in data series with minimal assumptions of normality, and, in some instances, serial dependence. However, these methods are of limited value in constructing the forms of any detectable trends. Regression analysis has been used for this purpose and has been applied to water quality data (El-Shaarawi *et al*. 1983; Esterby *et al*. 1989). The modelling approach used here

* Hysteresis - The dependence of the state of a system on its previous history, generally in the form of a lagging of an effect behind its cause.

Table 3. Summary of patterns in water quality constituent-discharge relationships. C = water quality constituent concentration, Q = river discharge (*after Williams 1989*).

CLASS	SHAPE	FORM	DESCRIPTION
1a			- both C and Q peak simultaneously *Class 1a:* both variables have simultaneous peaks and identical duration. *Class 1b* both variables have simultaneous peaks, but different duration.
1b			
2			Constituent concentration peaks before discharge with similar duration.
3			Constituent concentration lags behind discharge and with similar duration.
4			These single-value-plus-loop hysteresis are similar to class 2 and 3 hysteresis.
5			Occurs under certain circumstances that very rarely occur. Little attention has been given to this classification in available literature.

follows that used by Shaw and El Shaarawi (1995).

The data series was fit to the following model:

$$(1) \qquad y_{t_{ji}} = \beta_0 + \beta_1 x_{t_{ji}} + \beta_2 i + \alpha_1 \cos\omega t_{ji} + \alpha_2 \sin\omega t_{ji} + \varepsilon_{t_{ji}}$$

where :

$y_{t_{ji}}$ = Observed value of water quality variable at time t_{ji} within year i;

$x_{t_{ji}}$ = Flow rate at time t_{ji} within year i;

α_1, α_2 = Unknown parameters representing the phase of the seasonal cycle;

ω = Unknown parameter representing the frequency of the seasonal cycle;

$\varepsilon_{t_{ji}}$ = Error term assumed to follow a normal distribution with mean 0 and variance σ^2.

The regression technique used an iterative process of parameter estimation and analyses of model residuals and quantile plots.

The form in equation (1) above considers only a linear trend with slope β_2. The presence or absence of quadratic ($\cup$ or $\cap$ - shaped) trends may be determined by with addition of a quadratic term ($\beta_3 i^2$) to equation (1). ANOVA tables were then used to determine if the quadratic models resulted in significantly improved fit to the data series. Significance of the model coefficients was tested at the five percent level.

4.3.1 Intervention Analysis

Intervention analysis is a stochastic modelling technique (Box and Tiao 1975 and Hipel *et al*. 1975) for rigorous analysis of the effects of interventions on the mean level of a time series. In water resource applications, intervention analysis has been used for streamflow data (Hipel *et al*. 1975; Lettenmaier and Burges 1981; Baracos *et al*. 1981) and water quality series (McLeod *et al*. 1983).

In 1990-1991, pulp and paper mills in the Fraser River Basin implemented major changes in bleaching processes to improve the quality of effluent discharged to the Fraser River and its tributaries. Intervention analysis was used to examine the effects of these changes on downstream water quality .

The intervention model was similar in form to equation (1) except β_2 was used to detect a change between data collected before and after the process modifications rather than for changes every year. This was accomplished by including a dummy variable representing pre-process change (as a block of zeros) and post-process change (a block of ones).

5 Results and Discussion

Results of the EDA screening process are presented in Appendices 2 and 3. After data screening, a subset of 34 of the 42 constituents in the Environment Canada data and nine of the 52 variables from the BCMoELP data were selected for further analysis.

Constituents with data having known laboratory or contamination problems were treated in two ways. Variables with extensive suspect data, such as total copper, total mercury and total zinc were excluded from analyses. Where the period of suspect data was well-defined and readily identifiable, such as laboratory pH, dissolved silica, the time series were truncated to include only high quality data.

Step changes in the data series were induced by method changes during the period of record. For example, a change from a colourimetic method to inductively coupled plasma spectroscopy (ICP) for analysis of dissolved silica in 1990 resulted in step-change and a discontinuous record for the variable. Similarly, analytical methods for dissolved fluoride changed three times during the period of record, with resultant reductions in detection limits. As such, these constituents were not analyzed statistically at any sites except for the Salmon River where observed levels were sufficiently higher than the detection limits.

Data from the monitoring site on the Sumas River at Huntingdon was summarized, but was excluded from trend analyses. Sampling at this site has been sporadic and of short duration, making the available data unsuitable for the statistical analyses used in this report.

The results and discussion sections to follow include annual and seasonal boxplots of selected constituents at each site. Selection of variables for display was based on either a perceived environmental significance or where analyses indicated a significant trend in the time series. For presentation purposes, some extreme outliers were excluded from these plots. However, these values were included in the statistical analyses. Time series for each constituent at each site are presented in Appendices 4 and 5.

Graphical summaries of the statistical analysis are included in the following sections. Full numerical results are presented in Appendix 6.

In presenting trend results from non-parametric analyses, preference was given to significant outcomes from the modified Seasonal Kendall (mSK) test. In general, this test showed strong concordance with both the Van Belle tests for trend and the Seasonal Kendall tests, and was only significant when these latter statistics were also significant. In addition, the Sen's Slope estimates were generally stable (i.e.: no change in sign between the upper and lower confidence limits) when the mSK statistic was significant. Summary tables for each variable within sites (included in station-by-station discussions, below) reflect this result, with results of other analyses being considered when appropriate.

To evaluate the significance of measured levels for water users, the values are compared to relevant available water quality criteria, guidelines and objectives for protection of aquatic life, drinking, livestock watering, irrigation and contact recreation. Priority was given to guidelines from the Canadian Council of Ministers of the Environment (CCME 1988) and water quality criteria used by the B.C. Ministry of Environment, Lands and Parks (Nagpal 1995). These guidelines and criteria are summarized in Haines *et al.* (1994). In addition, recently developed objectives for the upper Fraser River (Swain *et al.* 1997) were applied for some select variables, particularly AOX.

5.1 Red Pass

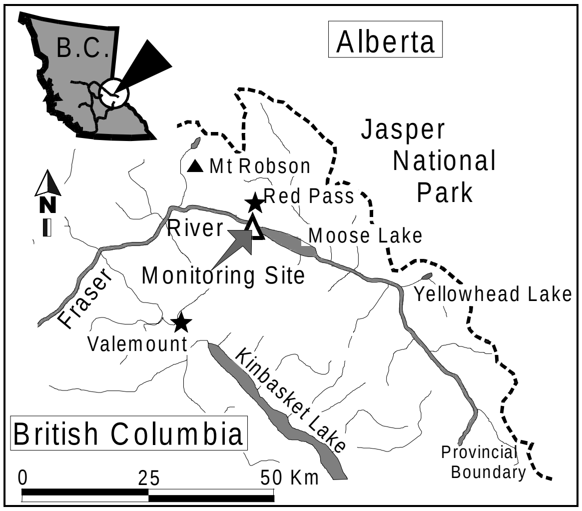


Figure 3. Location and surrounding area of the Environment Canada monitoring station on the Fraser River at Red Pass.

Monitoring of the Fraser River at Red Pass was initiated to provide an indication of water quality conditions in the “pristine” headwaters of the Fraser River. Water at this site drains from a basin area of 1640 km^2 of semi- to high alpine terrain, including areas of Mount Robson Provincial Park (Figure 3). More than half of the glaciers contributing to the upper Fraser River flows are within the 450 km^2 drainage basin of the Moose River, which drains from Mt. Robson and is the largest tributary in the Moose Lake watershed (Desloges and Gilbert 1995).

Cambrian limestones, and inter-bedded siltstones and shales dominate the bedrock in the basin, and are reflected in relatively high levels of dissolved calcium, magnesium and sulphate at this site. Immediately upstream of the monitoring station is Moose Lake, a major sedimentary basin in the upper reaches of the Fraser River (Desloges and Gilbert 1995). Consequently, suspended-sediment related water quality constituents at the site tend to be much lower than reaches either upstream of the lake or at the downstream monitoring site at Hansard.

While there is some adjacent anthropogenic activity in the form of rail lines and a highway, there are no local effluent sources in this portion of the basin, and as such, patterns in water quality at the site probably reflect natural processes.

Monitoring at this site has been conducted by Environment Canada, and spans the period from 1985 to the present. A one-year hiatus in sampling occurred in 1986/87, when personnel to conduct the sampling were unavailable.

Physical Parameters

No trends were found in flow, turbidity or laboratory pH. This is consistent with results reported for the period of 1985-1991 by Shaw and El-Shaarawi (1995).

Water Quality Criteria/Objectives

No trends in physical variables at Red Pass were identified which would affect water uses of the Fraser River at Red Pass. Although showing no trends, turbidity regularly exceeded the raw drinking water criterion during spring/summer freshet conditions.

Non-parametric analyses of specific conductivity revealed a significant increasing trend, while regression analysis indicated a negative quadratic trend. The non-parametric result is clearly supported by the annual summary plots (Figure 4) and is consistent with the trend result for the period 1985-1991 reported by Shaw and El-Shaarawi (1995).

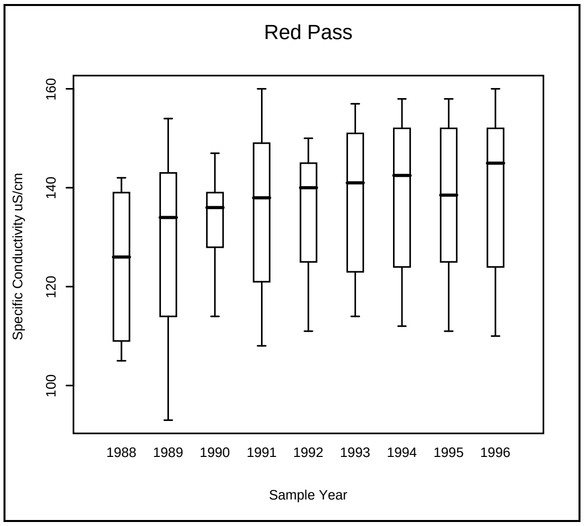


Figure 4. Annual summary of specific conductivity in the Fraser River at Red Pass, 1988 - 1996.

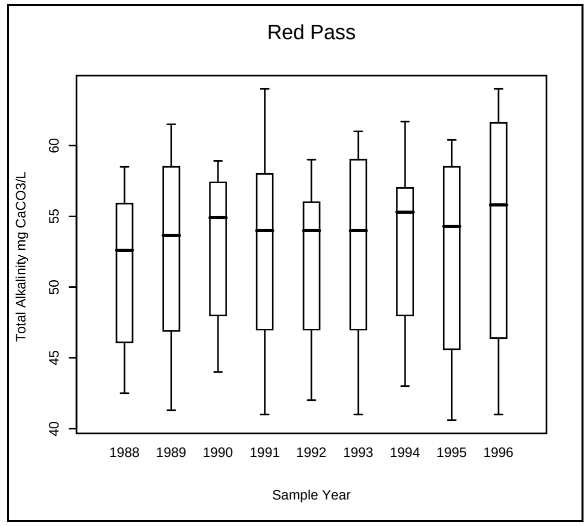


Figure 5. Annual summary of total alkalinity in the Fraser River at Red Pass, 1988 - 1996.

While non-parametric analysis indicated no trend in total alkalinity, regression analyses suggested a significant increasing trend (Table 4). An annual summary plot shows a slight increasing trend in median concentration, which may not be homogenous over months and thus not detected by N-P stats (Figure 5).

Specific conductivity and total alkalinity are both related to dissolved ion levels, as is reflected in the similarity in trends in the two variables. As discussed later in this section, a number of the dissolved-ion constituents at this site also show increasing trends (see *Dissolved Ions*, below).

Regression analysis of water temperature indicates a positive quadratic trend (Table 4). A summary plot (Figure 6) shows a fluctuating median level over the period of record.

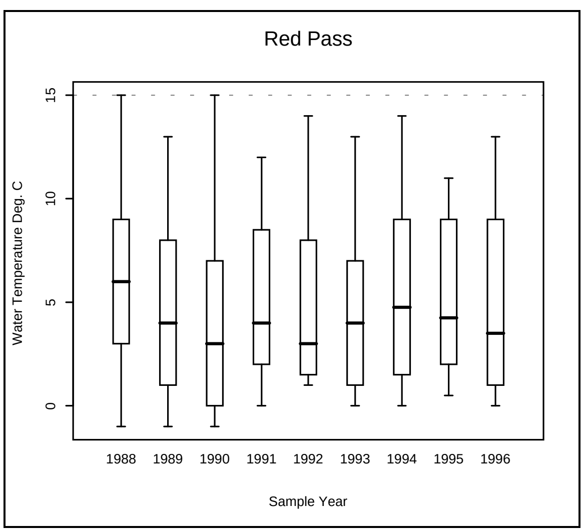


Figure 6. Annual summary of water temperature in the Fraser River at Red Pass, 1988 - 1996. The dashed line represents a proposed maximum water temperature for salmonid embryo survival (Nagpal 1994).

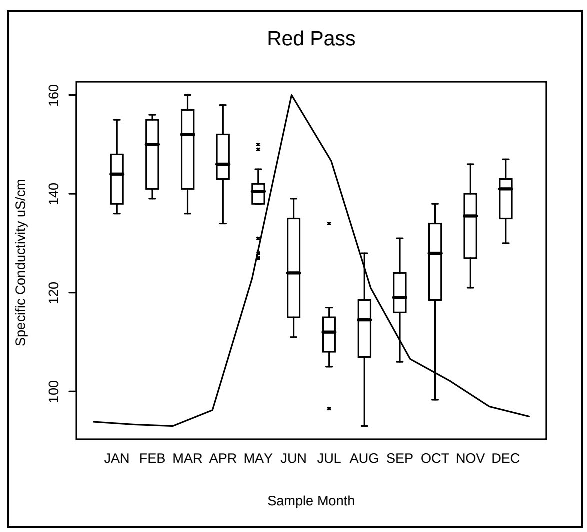


Figure 7. Seasonal summary of specific conductivity in the Fraser River at Red Pass. The solid line represents the seasonal discharge pattern at the site.

Table 4. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada physical water quality data in the Fraser River at Red Pass, 1985 - 1996.

Methods	**Physical Parameters**					
	Flow	**Water temperature**	**Laboratory pH**	**Specific conductivity**	**Turbidity**	**Total alkalinity**
Non-parametric	➔	➔	➔	➚	➔	➔
Regression	→	∪	→	∩	→	↗
Hysteresis						

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Strong seasonal effects are evident in physical parameters monitored at this site (seasonal terms, Table A6.2, Appendix 6). The lowest values of physical variables related to dissolved constituents, such as specific conductivity (Figure 7) and total alkalinity, are clearly due to flow dilution commencing with the spring freshet and sustained through summer flows. The seasonal terms in the regression models tend to suppress discharge effects in these models, but as the hysteresis figures (Table 4) indicate, most of the physical constituents at this site are affected by discharge.

Dissolved Ions

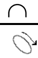
Non-parametric analyses revealed linear increasing trends for dissolved sulphate and chloride (Table 5). While regression analysis likewise indicated a linear increasing trend in dissolved sulphate for the chloride data were better represented as a positive quadratic trend, a result which is likely due to the slight apparent increase in 1991. Certainly, the increase in dissolved chloride is readily apparent in an annual summary plot (Figure 8).

Positive linear trends were also suggested in regression analyses of the calcium, magnesium and hardness. Trends were indicated for other dissolved ions, such as positive quadratic for silica, and a negative quadratic model for sodium (Table 5). Graphical evidence for a trend in sodium, in particular is weak (Figure 9).

Water Quality Criteria/Objectives

Increasing trends were indicated for a number of dissolved ions, but use of water from the Fraser River at Red Pass is unlikely to be affected.

Table 5. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion data in the Fraser River at Red Pass, 1985 - 1996.

Methods	**Dissolved Ions**						
	Dissolved calcium	**Dissolved chloride**	**Dissolved magnesium**	**Hardness**	**Dissolved silica**	**Dissolved sodium**	**Dissolved sulphate**
Non-parametric	➔	➚	➔	➔	➔	➔	➚
Regression	↗	∩	↗	↗	∪	∩	↗
Hysteresis							

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

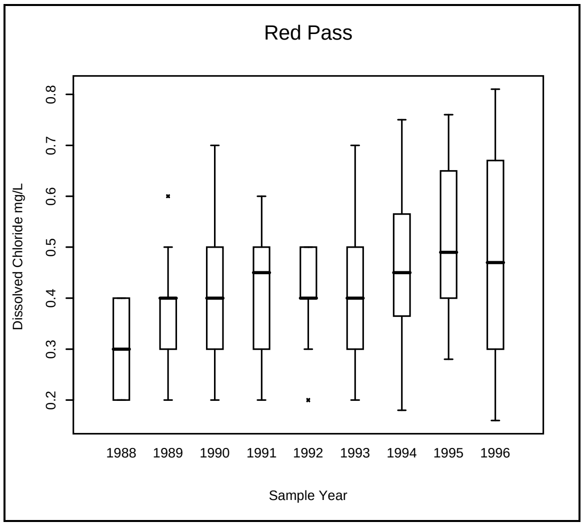


Figure 8. Annual summary of dissolved chloride in the Fraser River at Red Pass, 1988 - 1996.

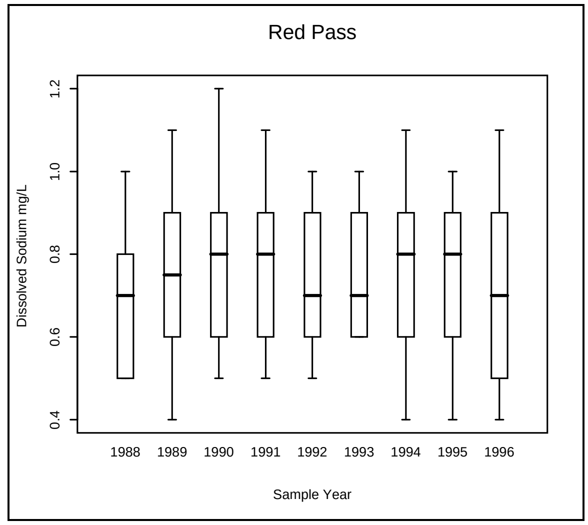


Figure 9. Annual summary of dissolved sodium in the Fraser River at Red Pass, 1988 - 1996.

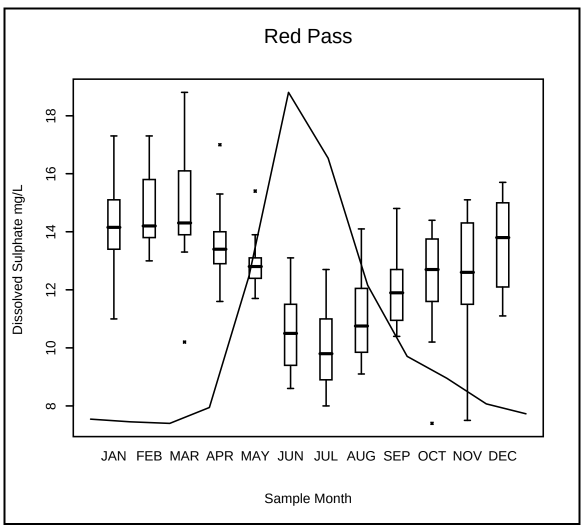


Figure 10. Seasonal summary of dissolved sulphate in the Fraser River at Red Pass. The solid line represents the seasonal discharge pattern.

The hysteresis plots (Table 5) indicate that all the dissolved ions share a similar inverse relationship with flow. Groundwater contribution to the instream flow supplies an excess of dissolved ions through the winter low-flow period. Increasing discharge in the spring and early summer by melting snow and ice depresses dissolved ion concentrations through dilution, as for example, is seen in an annual summary plot of dissolved sulphate levels at the site (Figure 10).

The detected patterns in ion levels are of particular interest. While the current dissolved ion concentrations are not of immediate environmental concern, the clearly increasing trends suggest an, as yet, undetermined change in some water quality process. This may be natural or perhaps a consequence of anthropogenic activities.

Nutrients

Regression analysis suggested a significant increasing trend in nitrate/nitrite levels, not detected in non-parametric analyses (Table 6; Figure 11). No trends were found in either dissolved nitrogen or total phosphorus data, consistent with results reported for the period 1985-1991 (Shaw and El-Shaarawi 1995).

Nitrate/nitrite and dissolved nitrogen increase in the winter low-flow period, declining sharply through dilution with the onset of spring freshet. Levels remain low through the summer peak-flow period (Figure 12). Total phosphorus tends to follow the opposite seasonal pattern, a reflection of the positive relationship between total P and suspended sediment (see the hysteresis patterns in Table 6).

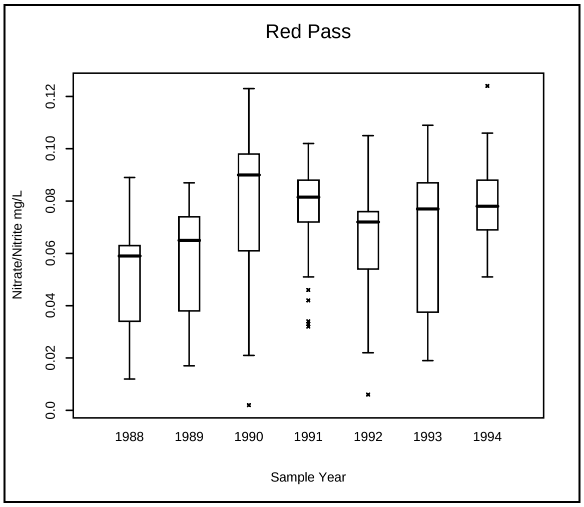


Figure 11. Annual summary of nitrate/nitrite in the Fraser River at Red Pass, 1988 - 1994.

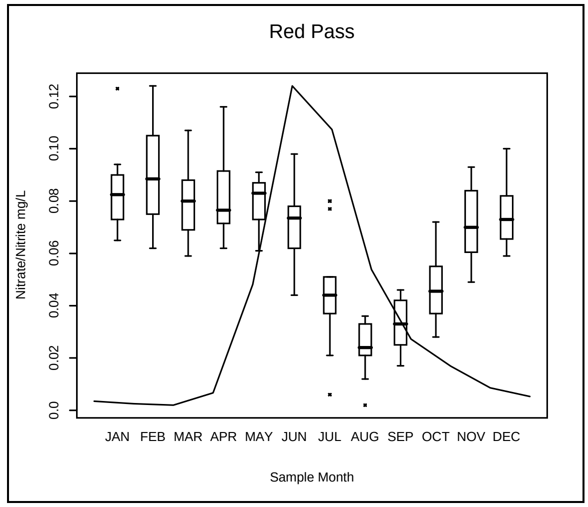


Figure 12. Seasonal summary of nitrate/nitrite in the Fraser River at Red Pass. The solid line represents the seasonal discharge pattern.

Table 6. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved nutrient data in the Fraser River at Red Pass, 1985 - 1996.

Methods	Nutrients		
	Nitrite/ nitrate	**Dissolved nitrogen**	**Total phosphorus**
Non-parametric	➔	➔	➔
Regression	↗	→	→
Hysteresis	↻	↻	↺

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Water Quality Criteria/Objectives

No trends in dissolved nutrients were detected which would affect water use of the Fraser River at Red Pass.

Metals

Eight total metals were deemed adequate for further analyses after the data screening and evaluation process (Appendix 2). Although no trends were detected for any of the metals with non-parametric analyses, regression modelling suggested otherwise (Table 7).

Water Quality Criteria/Objectives

Analyses of total metals in the Fraser River at Red Pass did not indicate a trend which would affect any water use. Levels of total aluminum, total chromium and total iron values did exceed water quality criteria for protection of aquatic life on occasion, particularly during freshet periods.

Table 7. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals monitoring data in the Fraser River at Red Pass, 1985 - 1996.

Methods	Total Metals							
	Al	Ba	Cr	Fe	Li	Mn	Ni	Sr
Non-parametric	➔	➔	➔	➔	➔	➔	➔	➔
Regression	↘	→	↘	∩	∩	→	↗	→
Hysteresis	/	\	[illegible]	[illegible]	\	[illegible]	[illegible]	[illegible]

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

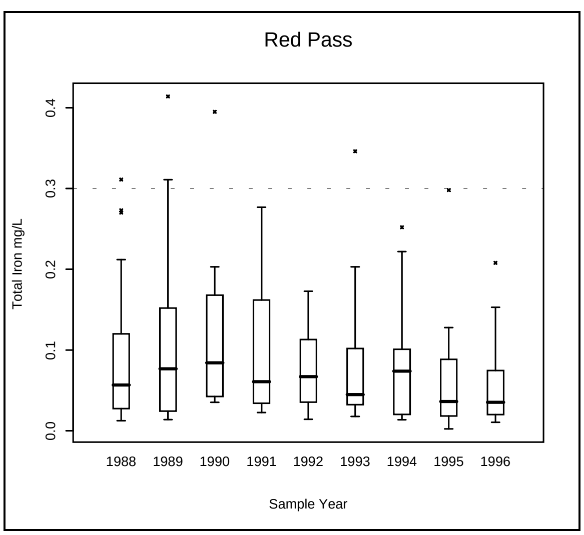


Figure 13. Annual summary of total iron in the Fraser River at Red Pass, 1988 - 1996. The dashed line represents both the CCME and BC MoELP water quality criterion for protection of aquatic life .

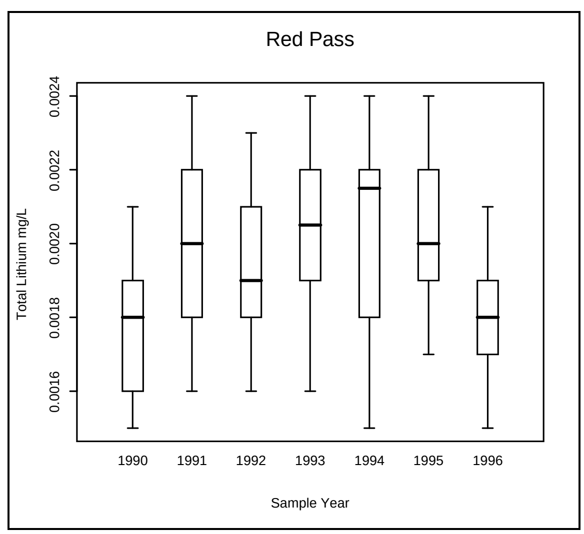


Figure 14. Annual summary of total lithium in the Fraser River at Red Pass, 1990 - 1996.

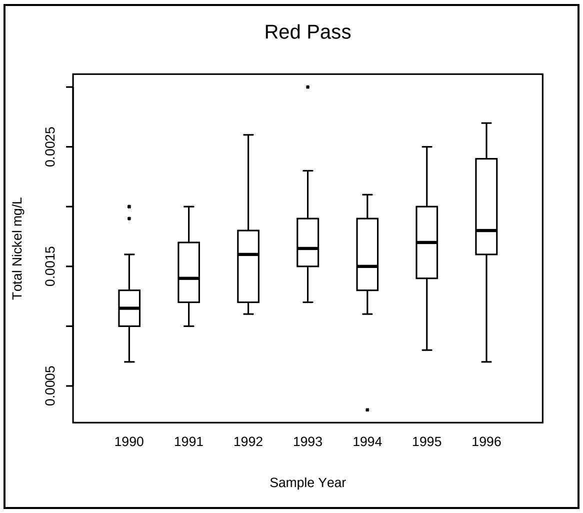


Figure 15. Annual summary of total nickel in the Fraser River at Red Pass, 1990 - 1996.

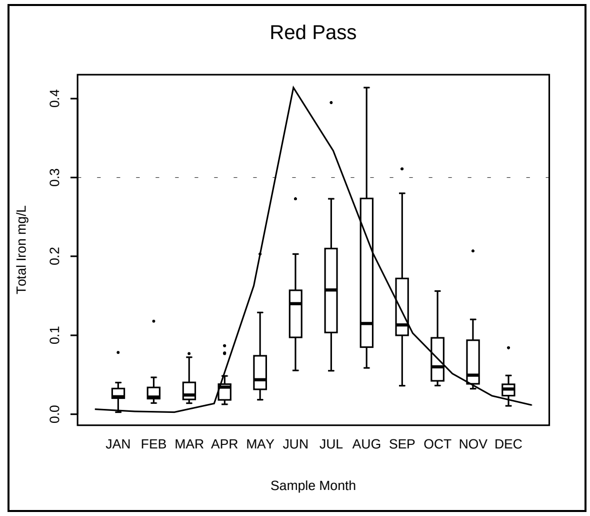


Figure 16. Seasonal summary of total iron in the Fraser River at Red Pass. The solid line represents seasonal discharge patterns and the dashed line is the CCME/BC MoELP water quality criterion for protection of aquatic life.

No trends were detected for either total barium or total manganese (Table 7). Regression analyses of total aluminum and chromium indicated linear decreasing trends, a negative quadratic trend was indicated for total iron and lithium (Table 7). Annual summary plots for iron and lithium (Figure 13 and Figure 14) show clear quadratic patterns in median levels over time.

Only in the total nickel was a significant linear increasing trend indicated in regression analyses. The trend is clearly evident in an annual summary plot (Figure 15), and thus it is surprising that the pattern was not detectable in non-parametric analyses.

Monthly summary plots of the total metals indicate an even split in seasonal patterns. Total aluminum, chromium, iron, manganese and nickel are associated with suspended particulates, exhibit similar seasonal (as in Figure 16 of total iron data) and hysteresis patterns. Trace metals, such as barium, lithium, and strontium, are negatively related to flow and behave in a manner similar to dissolved ions (*e.g.*: Figure 17).

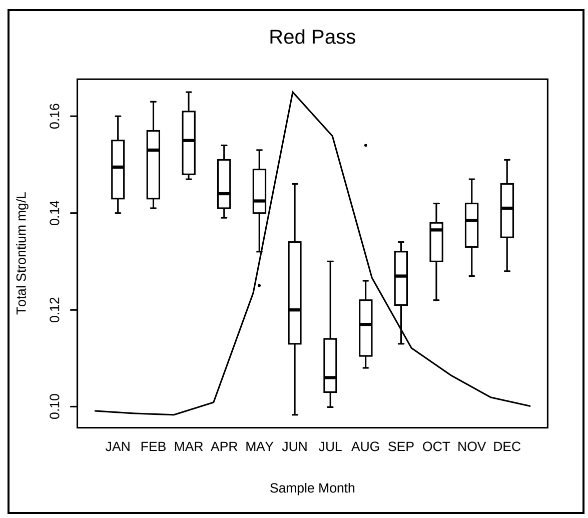


Figure 17. Seasonal summary of total strontium in the Fraser River at Red Pass. The solid line represents the seasonal discharge pattern.

5.2 Hansard

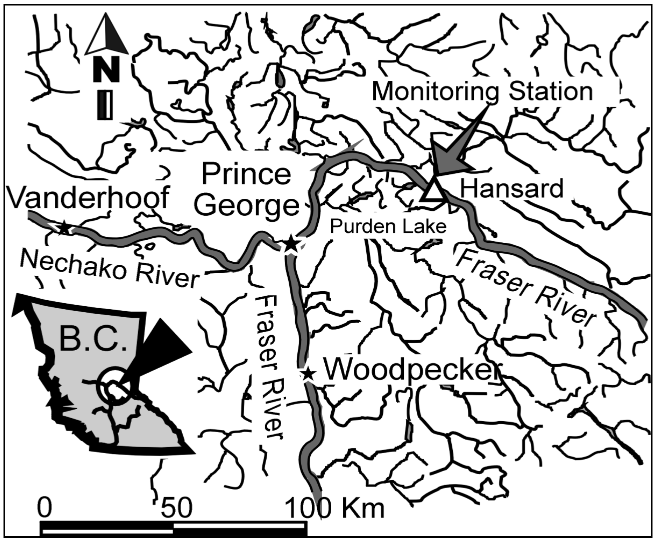


Figure 18. Location and surrounding area of the Environment Canada monitoring station on the Fraser River at Hansard.

The Hansard monitoring site is 318 river kilometers downstream of the site at Red Pass, and functions as a control location to monitor water quality in the Fraser River upstream of major industrial and municipal discharges in the Prince George area (Figure 18). In the reach between the two headwater monitoring stations, the river drops in elevation from 1030 m at Red Pass to 587 m at the Hansard site and increases in volume with confluence of the flows from tributaries draining south from the Cariboo Mountains and north from the Rockies. The total drainage area at the site is 18,000 km^2.

In passage between Red Pass and Hansard, the Fraser River acquires the natural sediment burden missing from the Red Pass site. Carbonates dominate the bedrock through this reach, and waters tend to have somewhat higher calcium and magnesium levels than at the upstream site.

The only permitted discharge in this reach is from the village of McBride, which releases approximately 300 m^3 of municipal wastewater to the river daily (French and Chambers 1995). Timber harvesting in the region is extensive, and is the primary industrial activity. Consequent elevation of some affected constituents, such as suspended sediments, might be expected although background levels are sufficiently high that the result might be difficult to detect. Other human activities near the sampling site are the sawmills at Sinclair Mills and at Upper Fraser, although neither facility has a permitted effluent release to the river.

Environment Canada and BC Environment, Lands and Parks jointly maintain this site and data spans the period from 1985 to present.

Physical Parameters

No trends were found in flow, laboratory pH, turbidity, total absorbance colour, total alkalinity or filterable residue using either the non-parametric or parametric analyses (Table 8). Conversely, both methods indicated a linear increasing trend in specific conductivity, particularly interesting result in its concordance with the trend observed upstream at Red Pass.

A linear increasing trend in apparent colour was found in regression analyses, however, with an $r^2 = 0.22$, much of the variability in the data is unexplained (Table 8). Regression analysis also suggested quadratic trends in water temperature (positive) and non-filterable residue (negative) (Table 8). Annual summary plots of these two variables (Figure 19, Figure 20) show clear oscillations in the median level in each data series. The quadratic trend in water temperature (Figure 19) probably reflects the small rise of the median level over the last two years (1995/1996) data.

Water Quality Criteria/Objectives

No trends in physical parameters were detected which would affect any water uses of the Fraser at Hansard.

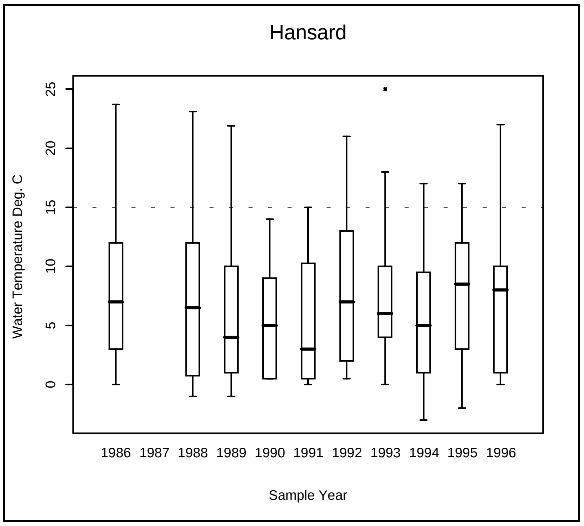


Figure 19. Annual summary of water temperature in the Fraser River at Hansard, 1986 - 1996. The dashed line represents a suggested maximum water temperature for salmonid embryo survival (Nagpal 1994).

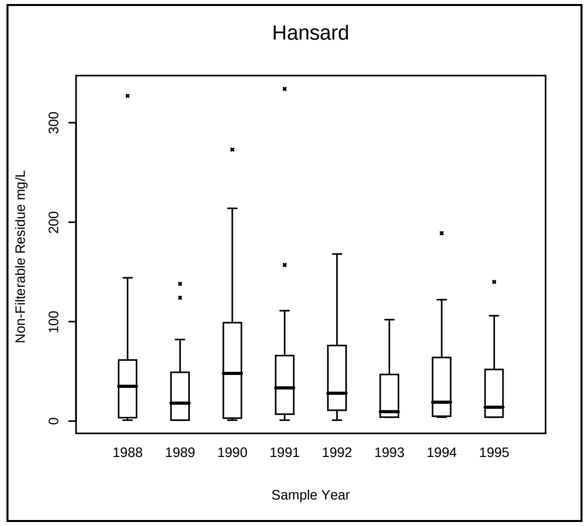


Figure 20. Annual summary of non-filterable residue in the Fraser River at Hansard, 1988 - 1995.

Table 8. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks physical monitoring data in the Fraser River at Hansard, 1985 - 1996.

Methods	**Physical Parameters**				
	Flow	**Water temperature**	**Laboratory pH**	**Total absorbance colour**	**Apparent colour**
Non-parametric	➔	➔	➔	➔	➔
Regression	→	∪	→	→	↗
Hysteresis					
	Specific conductivity	**Turbidity**	**Filterable residue**	**Non-filterable residue**	**Total alkalinity**
Non-parametric	➚	➔	➔	➔	➔
Regression	↗	→	→	∩	→
Hysteresis	\			/	

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

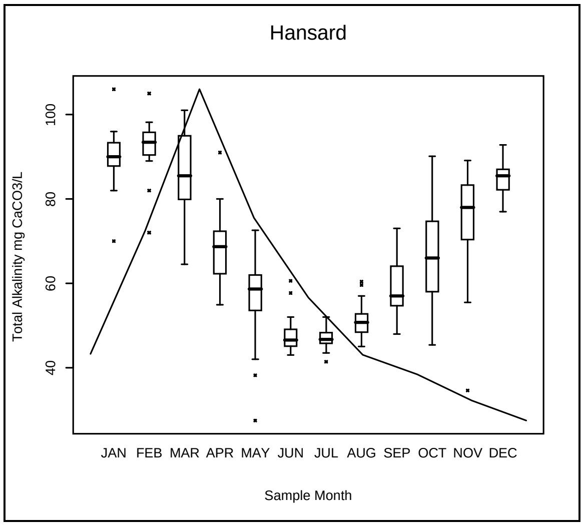


Figure 21. Seasonal summary of total alkalinity in the Fraser River at Hansard. The solid line represents the seasonal discharge pattern.

Regression analyses (Table A6.4 in Appendix 6) and hysteresis diagrams (Table 8) indicate both strong seasonality and significant flow relationships for all physical parameters monitored at this site. The exception was that of pH, for which both the seasonal and flow terms of the model were non-significant.

A typical seasonal pattern for a dissolved component, total alkalinity, is shown in Figure 21. Levels increase through the fall and winter as instream flows from meltwater decline and the groundwater contribution becomes more apparent. Increasing surface flows result in a dramatic decline in concentration due to dilution.

Dissolved Ions

No trend was observed in the dissolved chloride data using either non-parametric or regression analysis. Both non-parametric and regression analyses of the dissolved ions showed increasing linear trends in magnesium, hardness, potassium and sulphate (Table 9).

A significant increasing trend in dissolved potassium was detected by regression, but not by the non-parametric methods.

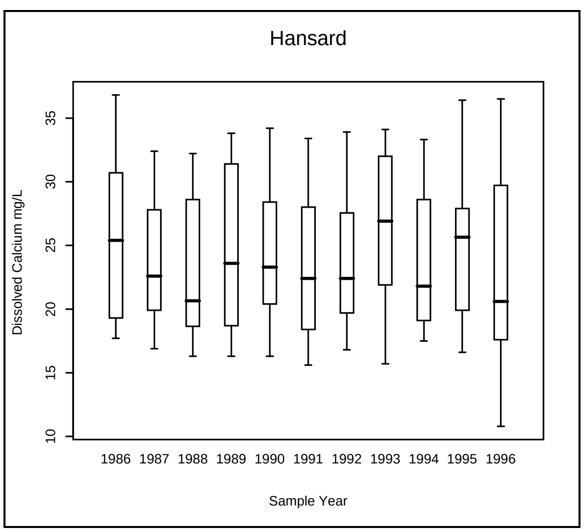


Figure 22. Annual summary of dissolved calcium in the Fraser River at Hansard, 1986 - 1996.

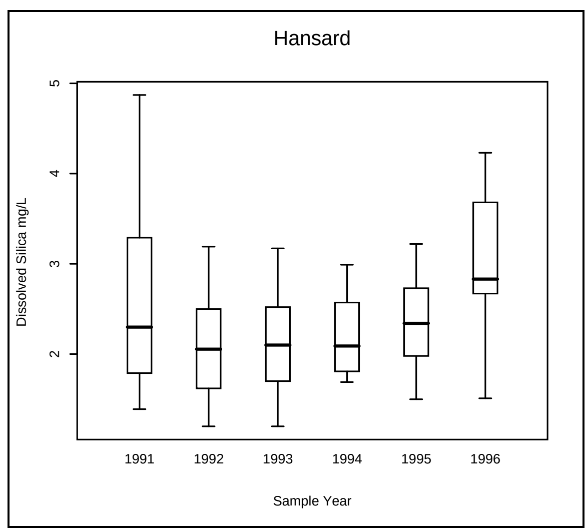


Figure 23. Annual summary of dissolved silica in the Fraser River at Hansard, 1991 - 1996.

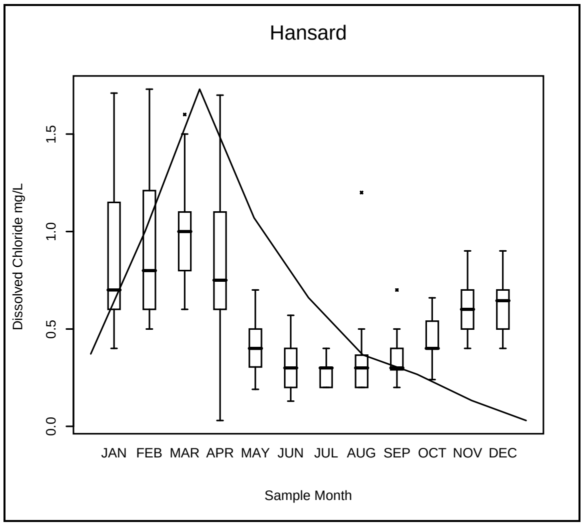


Figure 24. Seasonal summary of dissolved chloride in the Fraser River at Hansard. The solid line represents the seasonal discharge pattern.

Disparate results were found in analyses of dissolved calcium data, where no trend was indicated in the non-parametric analyses and a positive quadratic trend was found in regression modelling. Median dissolved calcium levels have been declining for several years (Figure 22). Elevated median concentrations observed in 1993 and 1995 are curious since they are not apparent in other dissolved ion data series, and are difficult to attribute to causal factors.

Dissolved silica data showed no trend with non-parametric tests but a positive quadratic by regression analysis. An annual summary plot of the silica data (Figure 23) shows clearly that median levels have been increasing since 1992, with levels increasing sharply in recent years.

Regression analysis (Table A6.4 in Appendix 6) and hysteresis diagrams (Table 9) indicate negative relationships between flow and all dissolved ions at this site. The strong seasonality of these constituents is evident in Figure 24.

Water Quality Criteria/Objectives

Increasing trends were detected for some dissolved ions measured at this site, but none jeopardize any water use. Dissolved ion concentrations were well below water quality criteria.

Table 9. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion data from the Fraser River at Hansard, 1985 - 1996.

Methods	Dissolved Ions			
	Dissolved calcium	**Dissolved chloride**	**Dissolved magnesium**	**Hardness**
Non-parametric	➔	➔	➚	➚
Regression	∪	→	↗	↗
Hysteresis	⟳	⟳	╲	╲
	Dissolved silica	**Dissolved potassium**	**Dissolved sodium**	**Dissolved sulphate**
Non-parametric	➔	➚	➔	➚
Regression	∪	↗	↗	↗
Hysteresis	⟳	╲	╲	⟲

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Nutrients

No trends were detected in BC MoELP ammonia or EC total phosphorus data (Table 10).

Non-parametric analyses of nitrate/nitrite and dissolved nitrogen data suggested no trends. However, subsequent regression modelling of the two data sets suggested quadratic trends (Table 10). Annual summary figures (Figure 25 and Figure 26) show weak quadratic trends. The trend in dissolved nitrogen is particularly important, since the most recent data (1994-1996) show a strong increasing trend in median level.

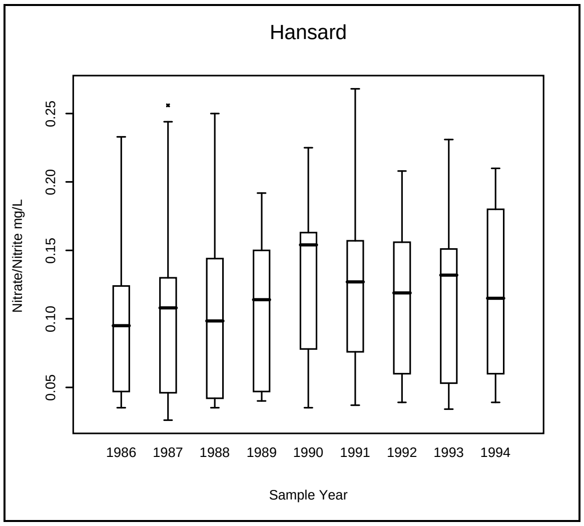


Figure 25. Annual summary of nitrate/nitrite in the Fraser River at Hansard, 1986 - 1994.

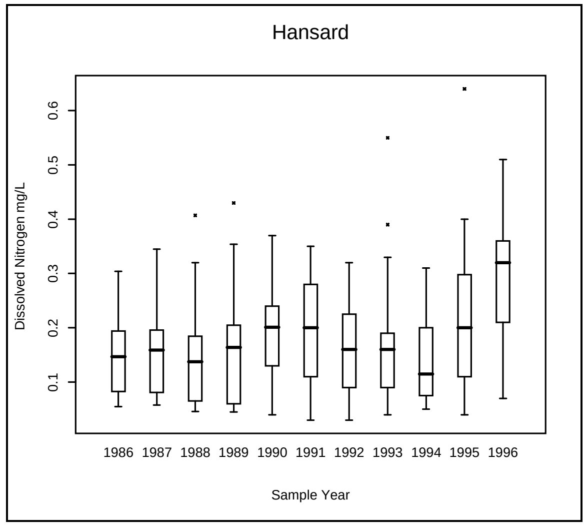


Figure 26. Annual summary of dissolved nitrogen in the Fraser River at Hansard, 1986 - 1996.

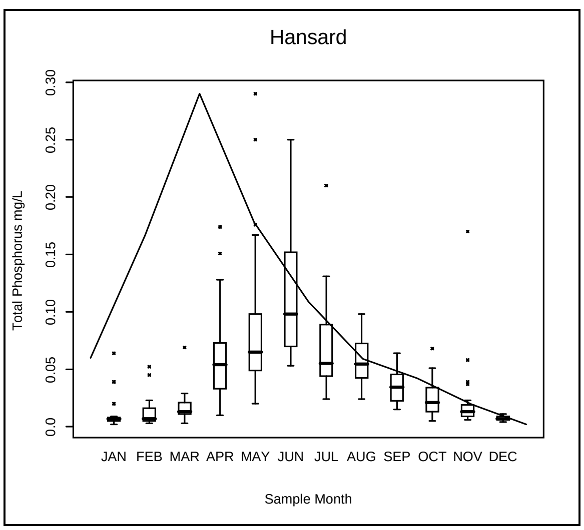


Figure 27. Seasonal summary of total phosphorus in the Fraser River at Hansard. The solid line represents the seasonal discharge pattern.

Strong seasonality is apparent in the nutrient constituents, as exemplified by total phosphorus (Figure 27). The pattern is typical of particulate-related parameters, with a significant lag between peak flows and peak concentration - a lag which manifests in a high degree of hysteresis in the discharge-concentration relationship (Table 10).

Table 10. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks nutrient monitoring data in the Fraser River at Hansard, 1985 - 1996.

Methods	Nutrients				
	Ammonia	**Nitrate/ Nitrite**	**Dissolved nitrogen**	**Dissolved phosphorus**	**Total phosphorus**
Non-parametric	➔	➔	➔	➔	➔
Regression	→	∩	∪	↗	→
Hysteresis					

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Water Quality Criteria/Objectives

Analysis of nutrients did not indicate trends that would jeopardize any particular water use in the Fraser River at Hansard.

Total Metals

No trends were detected in total iron, manganese, molybdenum, nickel or strontium. Linear declining trends were indicated in total cobalt and lead data series by both regression and non-parametric analyses (Table 11).

Linear declining trends in total aluminum and total lithium were detected using regression, but not non-parametric methods. Annual summaries certainly suggest the regression result, since declining median levels are clearly evident (Figure 28 and Figure 29). Likewise, regression analysis of total chromium and total vanadium data also indicated linear declining trends not evident in the non-parametric analyses. The time-series for these variables was truncated prior to analysis, and the inconsistent results may be attributable to the relatively short duration.

Table 11. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals data in the Fraser River at Hansard, 1985 - 1996.

Methods	Total Metals						
	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Fe**
Non-parametric	➔	➔	➔	➔	➔	⬊	➔
Regression	↘	∩	∪	∪	↘	↘	→
Hysteresis							
	Pb	**Li**	**Mn**	**Mo**	**Ni**	**Sr**	**V**
Non-parametric	⬊	➔	➔	➔	➔	➔	➔
Regression	↘	↘	→	→	→	→	↘
Hysteresis							

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

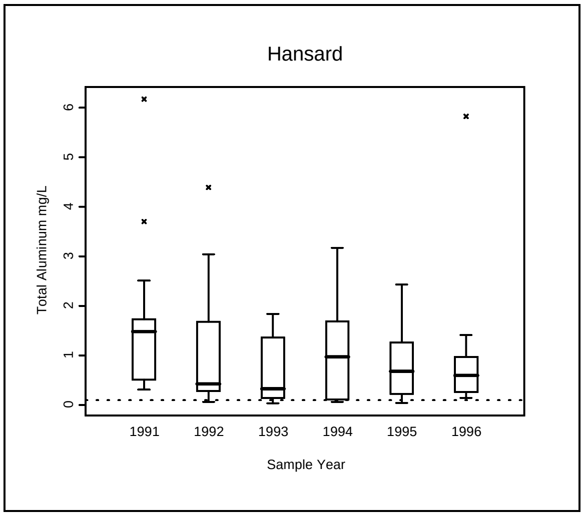


Figure 28. Annual summary of total aluminum in the Fraser River at Hansard, 1991 - 1996. The dashed lines represents the BC MoELP/CCME maximum water quality criterion for protection of aquatic life (0.1 mg/L).

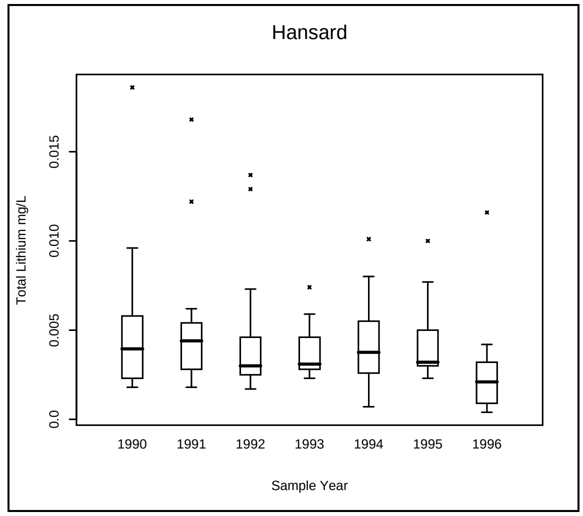


Figure 29. Annual summary of total lithium in the Fraser River at Hansard, 1990 - 1996.

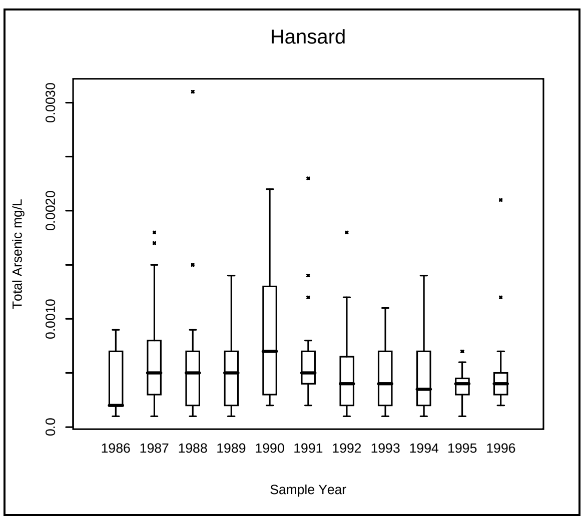


Figure 30. Annual summary of total arsenic in the Fraser River at Hansard, 1986 - 1996.

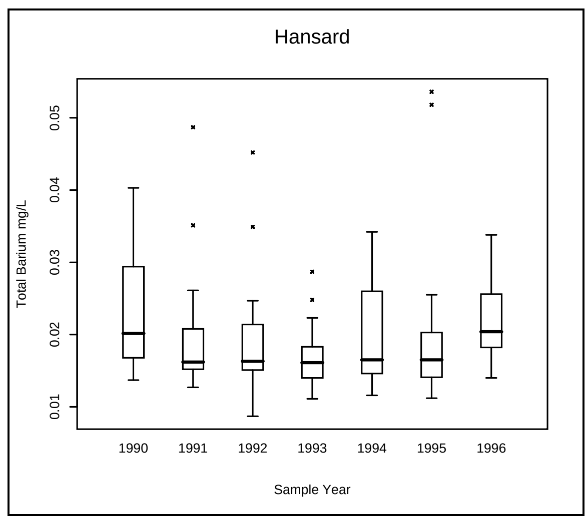


Figure 31. Annual summary of total barium in the Fraser River at Hansard, 1986 - 1996.

No linear trends were detected in non-parametric analyses of the total arsenic, barium or cadmium data at Hansard. Subsequent regression analyses revealed quadratic trends (Table 11) which perhaps better represent the patterns inherent in the data (Figure 30 and Figure 31).

Disparate results were identified in statistical analysis of many of the total metal variables (Table 11). In addition to the effects of truncated data series, some of the discrepancies may result from the sensitivity of the regression model fitting procedures to outliers and extreme values. Non-parametric methods are much more robust to the influence of these values and can be more conservative, but tend to be less sensitive.

Water Quality Criteria/Objectives

No trends in total metals which would affect any water uses in the Fraser River at Hansard were identified. A number of total metals, namely aluminum, cadmium, iron, chromium and cobalt exceeded water quality criteria for protection of aquatic life.

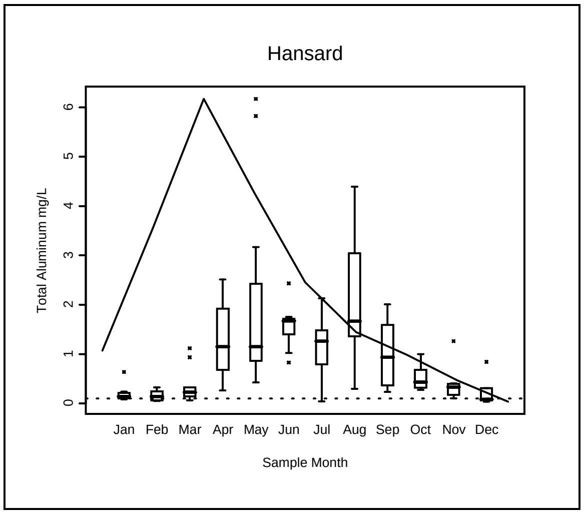


Figure 32. Seasonal summary of total aluminum in the Fraser River at Hansard. The solid line represents the seasonal discharge patterns. The dashed line represents BC MoELP/CCME maximum water quality criterion for protection of aquatic life (0.10 mg/l).

Most total metals variables at Hansard, with the exception of molybdenum and strontium, showed positive relationships with flow, (regression analyses Table A6.4 in Appendix 6; hysteresis Table 11). Most showed seasonal patterns typical of suspended sediment-related constituents (Figure 32).

Levels of a number of metals, such as iron, aluminum, cadmium, chromium and cobalt were in excess of water quality criteria for protection of aquatic life. The measured *total* concentrations were probably due to native metal in suspended particles and of little direct biological consequence.

Microbials

No trends were evident in BC MoELP fecal coliform data (Table 12), consistent with 1985-1991 results reported by Shaw and El-Shaarawi (1995).

The regression analysis (Table A6.4 in Appendix 6) and the hysteresis diagram (Table 12) indicate a positive relationship between fecal coliform and river discharge at this monitoring site, suggesting that at least some input to the Fraser is resulting from runoff.

Water Quality Criteria/Objectives

Analysis of fecal coliform data did not indicate levels which would affect water uses of the Fraser River at Hansard.

Table 12. Summary of non-parametric tests, regression modelling and hysteresis patterns of BC Ministry of Environment, Lands and Parks fecal coliform data from the Fraser River at Hansard, 1985 - 1996.

Methods	Microbials
	Fecal coliform
Non-parametric	➔
Regression	→
Hysteresis	

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

5.3 Stoner

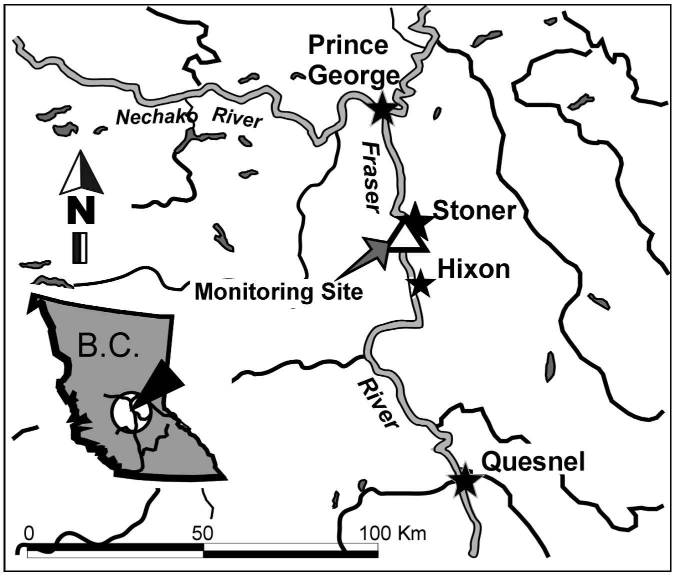


Figure 33. Location and surrounding area of the BC Ministry of Environment, Lands and Parks monitoring station on the Fraser River at Stoner.

Monitoring at Stoner was initiated by BC MoELP in 1990 to document improvements in water quality resulting from changes implemented by the three Prince George pulp and paper mills (Figure 33). Monthly averaged effluent discharges from these mills over the period 1985-1996 are presented in Figure 34.

Bleaching process changes, in particular the increased use of chlorine dioxide, implemented at most mills during 1991 were expected to reduce production and effluent release of organohalide byproducts. With this monitoring objective in mind, only adsorbable organohalides (AOX) were consistently measured at this sampling location.

There are presently no established general water quality guidelines or criteria for AOX. However, in the upper Fraser, Swain *et al.* (1997) established an objective for reaches of the Fraser River downstream of discharges such that there be “no increase at the 95% confidence level” from upstream concentrations. Unfortunately, there is too little monitoring of areas upstream of the present discharges with which to assess attainment of this objective.

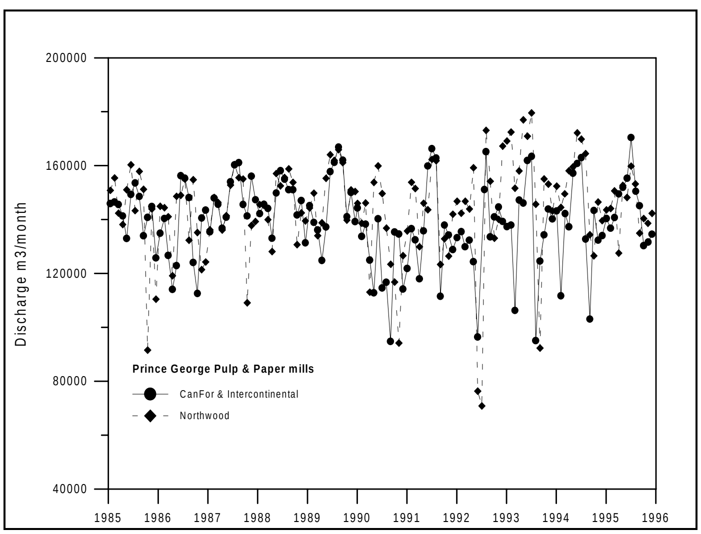


Figure 34. Average monthly effluent discharge volumes of the three pulp and paper mills in Prince George, 1985 - 1995.

Organics (AOX)

A declining trend in AOX was identified by regression but not by non-parametric analysis (Table 13). While the median AOX concentration has shown a modest decline since 1991, the range and frequency of excursions has dropped considerably (Figure 35). Other associated information regarding concentrations of other organohalides, notably chlorinated dioxins, in mill effluents have also supported the efficacy of the upgrades in reducing contaminant discharges (BC MoELP 1995, Krahn 1995).

The flow parameter in the fitted regression model was significant and negative (Table A6.6 in Appendix 6), a relationship clearly apparent in both Figure 36 and the associated hysteresis pattern (Table 13).

Water Quality Criteria/Objectives

Adsorbable organohalides were detectable throughout the year. Upstream monitoring data were not available, but it is probable that levels exceeded the current objective at all times.

Table 13. Summary of non-parametric tests, regression modelling and hysteresis pattern of BC Ministry of Environment, Lands and Parks AOX data from the Fraser River at Stoner, 1991 - 1996.

Methods	Organics Adsorbable organohalides
Non-parametric	➔
Regression	↘
Hysteresis	⟲

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

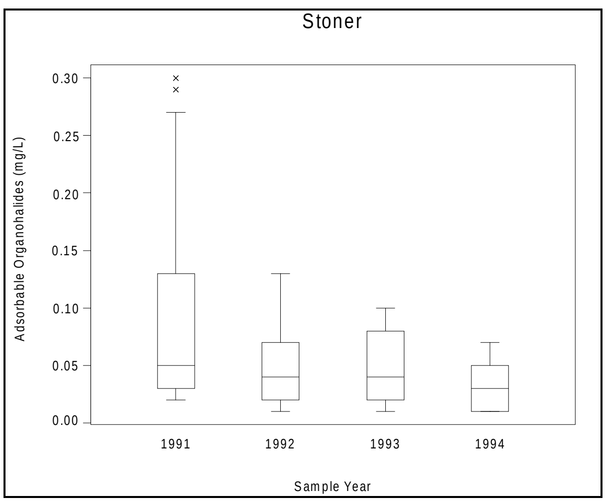


Figure 35. Annual summary of BC Ministry of Environment, Lands and Parks AOX in the Fraser River at Stoner, 1991 - 1994.

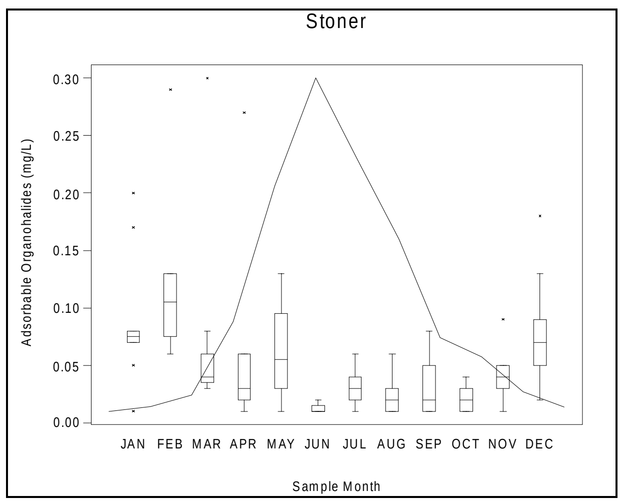


Figure 36. Seasonal summary of BC Ministry of Environment, Lands and Parks AOX in the Fraser River at Stoner. The solid line represents the seasonal discharge pattern.

5.4 Marguerite

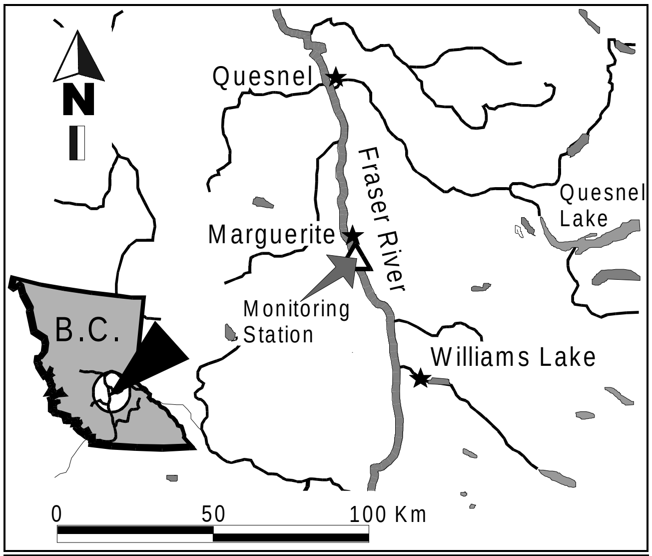


Figure 37. Location and surrounding area of the Environment Canada monitoring station on the Fraser River at Marguerite.

The reach of the Fraser River from Hansard downstream to the site at Marguerite receives effluents from a range of industrial sources, including pulp and paper mills, municipal effluents of Prince George and Quesnel, and the non point source effects of extensive timber harvesting and agricultural activities near the mainstem and tributaries (Figure 37). Major tributaries joining the Fraser in this reach include the Nechako, Quesnel and West Road Rivers that together result in flows at Marguerite that are roughly double those at Hansard. The drainage area at this monitoring site is 114,000 km^2.

Industrial discharges constitute the greatest anthropogenic influence on water quality in this reach. There are three kraft-process pulp mills, two in Prince George and one in Quesnel, and an additional non-kraft chemical thermal mechanical pulp (CTMP) mill in Quesnel, all of which discharge to the Fraser River (Figure 38). Based on the maximum permitted discharge and minimum flows at Marguerite (from Swain *et al.* 1997), the kraft mill effluents alone could represent as much as 2.9% of the total flow.

Of the constituents measured in the routine monitoring program, the effect of the change in mill effluent is most apparent in levels of dissolved chloride (Shaw and El-Shaarawi 1995).

The pulp and paper mills have implemented major improvements in process and effluent quality over the 10-year period of water quality monitoring. During the period 1990-1992, the three kraft mills shifted to the use of ClO_2 in bleaching, a change which has shown beneficial effects in both dioxin/furan levels in biota (Mellor *et al.* 1995, Raymond and Shaw 1997) and water quality, as evident in the time series data (below).

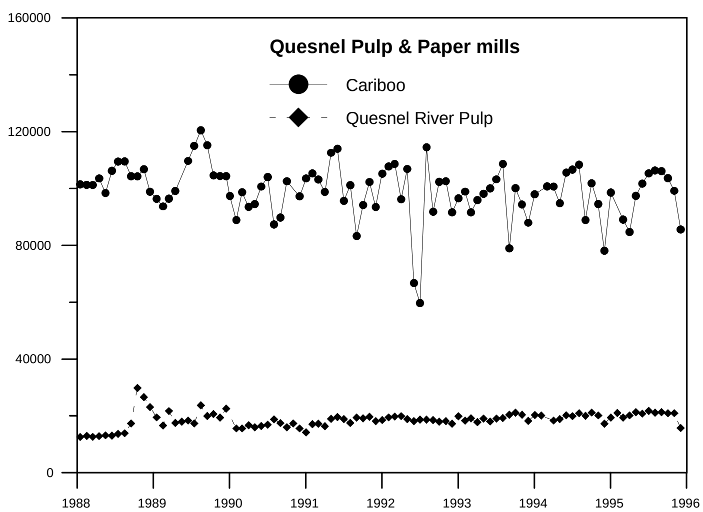


Figure 38. Average monthly effluent discharge volumes (m^3/day), Quesnel pulp and paper mills, 1988 - 1995.

Physical Parameters

No trends were found in any of the physical parameters using non-parametric analyses. Regression also yielded no significant trends in flow, colour (apparent or total absorbance), turbidity or non-filterable residue data (Table 14). Water temperature showed a negative quadratic trend in regression modelling.

Significant linear increasing trends were indicated by regression analyses of filterable residue, specific conductivity and total alkalinity (Table 14). Inspection of annual summary plots (Figure 39 to Figure 41) indicate support for the parametric results since (1) median filterable residue levels seem to have increased over the period 1988 to 1994, (2) median specific conductivity levels seem to be quite changeable from year to year, oscillating with about a three-year cycle, and (3) total alkalinity has been relatively stable, in concordance with the non-parametric analysis.

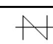
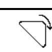
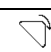
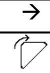
Non-parametric analysis of laboratory pH showed no trend, but the positive model fit by regression analysis. Surprisingly, even though the model is very poorly determined (r^2=0.06), the regression result is clearly apparent in an annual summary plot (Figure 42).

Strong seasonality is evident in most physical parameters at this site, related either to mobilization of sediments at the onset of freshet (Figure 43) or to flow-dilution (Figure 44).

Water Quality Criteria/Objectives

No trends in physical parameters were found which would affect water uses in the Fraser River at Marguerite.

Table 14. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks physical monitoring data in the Fraser River at Marguerite, 1985 - 1996.

Methods	Physical Parameters				
	Flow	**Water temperature**	**Laboratory pH**	**Total absorbance colour**	**Apparent colour**
Non-parametric	➔	➔	➔	➔	➔
Regression	→	∩	∪	→	→
Hysteresis					
	Specific conductivity	**Turbidity**	**Filterable residue**	**Non-filterable residue**	**Total alkalinity**
Non-parametric	➔	➔	➔	➔	➔
Regression	↗	→	↗	→	↗
Hysteresis					

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

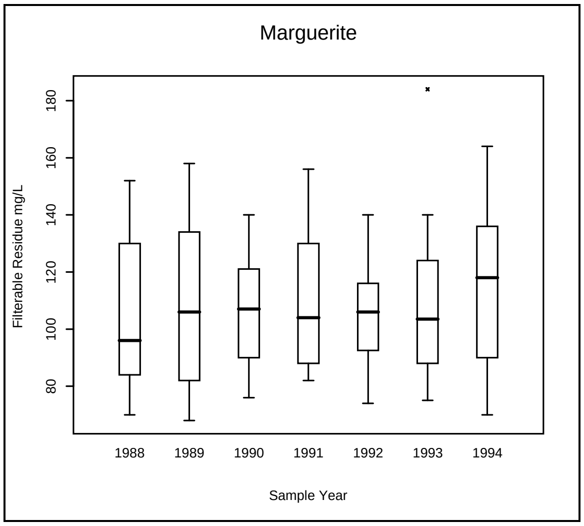


Figure 39. Annual summary of filterable residue in the Fraser River at Marguerite, 1988 - 1994.

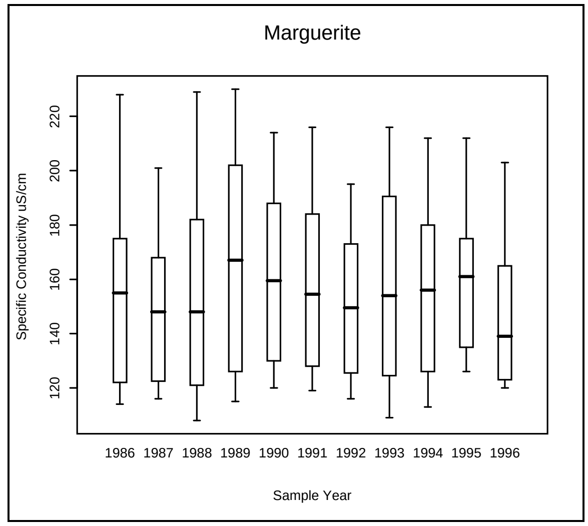


Figure 40. Annual summary of specific conductivity in the Fraser River at Marguerite, 1986 - 1996.

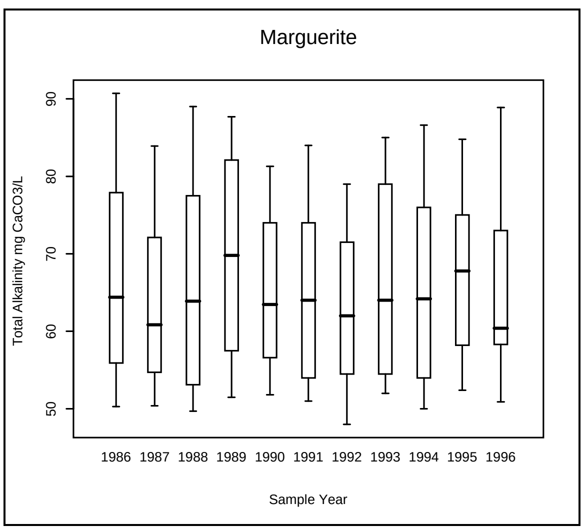


Figure 41. Annual summary of total alkalinity in the Fraser River at Marguerite, 1986 - 1996.

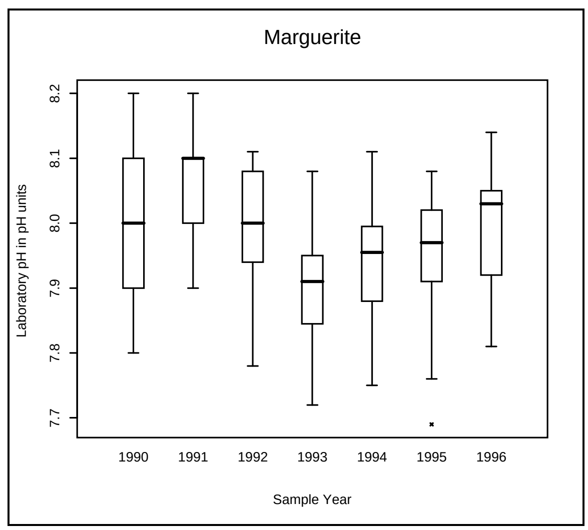


Figure 42. Annual summary of laboratory pH in the Fraser River at Marguerite, 1990 - 1996.

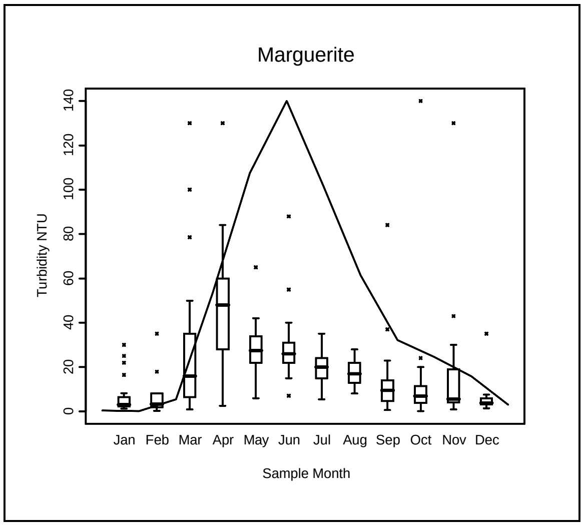


Figure 43. Seasonal summary of turbidity in the Fraser River at Marguerite. The solid line represents the seasonal discharge pattern.

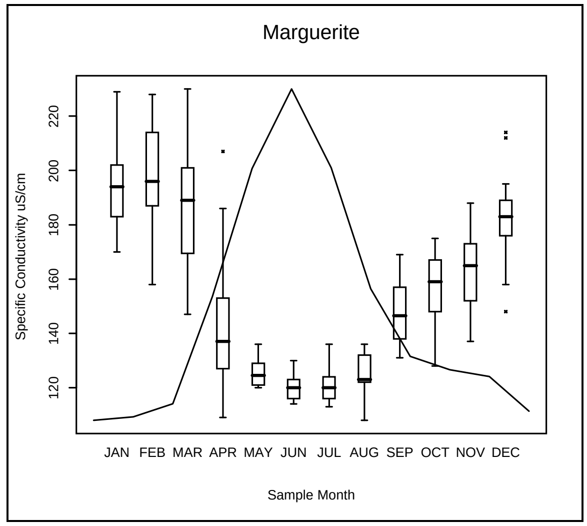


Figure 44. Seasonal summary of specific conductivity in the Fraser River at Marguerite. The solid line represents the seasonal discharge pattern.

The monitoring site at Marguerite receives effluents from four upstream mills, all of which implemented some changes to bleaching processes during the early 1990s. Simple intervention methods of the monitored physical parameters (see section 4) showed a significant reduction only in total absorbance colour, a finding consistent with the process changes.

Dissolved Ions

With the exception of dissolved sodium, all dissolved ion data at Marguerite showed some significant trend for the period of record (Table 15). Regression analysis of 1985-1991 data by Shaw and El-Shaarawi (1995) indicated an linear increasing trend, so present result could perhaps be a favourable consequence of a change in effluent quality.

A strong linear decreasing trend in dissolved chloride was detected by both non-parametric and regression methods. In the 1985-1991 data, prior to process changes at upstream mills, there was no apparent trend (Shaw and El-Shaarawi 1995), and the annual summary plot shows the dramatic effect of the implemented changes (Figure 45).

Dissolved potassium data, in contrast, showed a linear increasing trend as was found by Shaw and El-Shaarawi (1995). An increasing trend was also detected in dissolved magnesium, in contrast to the 1995 report where no trend was detected.

Disparate results were obtained in non-parametric and regression analyses of dissolved calcium, hardness, silica and sulphate data (Table 15). Annual median levels in hardness and dissolved calcium (Figure 46 and Figure 47) show clearly the non-monotonic long-term trends, although regression analyses of these two constituents indicated negative quadratic trends.

Water Quality Criteria/Objectives

Increasing trends in dissolved magnesium and potassium were detected in the Fraser River at Marguerite, but neither are at levels which would jeopardize any water uses. Measured concentrations of all dissolved ions were below criteria or guidelines.

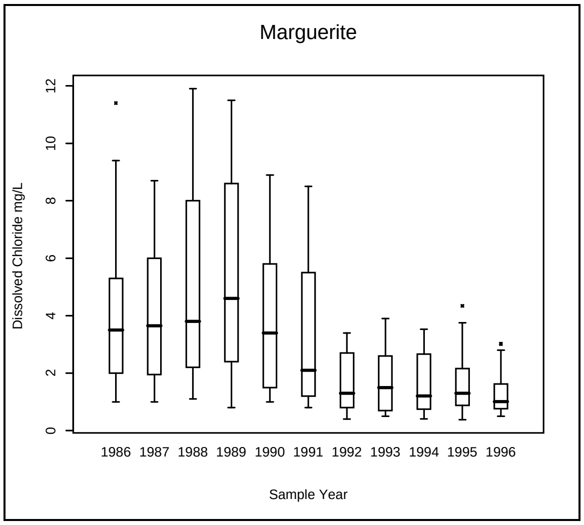


Figure 45. Annual summary of dissolved chloride in the Fraser River at Marguerite, 1986 - 1996.

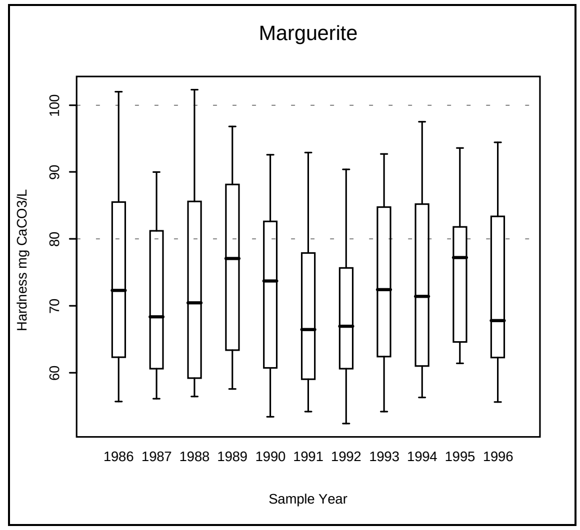


Figure 46. Annual summary of hardness in the Fraser River at Marguerite, 1986 - 1996. The dashed lines indicate the range of hardness for "acceptable" drinking water.

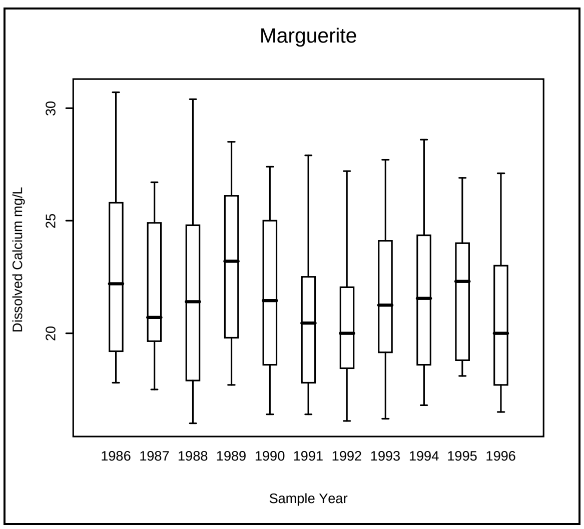


Figure 47. Annual summary of dissolved calcium in the Fraser River at Marguerite, 1986 - 1996.

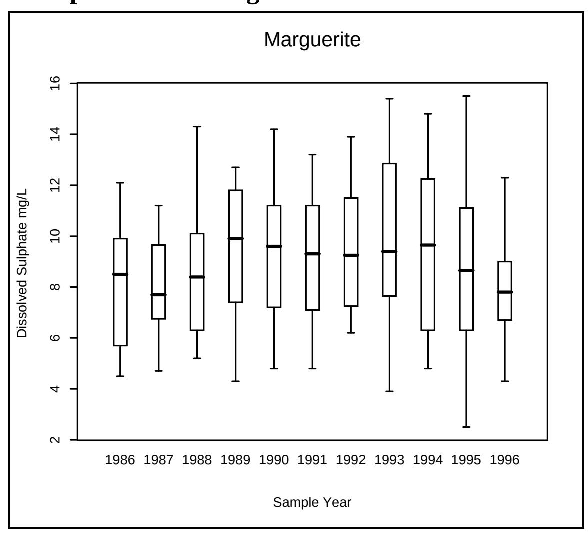


Figure 48. Annual summary of dissolved sulphate in the Fraser River at Marguerite, 1986 - 1996.

Regression analyses of dissolved sulphate and silica indicate quadratic trends (Table 15), patterns clearly evident in annual summary plots (Figure 48 and Figure 49). The increasing trend for dissolved sulphate reported by Shaw and El-Shaarawi (1995) for the period 1985-1991, seems to have reversed, since present concentrations are on a slight decline (Figure 48).

Changes in concentrations of several dissolved ions, including dissolved chloride, may be related to mill effluent changes. Intervention analysis of the data series indicated significant reductions for dissolved calcium, potassium, magnesium, sulphate and chloride after the 1991 upgrade period.

Strong seasonality is evident in all dissolved ions due to flow-dilution (Figure 50, regression analyses Table A6.8 in Appendix 6, and hysteresis diagrams Table 15).

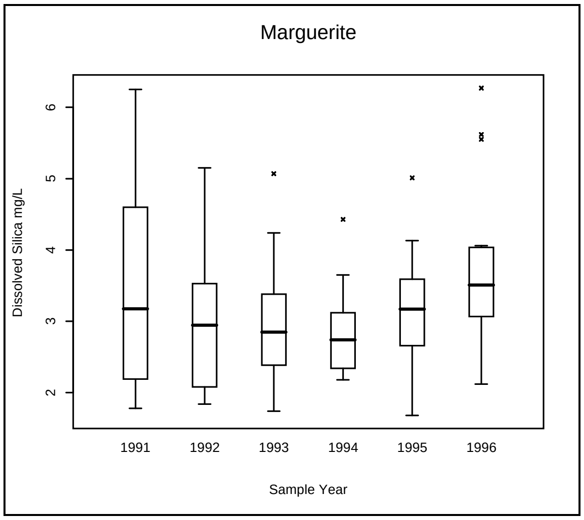


Figure 49. Annual summary of dissolved silica in the Fraser River at Marguerite, 1991 - 1996.

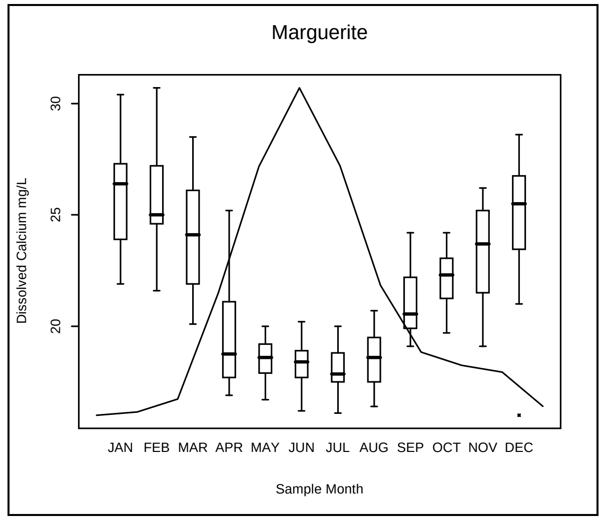
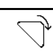


Figure 50. Seasonal summary of water hardness in the Fraser River at Marguerite, The solid line represents the seasonal discharge patterns.

Table 15. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion data in the Fraser River at Marguerite, 1985 - 1996.

Methods	**Dissolved Ions**			
	Dissolved calcium	**Dissolved chloride**	**Dissolved magnesium**	**Hardness**
Non-parametric	➔	➘	➚	➔
Regression	∪	↘	↗	∪
Hysteresis				
	Dissolved silica	**Dissolved potassium**	**Dissolved sodium**	**Dissolved sulphate**
Non-parametric	➔	➚	➔	➚
Regression	∪	↗	→	∩
Hysteresis				

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Nutrients

No trends in either dissolved or total phosphorus were detected by regression or non-parametric analyses (Table 16). Analyses of 1985-1991 total and dissolved phosphorus data produced the same result. Regression analysis over the 1985-1991 range indicated an increasing linear trend (Shaw and El-Shaarawi 1995).

Water Quality Criteria/Objectives

Analysis of nutrients in the Fraser River at Marguerite did not indicate trends which would jeopardize water uses. Increasing trends were detected for nitrate/nitrite, dissolved nitrogen and orthophosphorus.

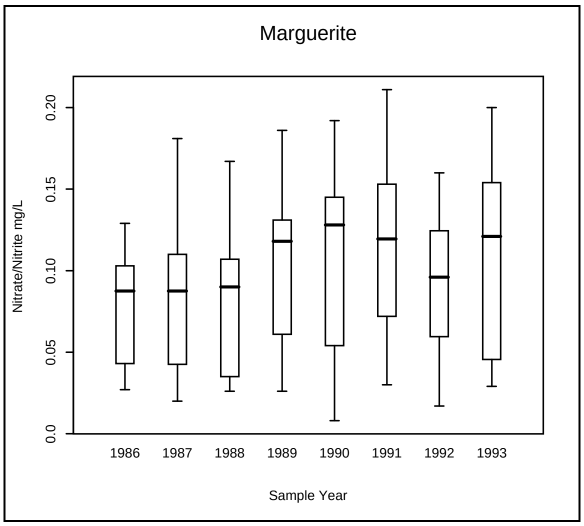


Figure 51. Annual summary of nitrate/nitrite in the Fraser River at Marguerite, 1986 - 1993.

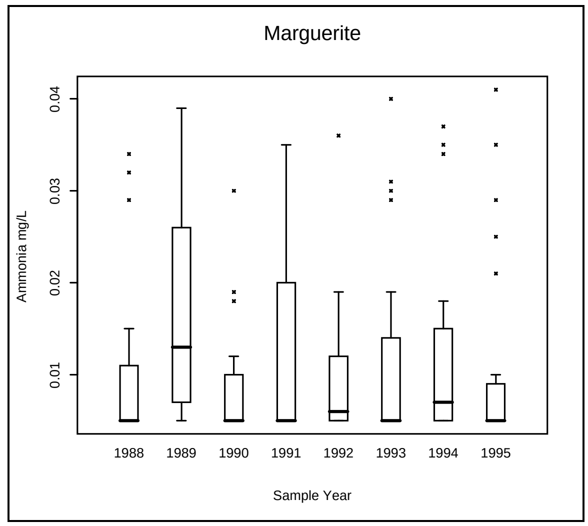


Figure 52. Annual summary of BC MoELP ammonia in the Fraser River at Marguerite, 1988 - 1995.

No trends were indicated in non-parametric analyses of nitrate/nitrite (Figure 51) and dissolved nitrogen data by the modified Seasonal Kendall (mSK) but linear increasing trends were detected in both variables by regression analysis (Table 16). Other non-parametric results, such as those of the Van Belle and Seasonal Kendall test indicate linear increasing trends (see Appendix 6), so the mSK may be responding to some inconsistency in the data series which may be masking possible trends. The increasing median levels in NO_2/NO_3 are possibly due to upstream effluent discharges to the river, although measured concentrations remain far below any guideline or criterion levels. Trends in NO_2/NO_3 detected in this data series are consistent with the results reported by Shaw and El-Shaarawi (1995), suggesting some long-term source of these constituents to the river.

BC MoELP ammonia levels were, with the exception of 1989 data, at or near the analytical detection limit (Figure 52). Regression analysis of ammonia showed no trend for the period of record (Table 16), consistent with the analysis of data from the period 1985-1991 by Shaw and El-Shaarawi (1995).

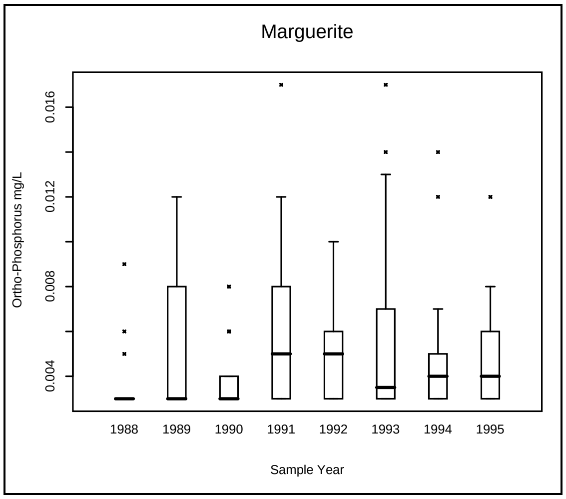


Figure 53. Annual summary of BC MoELP orthophosphorus in the Fraser River at Marguerite, 1988-1995

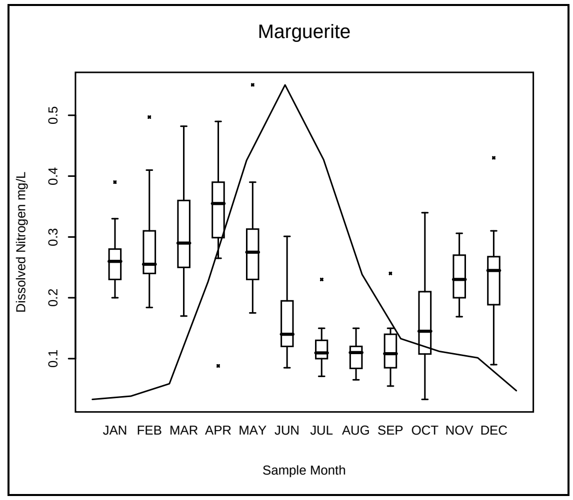


Figure 54. Seasonal summary of dissolved nitrogen in the Fraser River at Marguerite. The solid line shows the season discharge pattern at the site

Non-parametric analysis indicated a linear increasing trend in orthophosphorus, which was modelled as a negative quadratic trend in regression analyses. Higher median levels evident during 1991-1992 (Figure 53) probably produced the pattern reflected in the regression analysis. As with the NO_2/NO_3, the increasing trend detected in the ortho-P data are consistent with results from previous analyses (Shaw and El-Shaarawi 1995).

Seasonality in ortho-P and nitrogen is driven both by changes in river discharge and by biological activity (Figure 54, Table A6.10 in Appendix 6). Nutrient levels increase through the winter months, and decline sharply when dilution from spring freshet and increased biological activity and uptake maintain concentrations at low levels (Figure 54).

Table 16. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks dissolved nutrient data from the Fraser River at Marguerite, 1985 - 1996.

Methods	**Nutrients**					
	Ammonia	**Nitrate/ nitrite**	**Dissolved nitrogen**	**Dissolved phosphorus**	**Ortho-phosphorus**	**Total phosphorus**
Non-parametric	➘	➔	➔	➔	➚	➔
Regression	→	↗	↗	→	∩	→
Hysteresis						

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Metals

A number of the non-parametric analyses suggested trends by both the Van Belle test and Seasonal Kendall tests, but showed no trends with the *modified* Seasonal Kendall statistic (Appendix 6). Total metals variables showing this pattern were barium, cadmium, cobalt, and nickel. As outlined in introductory sections, the mSK was here used as the definitive trend indicator. As a result, although there were trends indicated by some of the non-parametric statistics, because of the non-significant mSK, "no trend" is indicated by some of the non-parametric statistics, because of the non-significant mSK, “no trend” is indicated in Table 17. The Sen’s Slope estimates for these variables are also very low (<0.00001 units/year), so any changes will be slight.

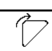
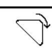
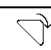
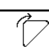
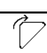
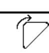
No trends were detected in total aluminum, beryllium or manganese. Non-parametric and regression analyses indicated a linear increasing trend in total molybdenum, although the slope of the trend is very shallow (Sen’s Slope <0.00001) and the relationship poorly determined ($r^2 = 0.26$). Linear decreasing trends were detected by both methods of statistical analyses for total chromium, lead, lithium and selenium (Table 17).

Non-parametric analyses of both total iron and arsenic indicated no trends, but subsequent regression analyses suggest negative quadratic trends. Annual summary plots show the implied trend, due to relatively elevated median levels of both variables in 1990/1991 (Figure 55 and Figure 56).

Water Quality Criteria/Objectives

No trends in total metals were detected which would affect water uses in the Fraser River at Marguerite. Total aluminum and iron frequently exceeded criteria for aquatic life. Total chromium and total cobalt exceeded the maximum criteria for aquatic life during freshet.

Table 17. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals data in the Fraser River at Marguerite, 1985 - 1996.

Methods	Total Metals							
	Al	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Fe**
Non-parametric	**→**	**→**	**→**	**→**	**→**	**↘**	**→**	**→**
Regression	→	∩	→	→	↗	↘	↘	∩
Hysteresis								
	Pb	**Li**	**Mn**	**Mo**	**Ni**	**Se**	**Sr**	**V**
Non-parametric	**↘**	**↘**	**→**	**↗**	**→**	**↘**	**→**	**→**
Regression	↘	↘	→	↗	↘	↘	↘	↘
Hysteresis								

→ - no trend **↗** - increasing linear trend **↘** - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

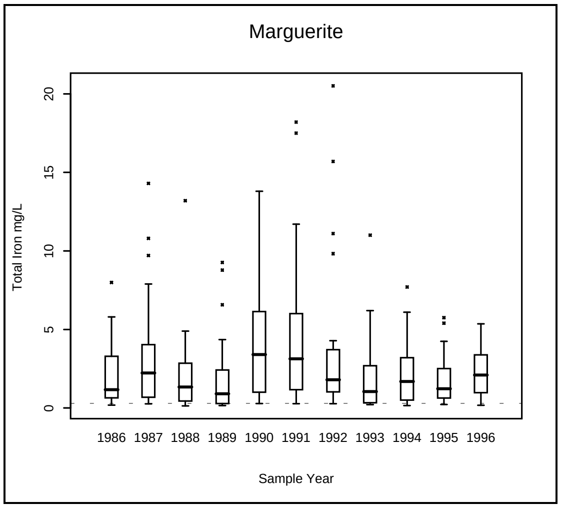


Figure 55. Annual summary of total iron in the Fraser River at Marguerite, 1986 - 1996. The dashed line represents the CCME/BC MoELP water quality criterion for protection of aquatic life.

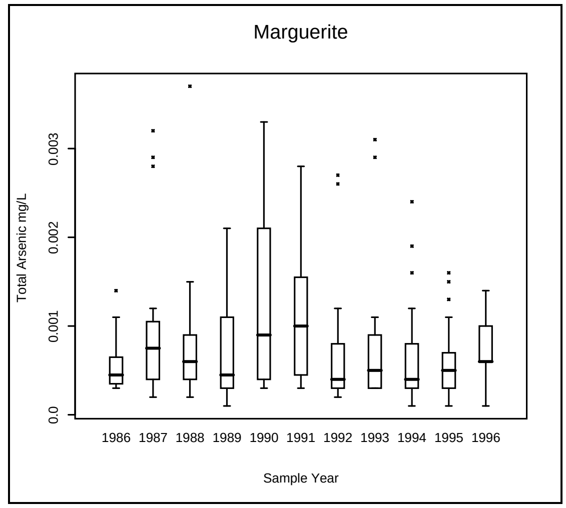


Figure 56. Annual summary of total arsenic in the Fraser River at Marguerite, 1986 - 1996.

Non-parametric analysis detected no trend in total cadmium, however, regression analysis showed a quadratic trend (Table 17). A summary plot (Figure 57) reinforces the quadratic trend, with relatively elevated levels in both the early and most recent portion of the data series.

Likewise, although non-parametric analyses showed no trends, regression analyses of cobalt, nickel, strontium and vanadium data indicated significant linear decreasing trends (Table 17). Annual summary plots in most cases support the regression results. The exception is vanadium which shows instead a very slight increase in median levels over the last three years of record (Figure 58).

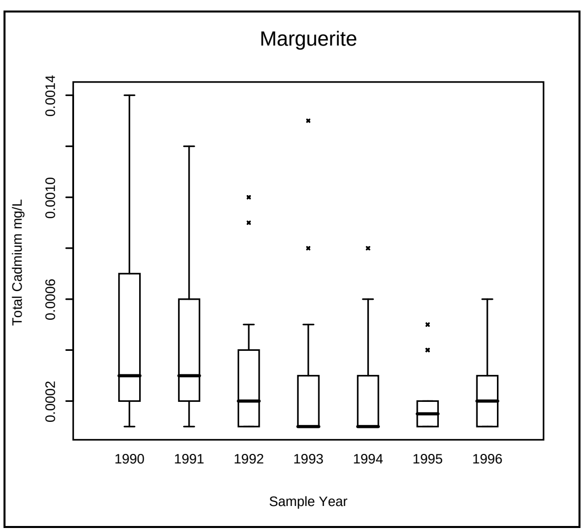


Figure 57. Annual summary of total cadmium in the Fraser River at Marguerite, 1990 - 1996.

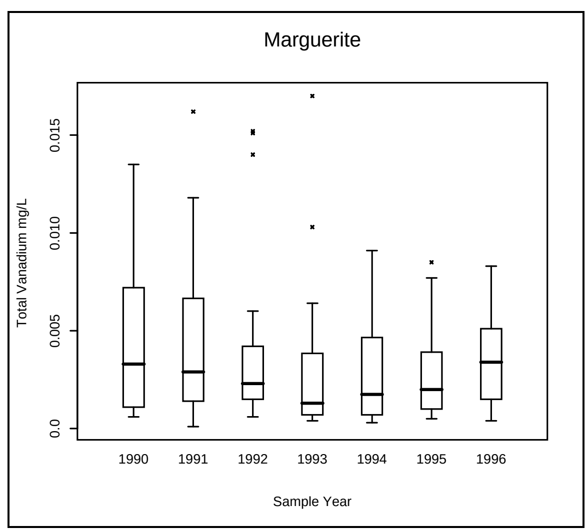


Figure 58. Annual summary of total vanadium in the Fraser River at Marguerite, 1986 - 1996.

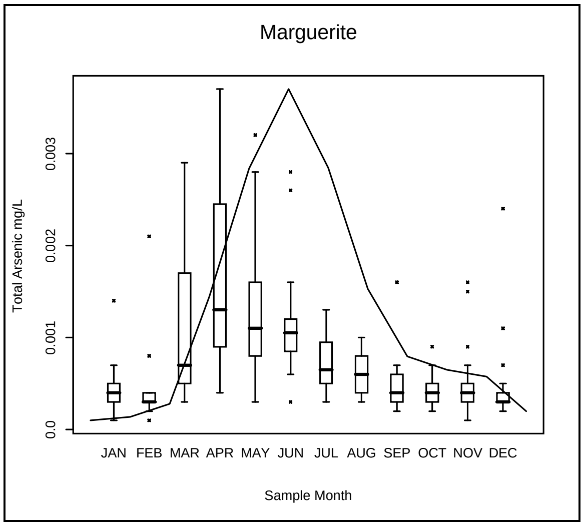


Figure 59. Seasonal summary of total arsenic in the Fraser River at Marguerite. The solid line represents the seasonal discharge pattern.

Seasonality related to seasonal changes in discharge is readily apparent in most of the total metals (Figure 59). Total metals levels are associated closely with particulates; it is not unusual to see excursions above normal levels at any time during the year. Levels increase dramatically at the onset of the spring freshet and then decrease steadily over the summer months. The trace metals, such as molybdenum, selenium and strontium behave differently, exhibiting either no (Se) or negative relationships with flow (Table A6.8 in Appendix 6), and are likely indicators of groundwater discharge.

Intervention regression analyses were performed on a subset of the metal data having a sufficiently long period of record. Significant differences before and after pulp mill process changes were found in total chromium and total lead. These are unexpected results, and may be related to effluent change and bear further examination.

Organics

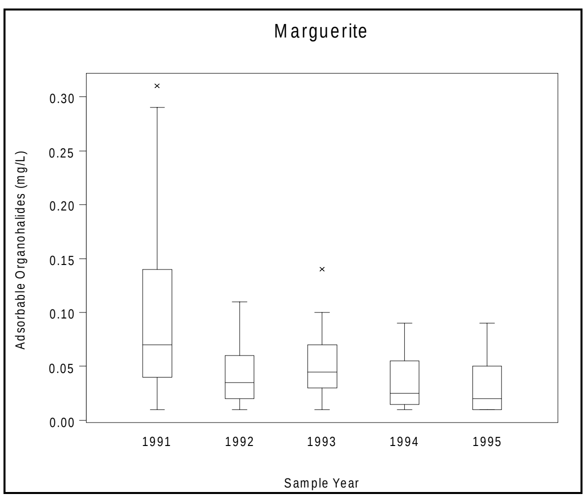


Figure 60. Annual summary of AOX in the Fraser River at Marguerite, 1991 - 1995.

Analyses of adsorbable organohalide data (AOX) revealed a strong linear declining trend (Table 18). Not surprisingly, intervention regression modelling suggests that this trend is probably attributable to pulp and paper mill process changes implemented circa 1991 (Figure 60).

Strong seasonality in AOX is evidenced in both regression modelling (Table A6.8 in Appendix 6) and a hysteresis diagram (Table 18).

In terms of the established objective (Swain et al. 1997), sufficient data are not available to assess the attainment. It would, however, seem probable that this objective was exceeded at most times.

Water Quality Criteria/Objectives

A declining trend in AOX at the site was probably a direct result of bleaching process changes implemented at upstream kraft mills. Although levels have been declining, it is likely that the objective for adsorbable organohalides was exceeded in the Fraser River at Marguerite.

Table 18. Summary of non-parametric tests, regression modelling and hysteresis pattern of BC Ministry of Environment, Lands and Parks AOX data from the Fraser River at Marguerite, 1991 - 1996.

	Organics
Methods	Adsorbable organohalides
Non-parametric	➘
Regression	↘
Hysteresis	

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Microbials

Non-parametric analysis suggested no trend in fecal coliform numbers, but regression modelling fit a positive quadratic model (Table 19). Coliform data are notoriously prone to excursions, and a summary plot of the data (Figure 61) suggests that the regression result may be an artifact of frequent outliers rather than a shifting in annual median levels. Levels exceeded the recreational guideline of 200 cfu/100ml in approximately 13% of the 181 observations in the data series, with three individual values in excess of 900 cfu/100ml. Predicting high values is problematic, since elevated levels occur both in winter low-flow conditions, when effluent dilution is relatively low, and in fall/summer, when warm temperatures encourage bacterial survival and growth. Seasonal effects were evident in fecal coliform levels, driven by a negative relationship with flow (Table A6.8 in Appendix 6, hysteresis diagram Table 19).

Table 19. Summary of non-parametric tests, regression modelling and hysteresis pattern of BC Ministry of Environment, Lands and Parks microbial data in the Fraser River at Marguerite, 1989 - 1996.

	Microbials
Methods	Fecal coliform
Non-parametric	➔
Regression	∪
Hysteresis	

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Water Quality Criteria/Objectives

Fecal coliform levels frequently (23/181 values) exceeded criteria for contact recreation in the Fraser River at Marguerite.

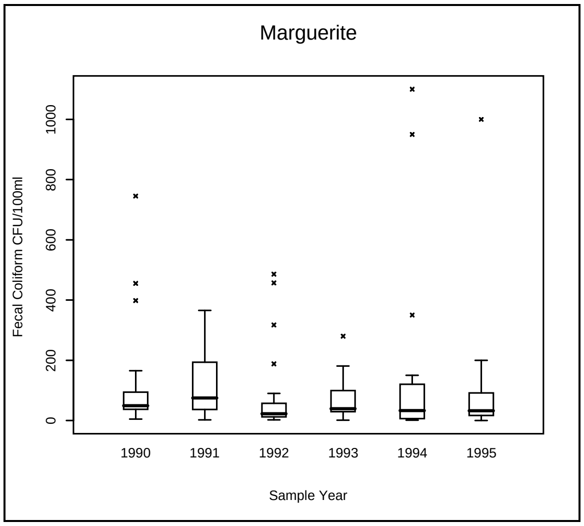


Figure 61. Annual summary of fecal coliform in the Fraser River at Marguerite, 1990 - 1995.

5.5 Hope

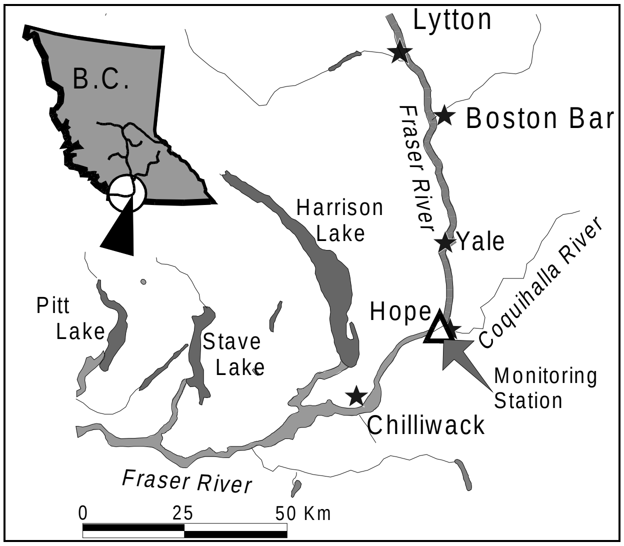


Figure 62. Location and surrounding area of the Environment Canada monitoring station on the Fraser River at Hope.

Water quality data at Hope represent the integrated effect of the array of natural processes and anthropogenic discharges within the whole of the upper and middle Fraser River. Data from the site are used both to estimate the effects of upstream activities and to provide background water chemistry for flows entering the heavily populated lower Fraser River (Figure 62).

In the reach from the monitoring site at Marguerite to Hope there are few direct discharges to the Fraser River which are of sufficient volume to affect water quality. The only permitted discharge is municipal wastewater from the City of Williams Lake (Swain *et al.* 1997). The primary concern in this release is in increased fecal coliform levels, which may be evident downstream.

Contributions of major tributaries such as the Chilcotin, Bridge, and Thompson Rivers result in roughly a doubling of instream flow, and significant changes in water chemistry. In particular, confluence of the Thompson and Fraser Rivers results in downstream dilution of many water quality constituents such as dissolved ions and suspended sediments (Shaw and El-Shaarawi 1995).

Regular water quality monitoring at the site, located slightly upstream of Hope on the Fraser River, commenced in 1985. Apart from a three-year period (1988-1990) when ready access to the sampling location was not possible, bi-weekly samples have been collected at the site since 1985.

Physical Parameters

No trends were found in turbidity or flow, but some form of trend was indicated for each of the remaining physical parameters at this site.

Linear increasing trends were indicated for both specific conductivity and total alkalinity, although the strength of the trend indicated by non-parametric analysis differed between the two variables. In both cases, although the trend statistics indicated significance, confidence intervals on the Sen's Slope estimate included zero (Appendix 6), suggesting a weak relationship (Table 20). Regression results indicated clear linear increasing trends, with r^2 values of 0.73 and 0.85 for conductivity and alkalinity, respectively (Appendix 6).

Non-parametric analysis suggested no trend in apparent colour, while subsequent regression analysis indicated a positive quadratic trend (Table 20). Annual summary plots of the data (Figure 64) shows the quadratic pattern in median levels indicated in regression modelling.

Water Quality Criteria/Objectives

No trends in physical variables were detected which would affect any water uses of the Fraser River at Hope.

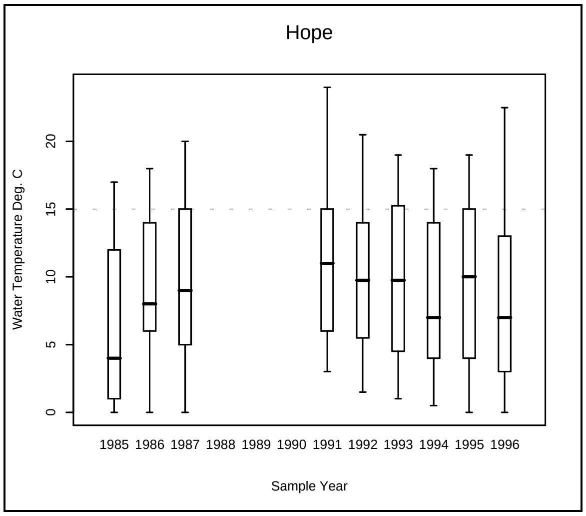


Figure 63. Annual summary of water temperature in the Fraser River at Hope, 1985 - 1996. The dashed line represents a suggested maximum water temperature for salmonid embryo survival (Nagpal 1994).

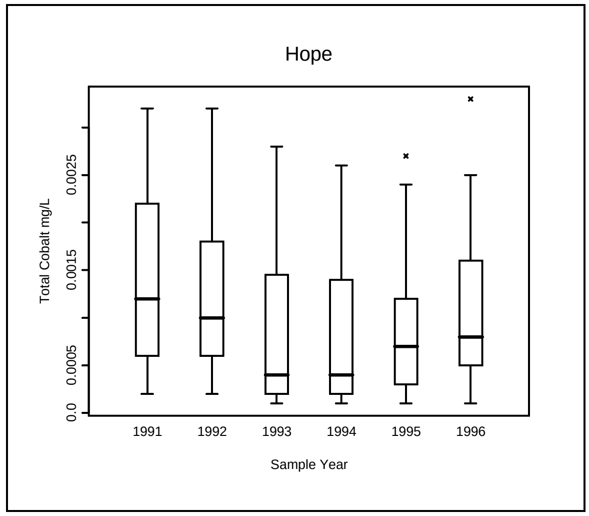


Figure 64. Annual summary of apparent colour in the Fraser River at Hope, 1985 - 1996. The dashed line represents the BC MoELP criteria for both drinking water and recreation aesthetics.

Non-parametric analysis of water temperatures indicated a linear increasing trend, but negative quadratic in regression analysis (Table 20). Median levels have clearly increased from the relatively low temperatures in the early part of the data record, but have apparently been declining somewhat in recent years (Figure 63).

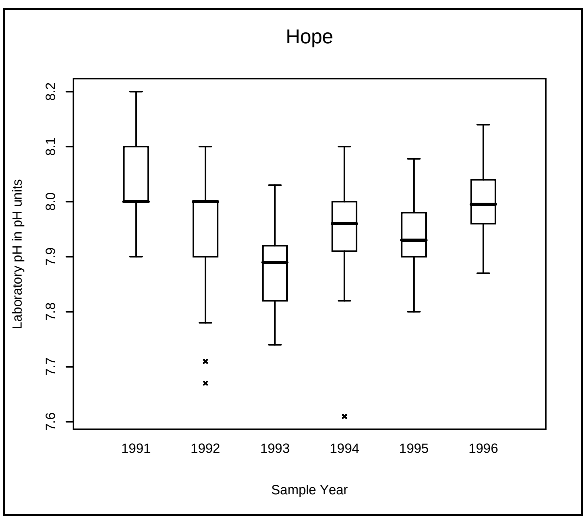


Figure 65. Annual summary of laboratory pH in the Fraser River at Hope, 1991 - 1996.

No trends were found in non-parametric analysis of laboratory pH data. In regression modelling, the pattern implied a weakly determined (r^2=0.28, Appendix 6) positive quadratic trend (Table 20). The data certainly show pH depression through 1993 (Figure 65), relative to adjacent years, the cause of which is unknown at present.

Analyses of the physical parameters at the site over the period 1985-1991 did not show any trends (Shaw and El-Shaarawi 1995).

Regression analyses confirm the expected relationships between the physical parameters and flow at this site. Concentrations of dissolved variables decline with increasing flow, due to dilution (Figure 66). Constituents that are related to particulate matter exhibit seasonal patterns evident in Figure 67. Both of these patterns are reflected in hysteresis diagrams (Table 20).

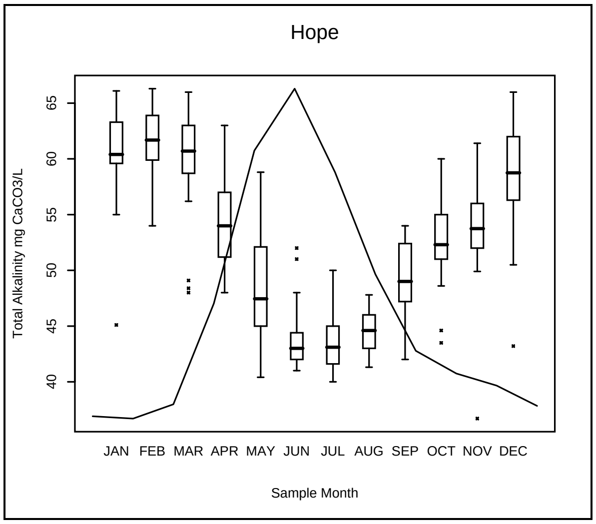


Figure 66. Seasonal summary of total alkalinity in the Fraser River at Hope. The solid line represents the seasonal discharge pattern.

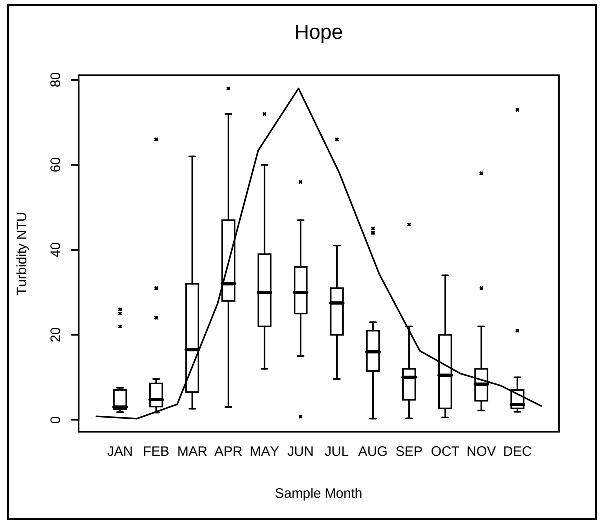
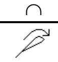
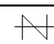
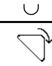


Figure 67. Seasonal summary of turbidity in the Fraser River at Hope. The solid line represents the seasonal discharge pattern.

Table 20. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada physical monitoring data in the Fraser River at Hope, 1985 - 1996.

Methods	**Physical Parameters**						
	Flow	**Water Temp**	**Lab pH**	**Apparent colour**	**Specific conductivity**	**Turbidity**	**Total alkalinity**
Non-parametric	➔	➚	➔	➔	➚	➔	➚
Regression	→	∩	∪	∪	↗	→	↗
Hysteresis							

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Dissolved Ions

Non-parametric and regression analysis of dissolved chloride indicated declining linear trends (Table 21), in contrast to the increasing trend reported for the 1985-1991 data (Shaw and El-Shaarawi 1995). That process changes at upstream pulp and paper mills are the main contributor to the reversal was corroborated by intervention regression analyses (Figure 68).

Increasing linear trends were indicated in dissolved magnesium and potassium by both non-parametric and parametric analyses (Table 21). Shaw and El-Shaarawi (1995) reported no trends in these two constituents sampled in 1985-1991. The increasing trends are congruent with trends at upstream monitoring sites at Hansard and Marguerite, suggesting that the trends at Hope may not be entirely due to sources downstream of Marguerite.

Water Quality Criteria/Objectives

No trends in dissolved ions were detected in this portion of the river which would jeopardize any water uses at the site.

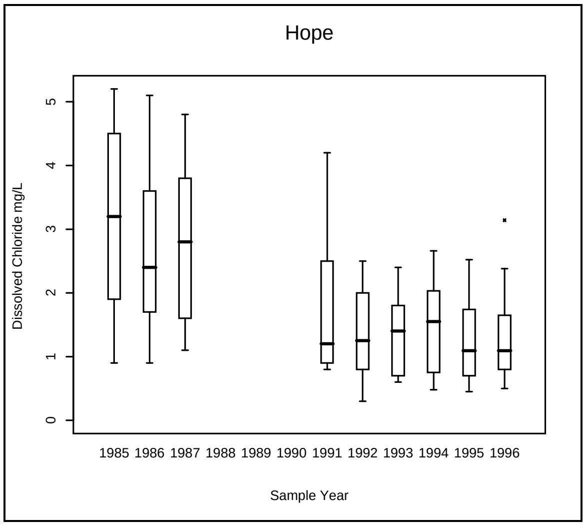


Figure 68. Annual summary of dissolved chloride in the Fraser River at Hope, 1985 - 1996.

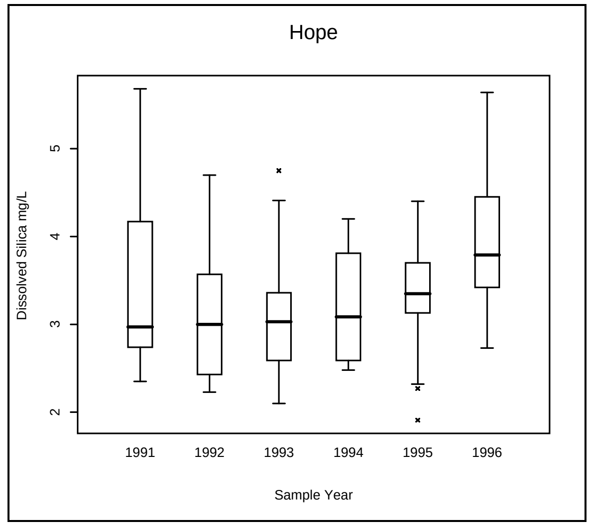


Figure 69. Annual summary of dissolved silica in the Fraser River at Hope, 1991 - 1996.

Non-parametric analysis of the dissolved silica record showed no apparent trend, although regression analysis indicated a positive quadratic relationship (Table 21). The increasing trend in median levels apparent in Figure 69 is driven by changes in the most recent (1995/1996) data. The regression relationship is quite weak, with an $r^2 = 0.17$ (Appendix 6).

Analyses of hardness, dissolved calcium, and dissolved sodium data indicated trends with regression modelling not indicated in non-parametric analyses (Table 21). Parametric analysis of hardness indicated an increasing linear trend while for dissolved calcium and sodium data, positive quadratic models best fit the time series (Table 21). Summary data plots (Figure 71 to Figure 72) show weak trends, with generally stable levels over time.

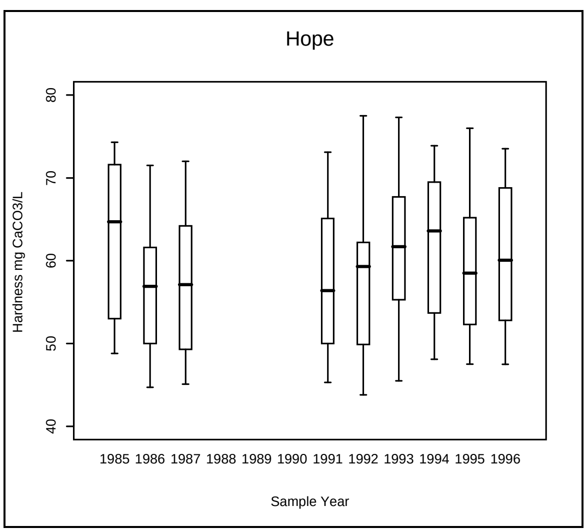


Figure 70. Annual summary of hardness in the Fraser River at Hope, 1985 - 1996.

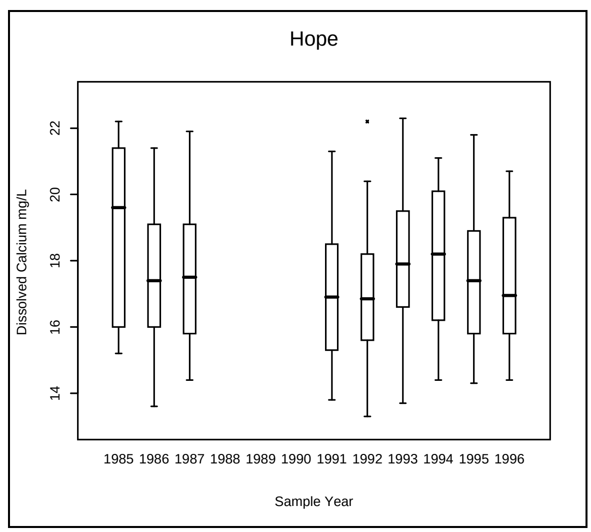


Figure 71. Annual summary of dissolved calcium in the Fraser River at Hope, 1985 - 1996.

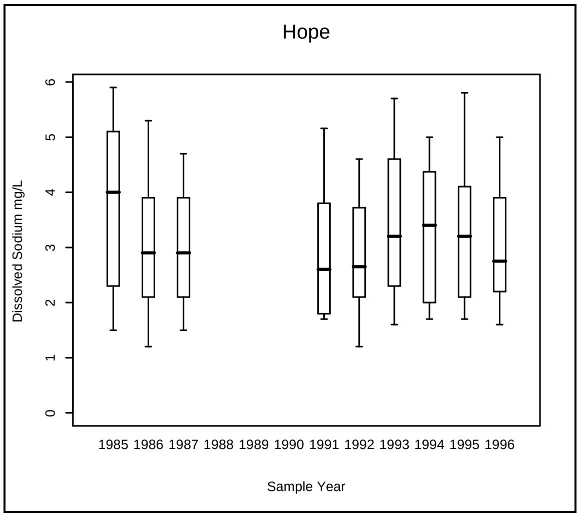


Figure 72. Annual summary of dissolved sodium in the Fraser River at Hope, 1985 - 1996.

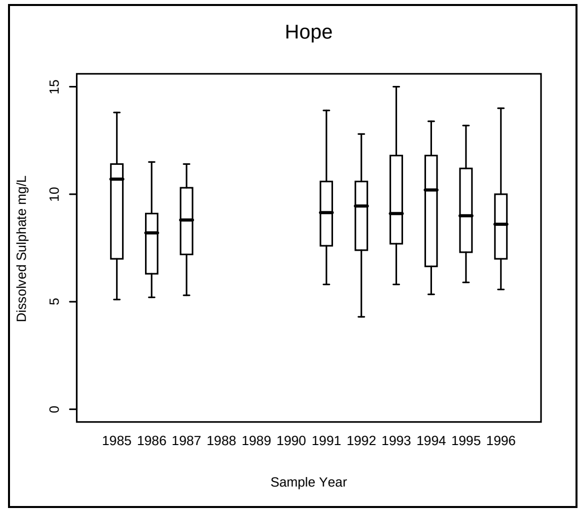


Figure 73. Annual summary of dissolved sulphate in the Fraser River at Hope, 1985 - 1996.

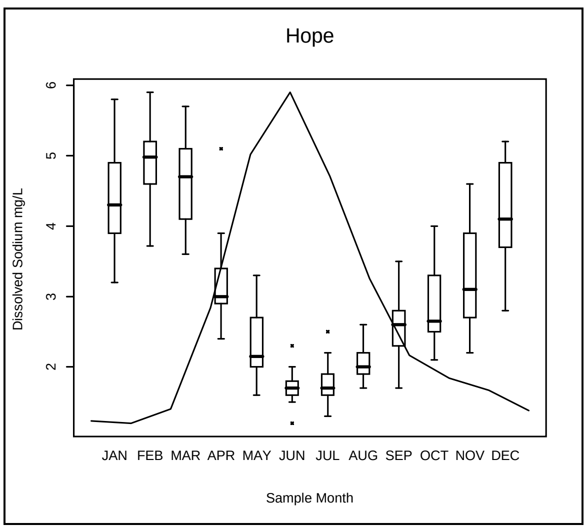


Figure 74. Seasonal summary of dissolved sodium in the Fraser River at Hope. The solid line represents the seasonal discharge pattern.

Non-parametric analysis of dissolved sulphate shows an increasing linear trend, which was modelled as a negative quadratic in subsequent regression modelling (Table 21). Here again, the pattern is only weakly supported by an annual summary plot (Figure 73).

Regression analyses (Table A6.10 in Appendix 6), hysteresis diagrams (Table 21) and seasonal summary plots (Figure 74) show the strong seasonality in the dissolved ion data series.

Nutrients

Non-parametric and regression analyses indicate a linear increasing trend in total phosphorus (Table 22), in contrast to results for 1985-1991 (Shaw and El-Shaarawi 1995) where no trend was found. The pattern may, in part, be due to contribution from the Thompson River which also showed an increasing trend in total phosphorus (see Thompson River at Spences Bridge discussion to follow). An annual summary plot of the data (Figure 75) shows clearly an increase in median concentration in recent years, which may be of concern in the future if the pattern persists.

Water Quality Criteria/Objectives

Analysis of dissolved nitrogen and total phosphorus did not indicate trends which would jeopardize any water use in the Fraser River at Hope.

Table 21. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion data in the Fraser River at Hope, 1985 - 1996.

Methods	**Dissolved Ions**			
	Dissolved calcium	Dissolved chloride	Dissolved magnesium	Hardness
Non-parametric	➔	⬊	⬈	➔
Regression	∪	↘	↗	↗
Hysteresis				
	Dissolved silica	Dissolved potassium	Dissolved sodium	Dissolved sulphate
Non-parametric	➔	⬈	➔	⬈
Regression	∪	↗	∪	∩
Hysteresis				

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

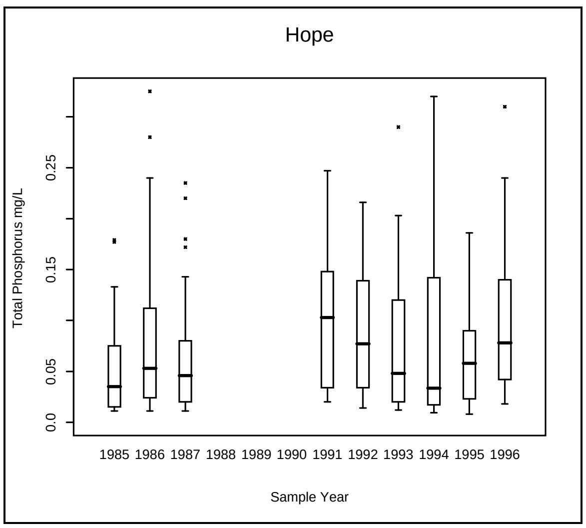


Figure 75. Annual summary of total phosphorus in the Fraser River at Hope, 1985 - 1996.

Annual summary plots of dissolved nitrogen (Figure 76) indicate little change in median levels over the period of record. Regression analysis, however, fit a positive quadratic model (Table 22). Non-parametric analysis did not suggest any trend, possibly due to the non-monotonic nature of the data series. Analysis of 1985-1991 data indicated a decreasing linear trend in both non-parametric and parametric analyses (Shaw and El-Shaarawi 1995).

The strong seasonality evident in the dissolved nutrients (Figure 77, Table A6.10 in Appendix 6, and hysteresis diagrams Table 22) is driven by both river discharge and dilution and biological uptake (Shaw and El-Shaarawi 1995).

Table 22. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved nutrient data in the Fraser River at Hope, 1985 - 1996.

Methods	**Nutrients**	
	Dissolved nitrogen	Total phosphorus
Non-parametric	➔	⬈
Regression	∪	↗
Hysteresis		

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

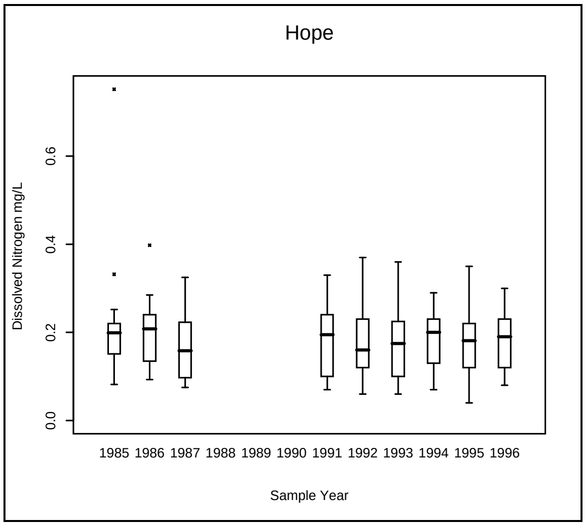


Figure 76. Annual summary of dissolved nitrogen in the Fraser River at Hope, 1985 - 1996.

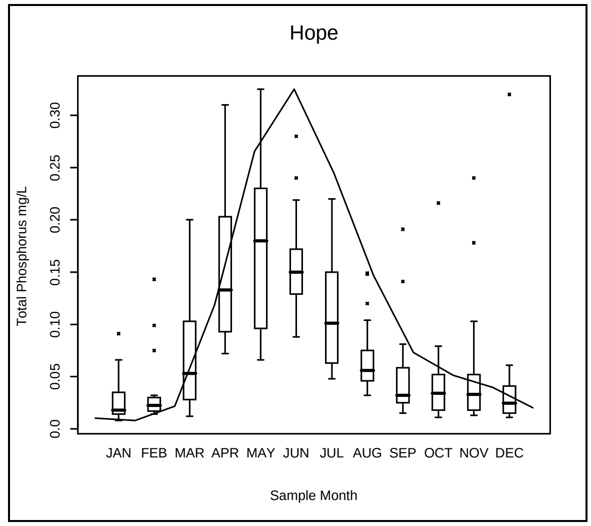


Figure 77. Seasonal summary of total phosphorus in the Fraser River at Hope. The solid line represents the seasonal discharge patterns.

Total Metals

No trends were detected for total cadmium, iron or manganese in either non-parametric or regression analyses (Table 23). The latter two results were consistent with results of analyses of 1985-1991 data (Shaw and El Shaarawi 1995; no comparison with total cadmium could be made since this was not analyzed for the period 1985-1991).

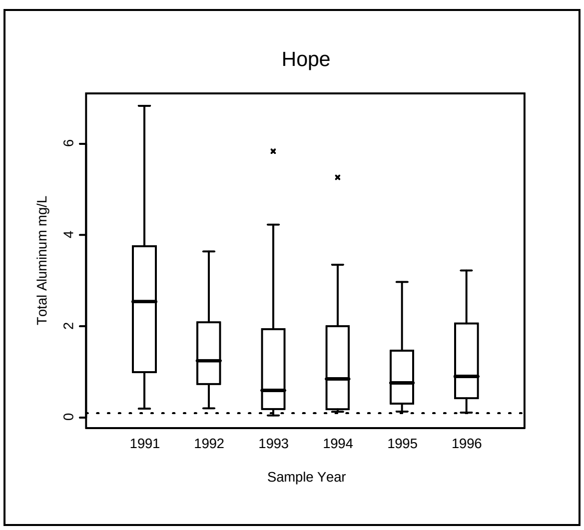


Figure 78. Annual summary of total aluminum in the Fraser River at Hope, 1991 - 1996. The dashed line represents the maximum BC MoELP dissolved and CCME total Al water quality criterion for protection of aquatic life (0.10 mg/l).

Linear declining trends in total lead and lithium were detected by both non-parametric and regression analyses (Table 23). While the cause of a decline in lithium might be difficult to ascertain, it is possible that a decline in lead may be due to the removal of lead as an anti-knock additive in automotive fuel. Whether such a change could translate to declining levels in a large river is open to debate.

Total aluminum (Figure 78) and total strontium showed no trends by non-parametric analyses, but decreasing linear trends were detected in regression.

Although non-parametric analyses of total barium, cobalt, nickel molybdenum and vanadium failed to identify any trends, regression modelling identified positive quadratic trends. Even in the relatively short data series, a U-shape (positive quadratic) is clearly evident in annual summary plots of these data (Figure 79 to Figure 82).

Total molybdenum data were dominated by measurements at or near the detection limit, and non-parametric analysis showed no trend. Regression analysis of these data indicated a positive quadratic trend (Table 23). The annual summary plot (Figure 83) suggests a stable median level, but a slight increase in maximum concentrations in recent years. Since Mo has replaced Pb as an antiknock agent in fuels, it is conceivable that a measurable increase in ambient levels might be associated with this application.

Water Quality Criteria/Objectives

No trends in total metals would affect water uses in the Fraser River at Hope. Some variables, such as total aluminum, iron, chromium, cobalt and manganese exceeded water quality guidelines and criteria but these excursions were likely related to suspended sediment load.

Table 23. Summary of non-parametric tests, regression modelling and hysteresis analysis of Environment Canada total metals monitoring data in the Fraser River at Hope, 1985 - 1996.

	Total Metals						
Methods	Al	As	Ba	Cd	Cr	Co	Fe
Non-parametric	➔	➔	➔	➔	➔	➔	➔
Regression	↘	→	∪	→	↘	∪	→
Hysteresis							
	Pb	Li	Mn	Mo	Ni	Sr	V
Non-parametric	➘	➘	➔	➔	➔	➔	➔
Regression	↘	↘	→	∪	∪	↘	∪
Hysteresis							

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

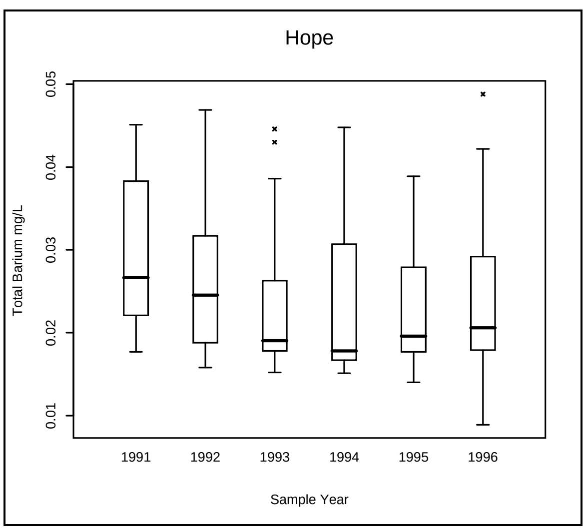


Figure 79. Annual summary of total barium in the Fraser River at Hope, 1991 - 1996.

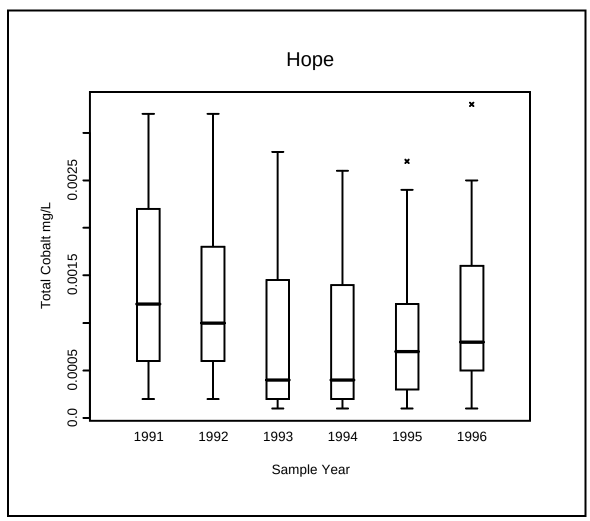


Figure 80. Annual summary of total cobalt in the Fraser River at Hope, 1991 - 1996.

Although non-parametric analysis showed no trend in total chromium data, subsequent regression analysis suggested a linear decreasing trend. This apparent decline is probably due to somewhat elevated levels in the 1991 data, since median concentrations have remained low and stable in recent years (Figure 84).

Seasonality is a strong characteristic of all total metal constituents as evidenced by regression analyses (Table A6.10 in Appendix 6), hysteresis diagrams (Figure 83) and monthly boxplots (e.g. Figure 85).

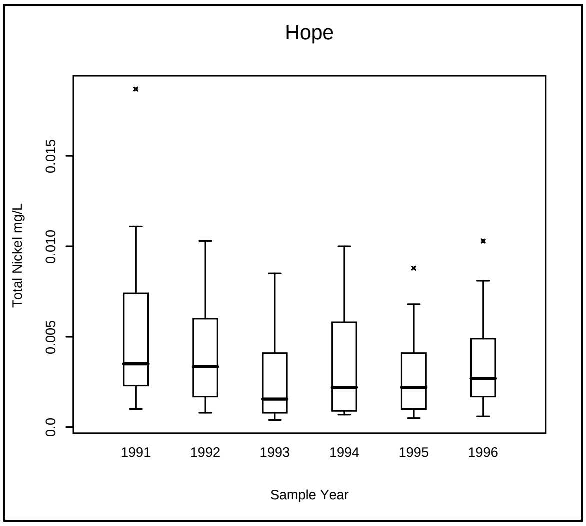


Figure 81 Annual summary of total nickel in the Fraser River at Hope, 1991 - 1996.

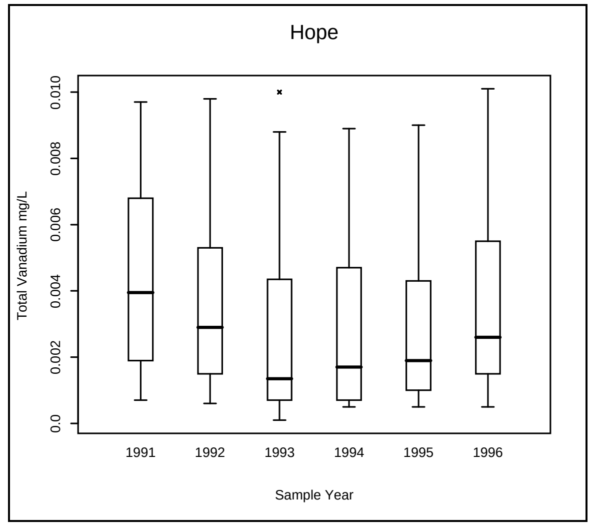


Figure 82 Annual summary of total vanadium in the Fraser River at Hope, 1991 - 1996.

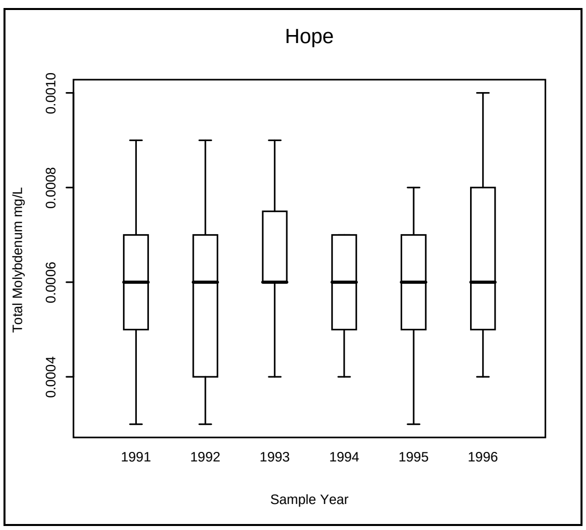


Figure 83. Annual summary of total molybdenum in the Fraser River at Hope, 1991 - 1996.

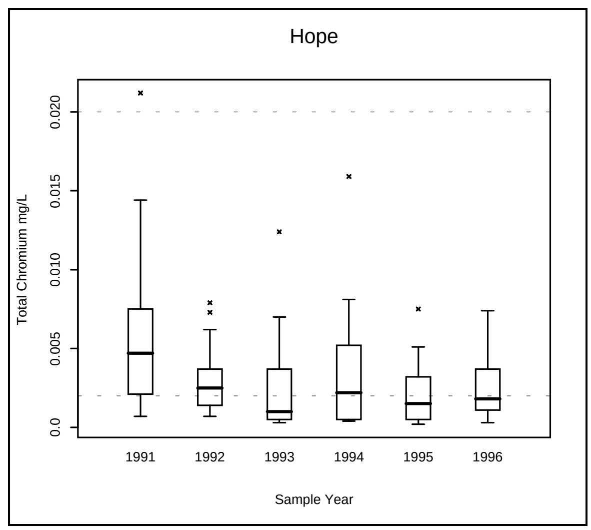


Figure 84. Annual summary of total chromium in the Fraser River at Hope, 1991 - 1996. The dashed lines are BC MoELP water quality criteria for protection of aquatic life - 0.002 mg/l - phyto and zooplankton, 0.020 mg/l- freshwater fish.

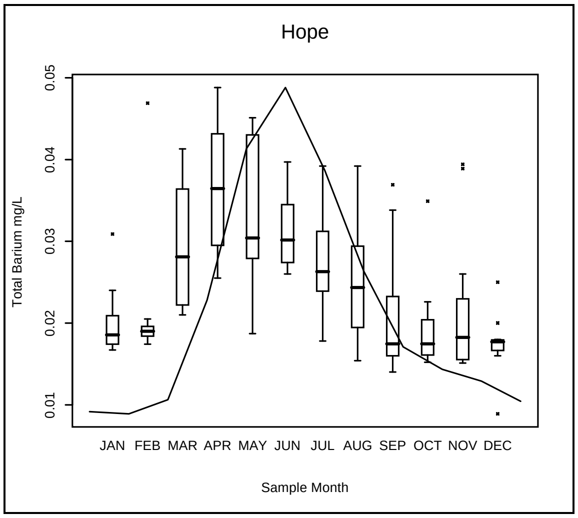


Figure 85. Seasonal summary of total barium in the Fraser River at Hope. The solid line represents the seasonal discharge patterns.

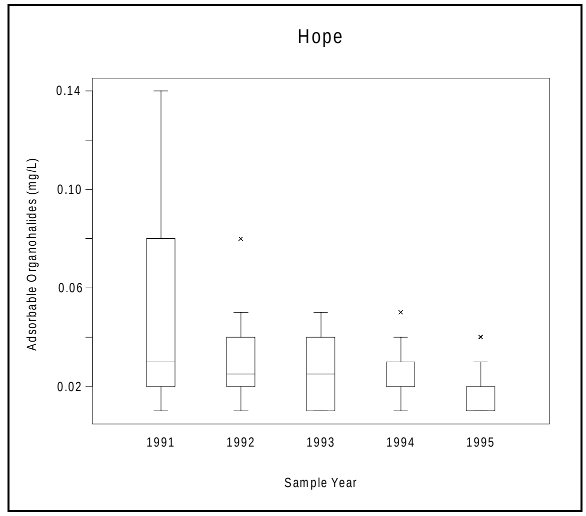


Figure 86. Annual summary of AOX in the Fraser River at Hope, 1991 - 1995.

Organics

Both non-parametric and regression analyses of BC MoELP AOX data showed a strong linear decreasing trend (Table 24). An annual summary plot of the data shows clearly the declining range and median levels over the period of record (Figure 86). Reduction of AOX in effluent is a direct result of the pulp and paper mill process changes discussed above. Intervention regression analysis identified a decrease between pre- and post- 1991 AOX data.

Water Quality Criteria/Objectives

AOX levels in the Fraser River declined over the period of record. However, it is likely that even the relatively low current levels continue to exceed the BC MoELP objective for the upper Fraser.

Table 24. Summary of non-parametric tests, regression modelling and hysteresis patterns of BC Ministry of Environment, Lands and Parks AOX monitoring data in the Fraser River at Hope, 1991 - 1996.

Methods	Organics
	Adsorbable organohalides
Non-parametric	➘
Regression	↘
Hysteresis	↻

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

5.6 Nechako River

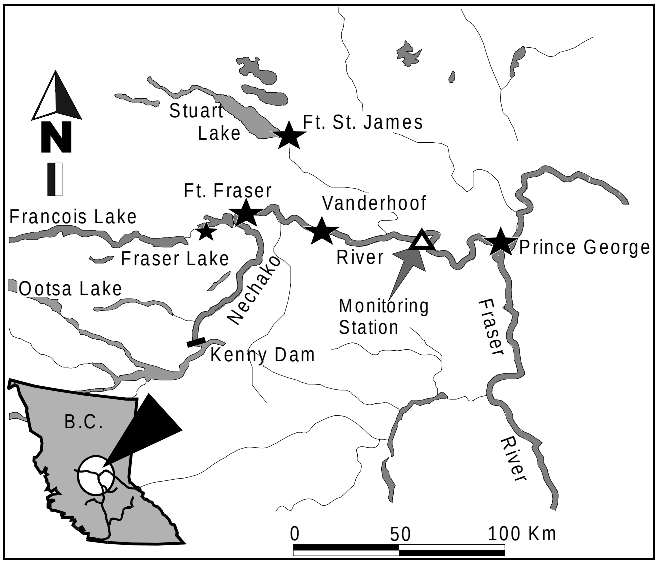


Figure 87. Location and surrounding area of the Environment Canada monitoring station on the Nechako River.

The Nechako River drains a sparsely populated watershed in the northeast corner of the Fraser Basin (Figure 87). The Kenny Dam, a hydroelectric generating facility produces electricity for Alcan aluminum smelters in Kitimat, and regulates instream flows in the Nechako. Since the facility was completed in 1954, Nechako flows have dropped to 70% of unregulated discharge volumes. Water quality monitoring near the confluence of the Nechako and Fraser Rivers commenced in 1985 as a jointly funded federal and provincial program to measure the effects of upstream regulation and to determine the character of the water entering the Fraser mainstem.

Forestry and mining are the principal industrial activities in the basin.

The three communities in the basin, Fort Fraser, Vanderhoof and Fraser Lake, together support a population of 42,000 persons (1996 census). Over the period of water quality monitoring, the population in the watershed has increased 12%, from 37,500 in 1985 to 42,000 in 1995.

Previous trend analyses of the Nechako River monitoring data (Shaw and El-Shaarawi 1995) showed that although no monotonic increasing or decreasing trends were evident, the effect of flow regulation was quite apparent. Quadratic trends were distributed liberally through the analyses of the six years of data, a possible result of an unnatural groundwater/surface water interaction resulting from water releases at the Kenny Dam.

Physical parameters

Of the flow data from the eight water quality monitoring sites in this report, only statistical analyses from the Nechako River have suggested increasing flows. An increasing trend was evident in the regression analyses, although the fit of the model was very poor (r^2=0.03). Results of the non-parametric tests are somewhat ambiguous since, although both the Van Belle and Seasonal Kendall results indicate a trend, the Sen's Slope confidence interval (negative lower CI, positive upper CI; Appendix 6, Table 11) suggests that the results should be viewed with caution. Annual summary plots (Figure 89) indicate the trend may be due to somewhat anomalous 1996 data, a period of increased releases from the Kenny Dam.

No trends in apparent colour, turbidity, filterable residue, water temperature, laboratory pH or total alkalinity were detected with either non-parametric or regression analyses. A linear increasing trend was, however, detected in non-filterable residue data in both sets of analyses (Table 25). A slight decreasing trend in water temperature was suggested in regression analysis (Figure 88), although not by non-parametric statistics. Likewise, no trend was evident in total alkalinity using non-parametric statistics

Water Quality Criteria/Objectives

No trends in physical parameters were identified that would affect water uses in the Nechako River.

(Figure 93). The annual summary plots show higher levels at the beginning and end of the data record which would have contributed to a positive quadratic model fit by regression analysis but, overall, support the non-significant non-parametric result.

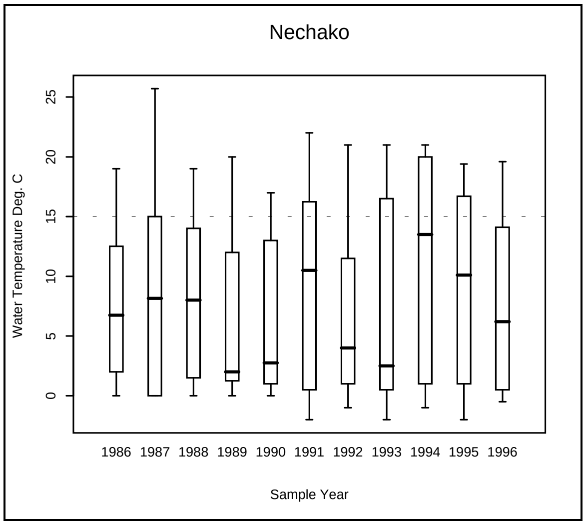


Figure 88. Annual summary of water temperature in the Nechako River, 1986 - 1996. The dashed line represents a recommended maximum water temperature for salmonid embryo survival (Nagpal 1994).

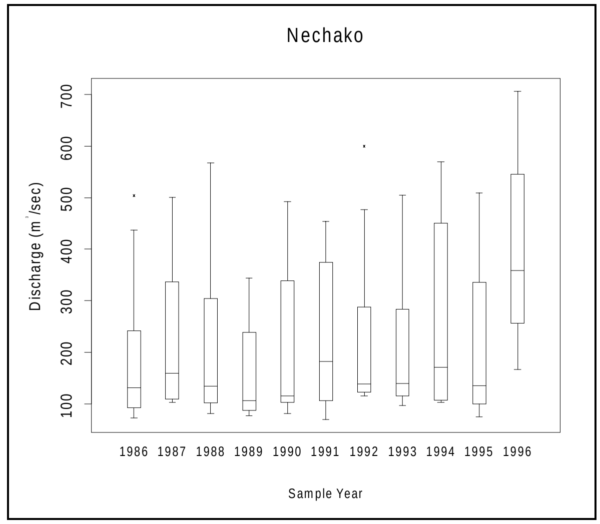
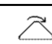
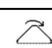
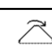
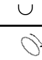


Figure 89. Annual summary of discharge in the Nechako River, 1986 - 1996.

Table 25. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks physical monitoring data in the Nechako River, 1985 - 1996.

Methods	**Physical Parameters**				
	Flow	Water temperature	Laboratory pH	Apparent colour	Specific conductivity
Non-parametric	➔	➔	➔	➔	➚
Regression	↗	↘	∪	→	∪
Hysteresis					
		Turbidity	Filterable residue	Non-filterable residue	Total alkalinity
Non-parametric		➔	➔	➚	➔
Regression		→	→	↗	∪
Hysteresis					

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

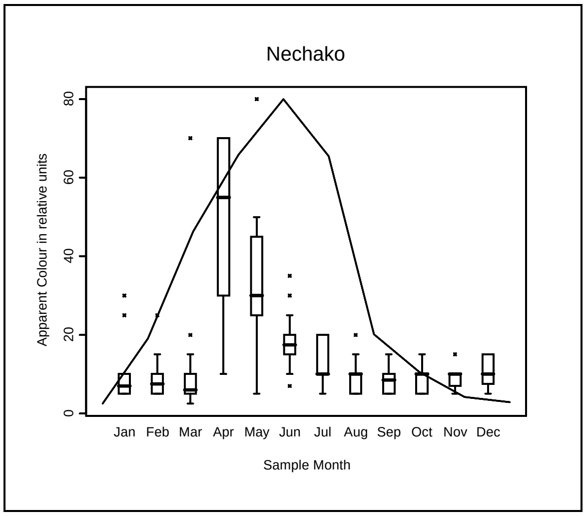


Figure 90. Seasonal summary of apparent colour in the Nechako River. The solid line represents the seasonal discharge pattern at the site.

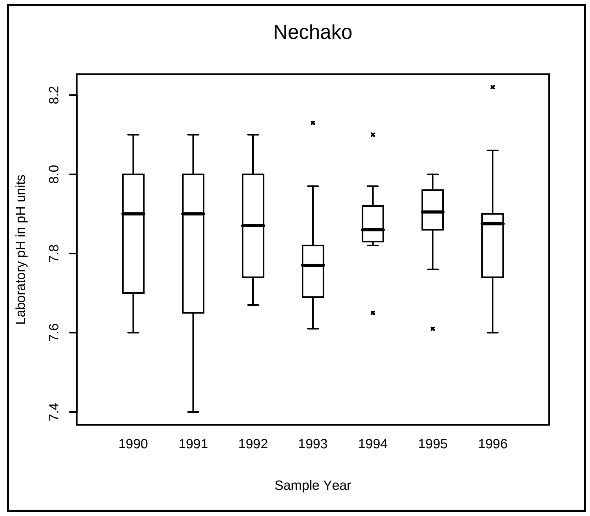


Figure 91. Annual summary of laboratory pH in the Nechako River, 1990 - 1996.

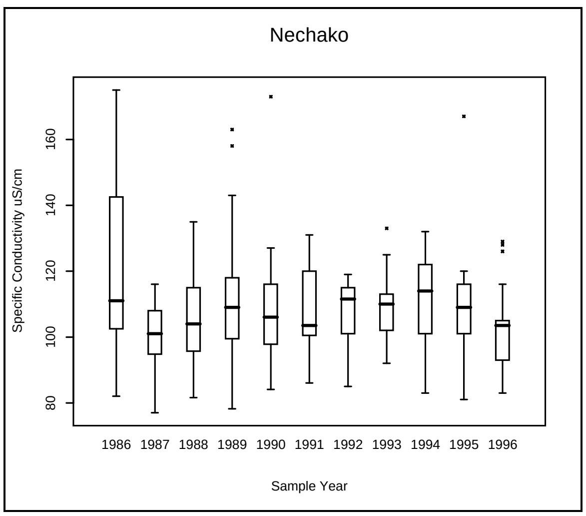


Figure 92. Annual summary of specific conductivity in the Nechako River, 1986 - 1996.

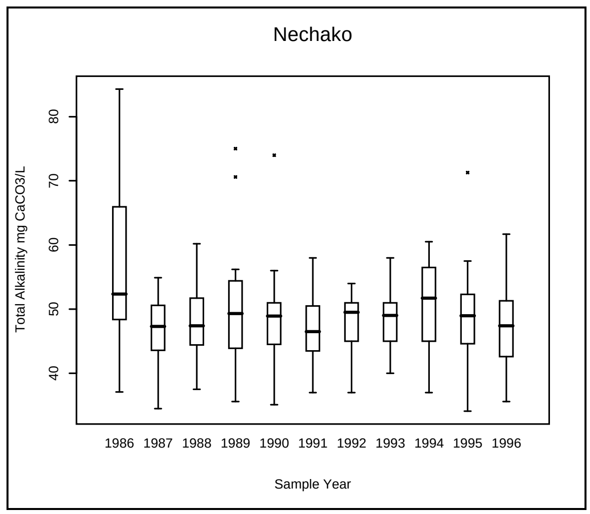


Figure 93. Annual summary of total alkalinity in the Nechako River, 1986 - 1996.

Regression analysis of laboratory pH suggested a positive quadratic trend, probably resulting from lower values observed in 1993 (see Figure 91). The cause of this apparent depression in median levels is not known.

Generally increasing trends in specific conductivity were identified in both non-parametric (linear increasing) and regression analysis (positive quadratic) (Table 25). A summary plot of the data (Figure 92) shows little change in median levels, hovering between 100 and 120 μS/cm for the period of record.

Most physical constituents at this site follow the seasonal patterns illustrated in Figure 90. The forms of hysteresis diagrams (Table A6.12 in Appendix 6) agree generally with those seen monitoring sites elsewhere in the Fraser Basin. Some constituent-flow relationships will vary slightly, perhaps due to flow regulation at the Kenny Dam.

Dissolved Ions

In contrast to analyses of data from monitoring sites on the mainstem Fraser River, the fit of regression models to dissolved ion data from the Nechako (Table A6.12 in Appendix 6) was generally poor ($r^2 < 0.5$). This may be a consequence of the flow regulation in the river and a general disruption of normal patterns of groundwater/surface water interactions - further analytical effort is required to investigate the causes.

Positive quadratic trends were indicated by regression analyses of dissolved calcium, magnesium, hardness, silica and sodium data (Table 26). Annual summary plots of magnesium and sodium (Figure 94 and Figure 97) suggest that an increasing trend does exist, although decreases in median levels were seen in 1996. Variability of both data series in 1996 data was considerably higher than in previous years, perhaps attributable to the increase in flows as discussed above.

No trend was identified in dissolved chloride data (Figure 95), and a linear increasing trend was detected in dissolved potassium data by regression but not in non-parametric analyses (Table 26).

Water Quality Criteria/Objectives

Increasing trends were detected for all dissolved ion constituents, except for chloride, but none jeopardize any water use. Dissolved ion concentrations were well below water quality criteria/objectives.

Analysis of dissolved calcium data using non-parametric statistics indicated no trend, while regression analyses suggested a positive quadratic trend. Graphical evidence (Figure 96) would suggest that the regression results are probably due to anomalous high values in the early part of 1986, the cause of which is unknown at present.

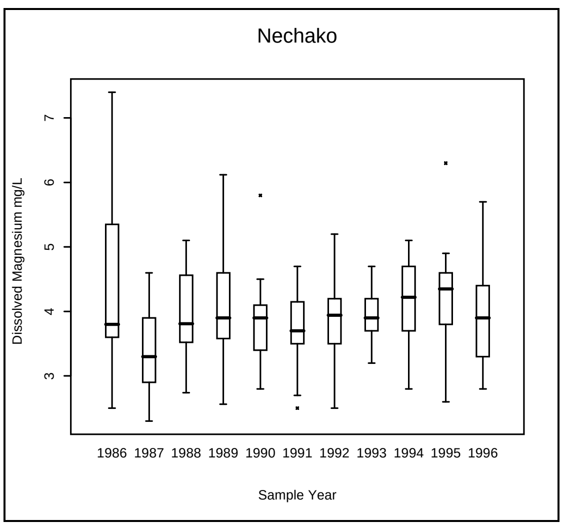


Figure 94. Annual summary of dissolved magnesium in the Nechako River, 1986 - 1996.

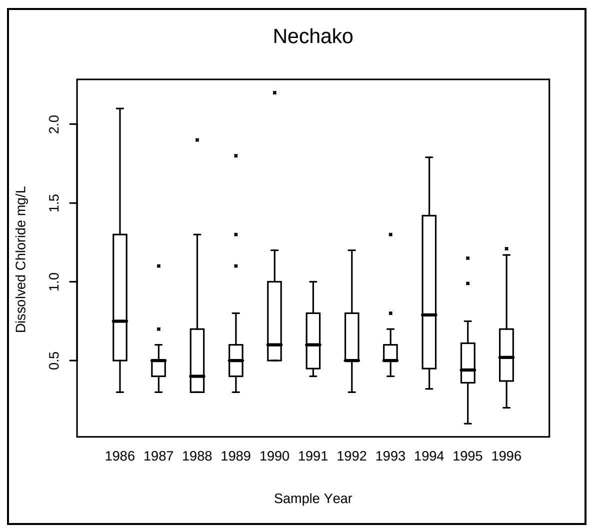


Figure 95. Annual summary of dissolved chloride in the Nechako River, 1986 - 1996.

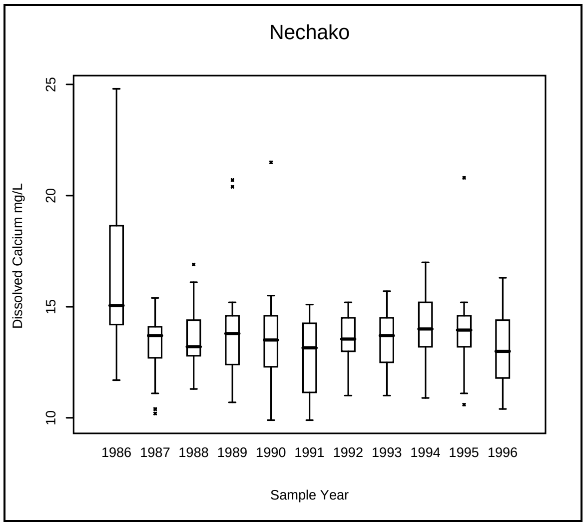


Figure 96. Annual summary of dissolved calcium in the Nechako River, 1986 - 1996.

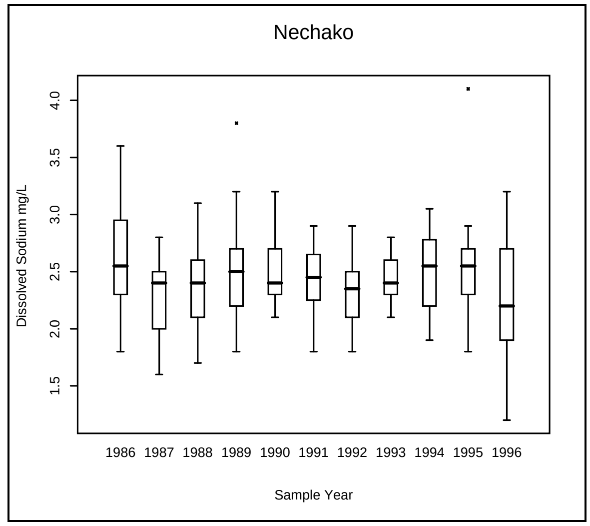


Figure 97. Annual summary of dissolved sodium in the Nechako River, 1986 - 1996.

Table 26. Summary of non-parametric tests, regression modelling and hysteresis patterns of dissolved ion-related Environment Canada monitoring data in the Nechako River, 1985 - 1996.

Methods	**Dissolved Ions**			
	Dissolved calcium	Dissolved chloride	Dissolved magnesium	Hardness
Non-parametric	➔	➔	➚	➔
Regression	∪	→	∪	∪
Hysteresis				
	Dissolved silica	Dissolved potassium	Dissolved sodium	Dissolved sulphate
Non-parametric	➔	➚	➚	➔
Regression	∪	↗	∪	∩
Hysteresis				

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Annual summary plots of hardness data (Figure 99) tend to support the positive quadratic model indicated in regression analysis. Non-parametric tests did not detect a trend (Table 26).

The quadratic regression models fit to dissolved silica and dissolved sulphate are clearly supported in summary plots (Figure 98 and Figure 100). Non-parametric analyses of these constituents suggested no trends. The cause of the trends, particularly for dissolved sulphate, is not known.

Seasonality in dissolved ion constituents at this site is evident but is not as pronounced as that seen at other sites (Figure 101, Table A6.12 in Appendix 6, and hysteresis diagrams Table 26), possibly another effect of upstream flow regulation.

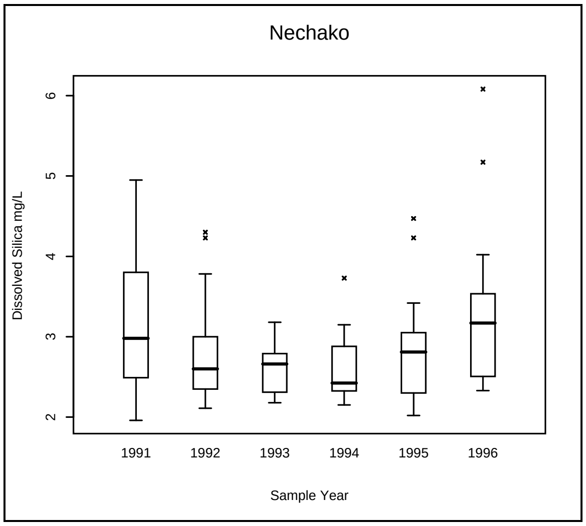


Figure 98. Annual summary of dissolved silica in the Nechako River, 1986 - 1996.

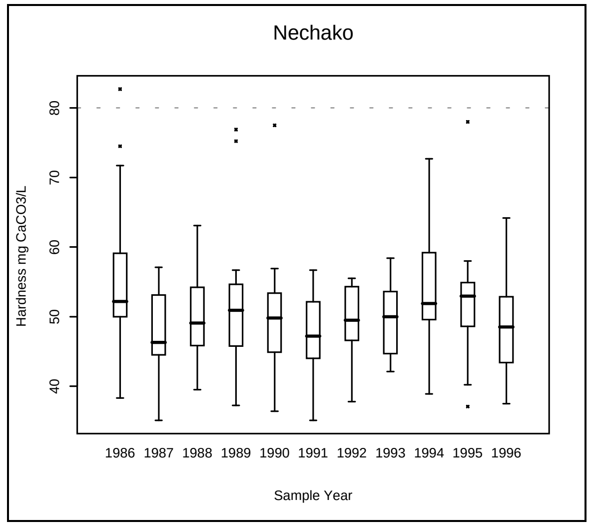


Figure 99. Annual summary of hardness in the Nechako River, 1986 - 1996. The dashed line represents the upper limit for "good quality" drinking water

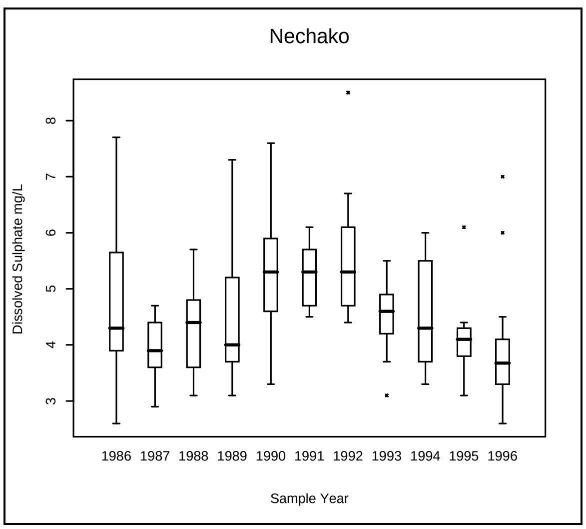


Figure 100. Annual summary of dissolved sulphate in the Nechako River, 1986 - 1996.

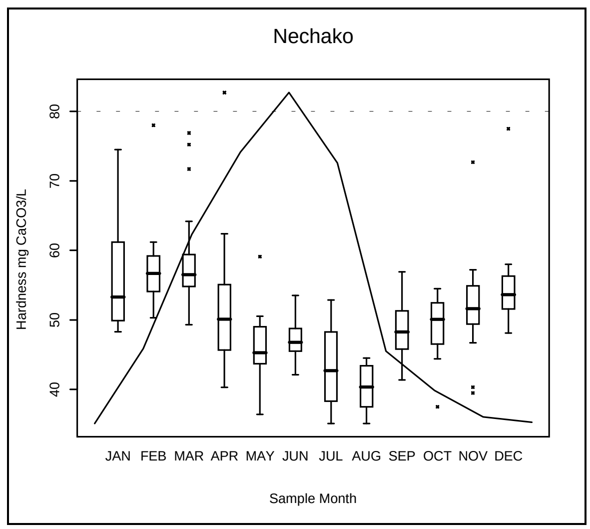


Figure 101. Seasonal summary of hardness in the Nechako River. The solid line represents seasonal discharge patterns while the dashed line represents the upper limit for "good quality" drinking water.

Nutrients

No trends in nitrate/nitrite, dissolved phosphorus or total phosphorus were identified in either non-parametric or regression analyses of the data (Table 24). This result is consistent with results reported by Shaw and El-Shaarawi (1995) for the 1985-1991 period.

Water Quality Criteria/Objectives
No trends in nutrients were identified which would jeopardize any water use in the Nechako River. No criteria were exceeded.

For dissolved nitrogen, although non-parametric analysis identified no increasing or decreasing trend (Table 27), subsequent regression analysis suggested a linear increasing concentration. The trend is weak in a summary plot (Figure 102), and is probably of little consequence. For this same site, a quadratic trend was reported in 1985-1991 data by Shaw and El-Shaarawi (1995), a pattern which is clearly evident in the summary plot.

Table 27. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks nutrient monitoring data in the Nechako River, 1985 - 1996.

Methods	**Nutrients**			
	Nitrate/ nitrite	Dissolved nitrogen	Dissolved phosphorus	Total phosphorus
Non-parametric	➔	➔	➔	➔
Regression	→	∪	→	→
Hysteresis				

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

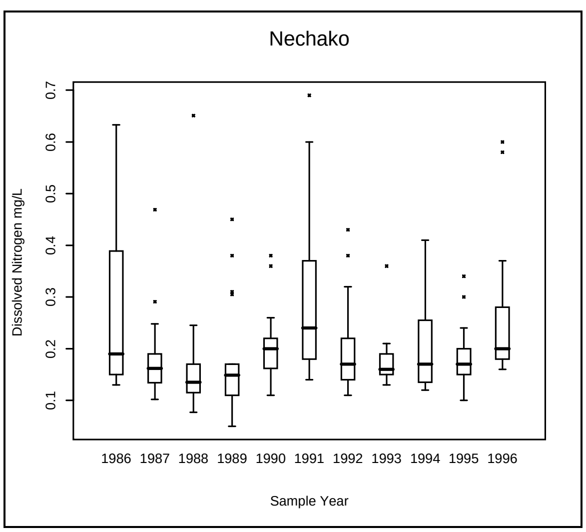


Figure 102. Annual summary of dissolved nitrogen in the Nechako River, 1986 - 1996.

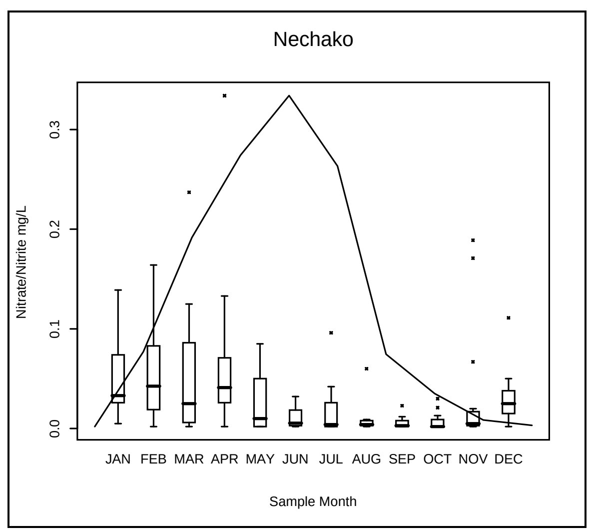


Figure 103. Seasonal summary of nitrate/nitrite in the Nechako River. The solid line represents the seasonal discharge pattern.

Dissolved nutrients at this site, with the exception of dissolved phosphorus, all showed significant seasonality (see Figure 103 as an example), and all exhibited significant relationships with flow (Table 27).

Metals

Negative trends were detected in non-parametric analyses of data for total aluminum, total barium and for total chromium. Results were, however, ambiguous in that statistical results suggest trends in the data while the Sen's Slope estimate includes both positive and negative values in the confidence interval, suggesting a zero slope (Appendix 6). As such, results of non-parametric analyses are considered weak and reported as having no trend in Table 28. No trends were found for other total metal variables.

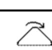
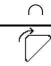
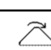
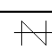
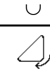
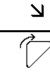
Water Quality Criteria/Objectives

There were no trends in total metals which would affect water uses in the Nechako River. Total aluminum, total iron, total chromium and total manganese exceeded water quality guidelines or criteria, but levels were associated with increases in suspended sediment load.

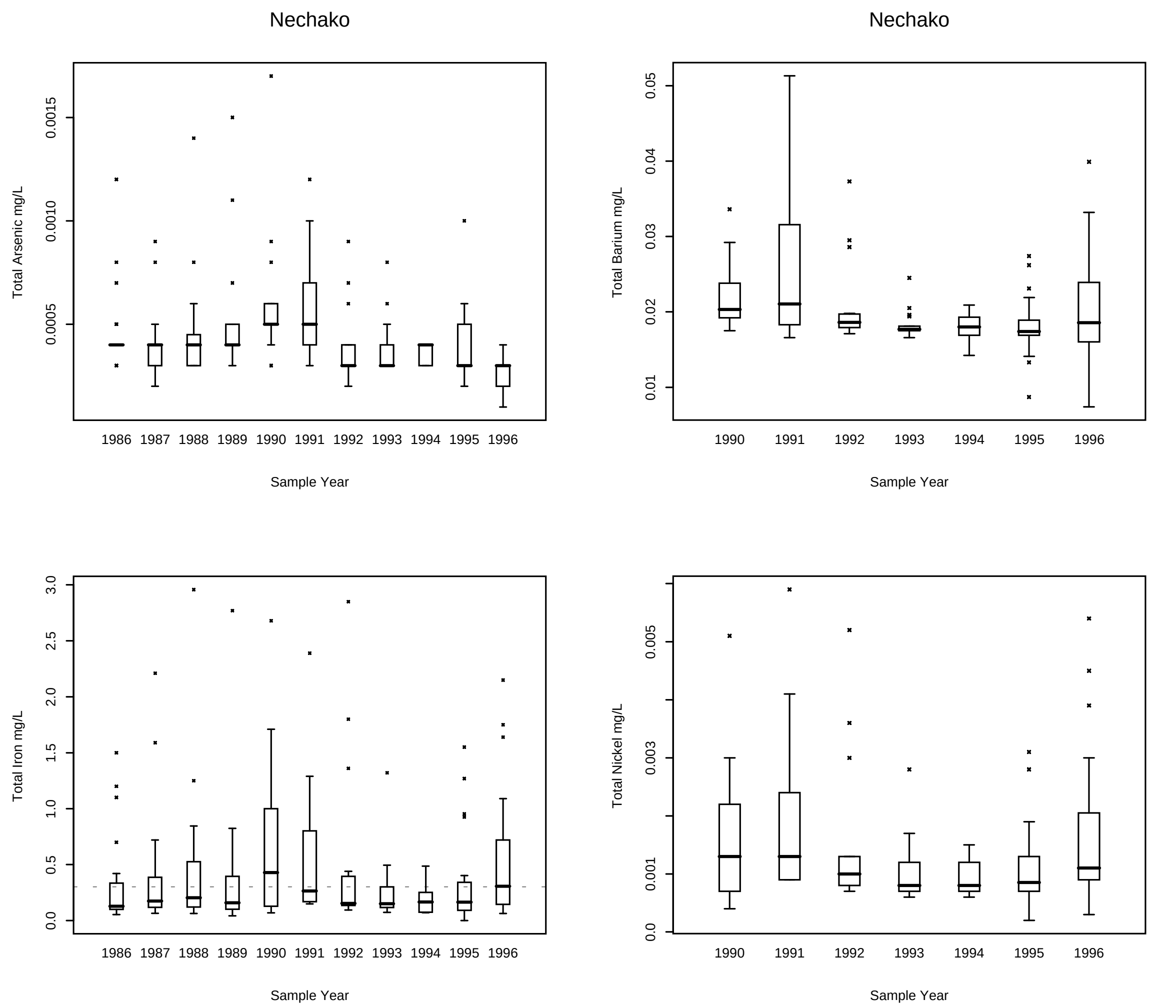
Regression analyses suggested negative linear trends in total aluminum, chromium and vanadium but quadratic trends for total arsenic, barium, iron, and nickel (Table 28). The quadratic trends in particular would seem to be supported by the apparent shift in median levels which is evident in annual summary plots (Figure 104). The model fits are weak ($r^2 < 0.30$ typically), and appear to be driven by a rise in concentrations in recent years. This may perhaps be attributable to releases from the Kenny Dam, although more work will be required to confirm. A linear declining trend in vanadium was suggested by regression, somewhat contrary to the pattern evident in a summary plot (see Table 28, and Tables A6.11 and A6.12 in Appendix 6 to compare the statistical findings).

Seasonality in total metals reflects the association with suspended particulates. Discharge gradually increases through the spring, eventually mobilizing bed-sediments which contribute significantly to total metals levels (Figure 105 and Figure 106, hysteresis diagrams, Table 28).

Table 28. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals monitoring data in the Nechako River, 1985 - 1996.

Methods	Total Metals					
	Al	As	Ba	Cr	Fe	Li
Non-parametric	➔	➔	➔	➔	➔	➔
Regression	↘	∩	∪	↘	∩	→
Hysteresis						
		Mn	Mo	Ni	Sr	V
Non-parametric		➔	➔	➔	➔	➔
Regression		→	→	∪	→	↘
Hysteresis						

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend



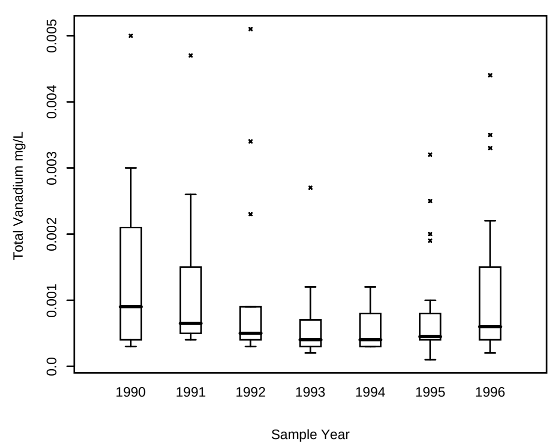


Figure 104. Annual summaries of selected Environment Canada total metals data for the Nechako River, 1986 - 1996. The dashed line in the total iron figure represents the CCME/BC MoELP water quality criterion for protection of aquatic life. All other metals were far below relevant water quality criteria.

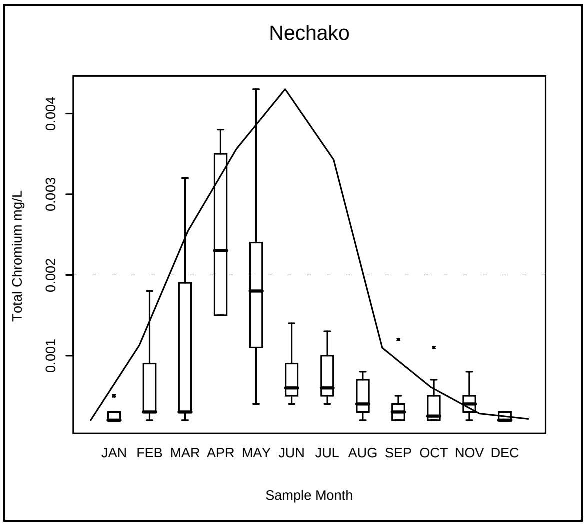


Figure 105. Seasonal summary of total chromium in the Nechako River. The solid line represents seasonal discharge patterns while the dashed line represents the BC MoELP water quality criterion (0.002 mg/L) for protection of aquatic life - phytoplankton and zooplankton.

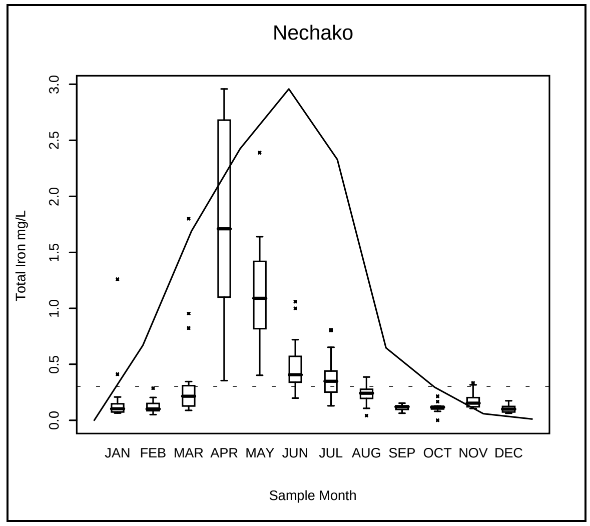


Figure 106. Seasonal summary of total iron in the Nechako River. The solid line represents seasonal discharge patterns while the dashed line represents the CCME/BC MoELP water quality criterion for protection of aquatic life.

5.7 Salmon River

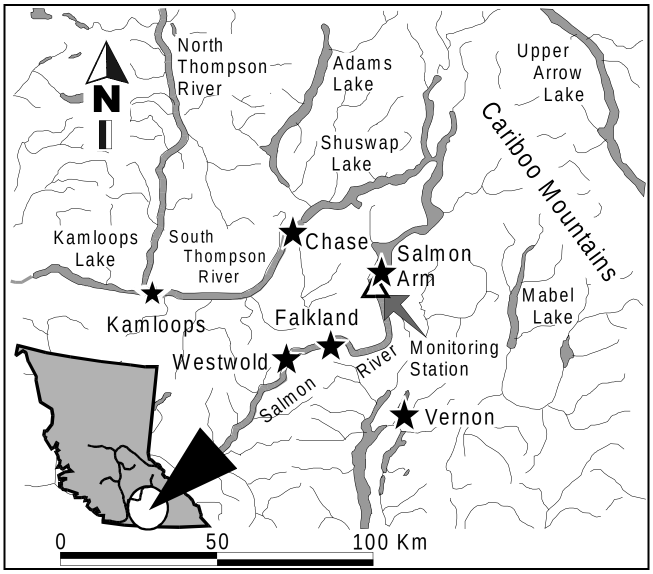


Figure 107. Location and surrounding area of the Environment Canada monitoring station on the Salmon River.

The Salmon River differs significantly from other sites considered in this report in its physiographic setting, comparatively low flows and the dominance of the annual hydrograph by groundwater flow rather than alpine meltwaters. The headwaters are at an elevation of about 1000 m, and support no permanent ice. As such, flows are near base-levels through much of the year, with the exception of a short snowmelt-driven freshet. In addition, during much of the year, the river disappears into the streambed near Westwold, resurfacing approximately 10 km downstream near Falkland (Figure 107). Consequently, dissolved ions and associated physical constituents such as hardness and specific conductivity are very high relative to other long-term monitoring sites in the Fraser Basin (Shaw and El-Shaarawi 1995).

There are no industrial discharges in the basin, and water quality concerns relate principally to agricultural practices and to some extent, timber harvesting in the upper basin and tributaries. In 1991, an estimated 40% of the total watershed area had been logged, of which 10% was "recent" (McPhee *et al.* 1996). Agricultural activities have become a particular concern in recent years (Aquametrix Ltd. 1995; McPhee *et al.* 1996), especially with respect to the extent of water withdrawal from both surface and groundwater (Obedkoff 1974). A critical consequence of these activities has been a decline of instream flow (Obedkoff 1974).

Monitoring in the Salmon River was initiated to address concerns about declining water quality and to examine contributions by the river to eutrophication problems in the recipient Salmon Arm of Shuswap Lake. Naturally high phosphorus in the Salmon River headwaters, combined with residential and agricultural drainage, result in the river being a significant source of nutrients to the lake (Aquametrix Ltd. 1995).

Bi-weekly water quality data at the site span 1988 to 1996 with a six-month interruption due to a change in sampling personnel.

Physical Parameters

No trends were identified in either flow or water temperature at this site (Table 29).

Some trends were evident, but were not strong. Apparent colour, showed a non-significant result with the mSK, but showed significant results in both the Van Belle and SK tests (Appendix 6). The results here are the same as was found for 1988-1991 (Shaw and El-Shaarawi 1995). Likewise, both Van Belle and SK tests for trend in pH were significant, but mSK was non-significant so the data series is judged to have no trend by non-parametric analysis (Table 29). In the case of the pH data, however, a decreasing trend was also identified by regression with a slope of but 0.015 units/year (Appendix 6).

Both non-parametric and regression methods showed linear increasing trends in turbidity and non-filterable residue (Table 5.26). The increases were not apparent in analyses of 1988-1991 data (Shaw and El-

Shaarawi 1995), and seem to be evidenced in an annual summary plot (Figure 108) as slightly increasing median level and dramatically increasing variability. Although difficult to conclusively attribute cause to the observed trend, this increase might be expected from streambank erosion associated with development, cattle ranching and timber harvesting - all of which are activities of concern for water quality in the watershed.

Table 29. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks physical monitoring data in the Salmon River, 1985 - 1996.

Methods	**Physical Parameters**			
	Flow	Water temperature	Laboratory pH	Apparent colour
Non-parametric	→	→	→	→
Regression	→	→	↘	→
Hysteresis			\	/
	Specific conductivity	Turbidity	Non-filterable residue	Total alkalinity
Non-parametric	→	↗	↗	→
Regression	↗	↗	↗	↗
Hysteresis	\			\

→ - no trend　　**↗** - increasing linear trend　　**↘** - decreasing linear trend
→ - no trend　　↗ - increasing linear trend　　↘ - decreasing linear trend
∪ - positive quadratic trend　　∩ - negative quadratic trend

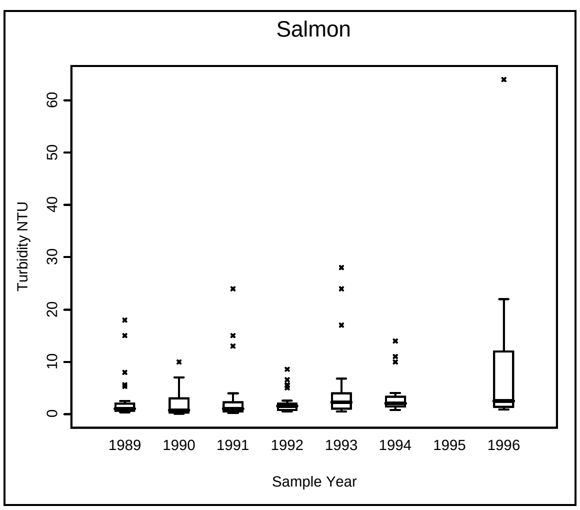
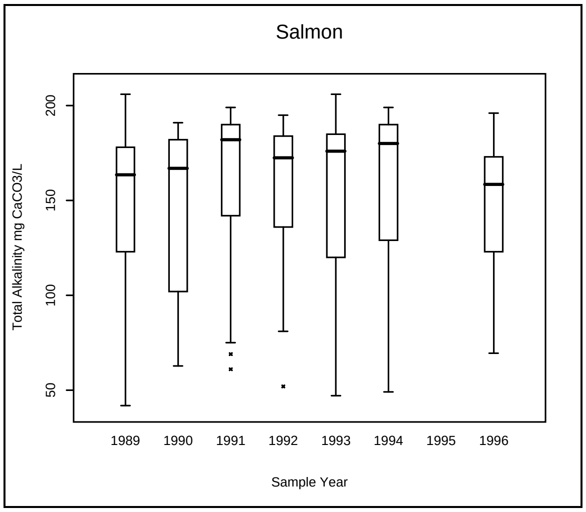


Figure 108. Annual summary of turbidity in the Salmon River, 1989 - 1996.

While non-parametric analyses of specific conductivity and total alkalinity indicated no trends, regression analyses identified linear increasing patterns in the data (Table 29). A summary plot of total alkalinity does show a distinct increase in median levels over the 1988-1994 period (Figure 109) and a decline in the most recent data. Seasonal patterns in the physical parameters in the Salmon River are similar to those at other monitoring sites in the Fraser basin, although perhaps better defined due to the brief freshet period (Figure 112 and Figure 111). Positive correlations with flow are evident in sediment-related constituents, while the short spring freshet results in temporary depression of laboratory pH, specific conductivity and total alkalinity (hysteresis diagrams Table 29).



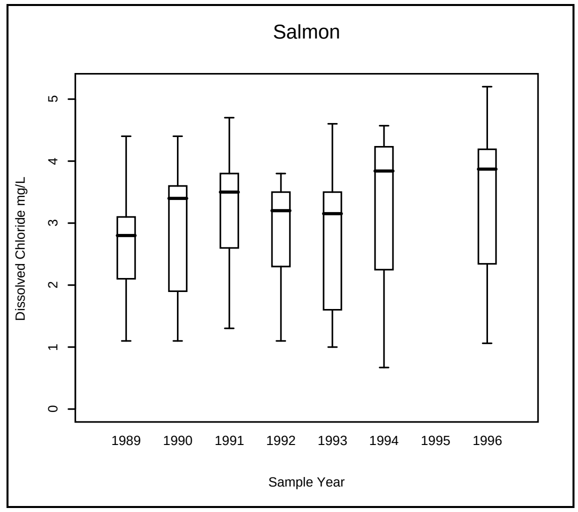
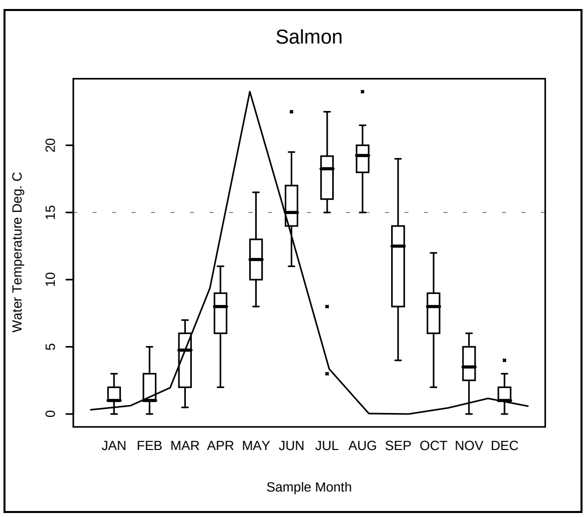


Figure 109. Annual summary of total alkalinity in the Salmon River, 1989 - 1996.

Figure 110. Annual summary of dissolved chloride in the Salmon River, 1989 - 1996.

Water Quality Criteria/Objectives

An increasing trend in turbidity may be of concern for use of the Salmon River by spawning salmonids. Summer water temperatures exceeded a suggested maximum temperature (15°C) for salmonid embryo survival (Nagpal 1994).



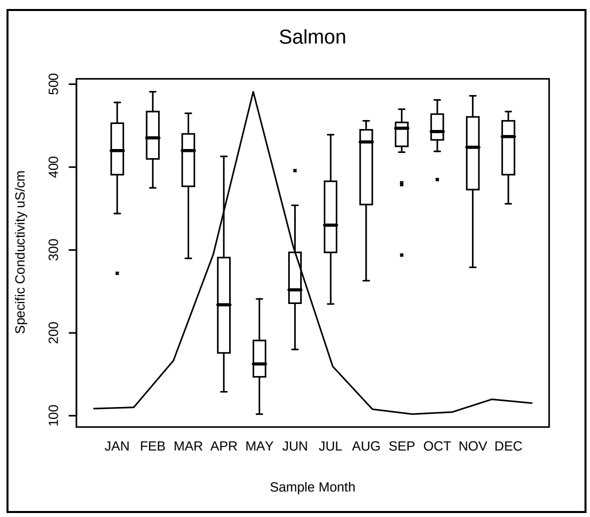


Figure 111. Seasonal summary of water temperature in the Salmon River. The solid line represents seasonal discharge patterns and the dashed line represents a suggested maximum temperature for salmonid embryo survival (Nagpal 1994).

Figure 112. Seasonal summary of specific conductivity in the Salmon River. The solid line represents the seasonal discharge pattern.

Dissolved Ions

A linear increasing trend in dissolved chloride was detected in both non-parametric and regression analyses (Figure 110).

Regression analyses also suggested linear increasing trends in dissolved calcium, hardness, potassium, magnesium and sodium (Figure 116 to Figure 113). Non-parametric analyses showed no trends for calcium, hardness, potassium, but for magnesium and sodium data, although the mSK tests were non-significant, trends were indicated in both the Van Belle and SK tests (Appendix 6).

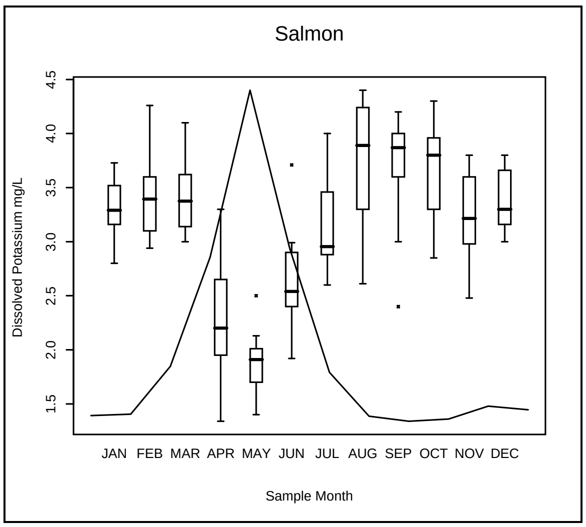


Figure 113. Seasonal summary of dissolved potassium in the Salmon River. The solid line represents seasonal discharge pattern.

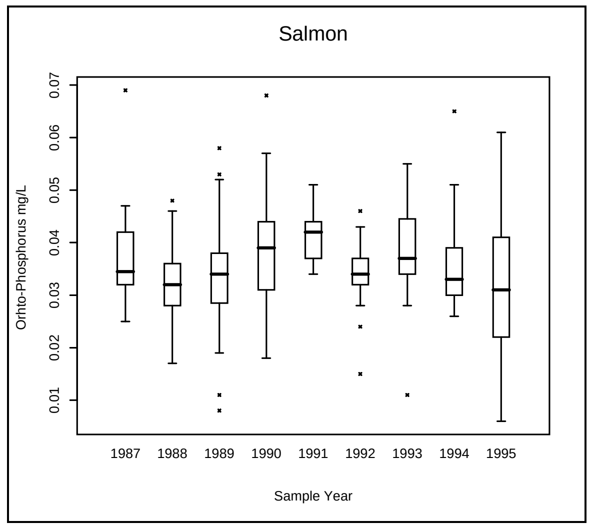


Figure 114. Annual summary of BC MoELP orthophosphorus in the Salmon River, 1987 - 1995.

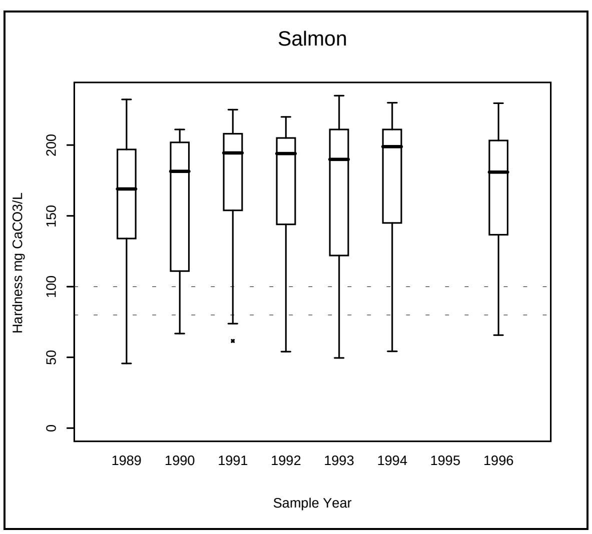


Figure 115. Annual summary of hardness in the Salmon River, 1989 - 1996. The dashed lines represent the hardness range for "acceptable" drinking water.

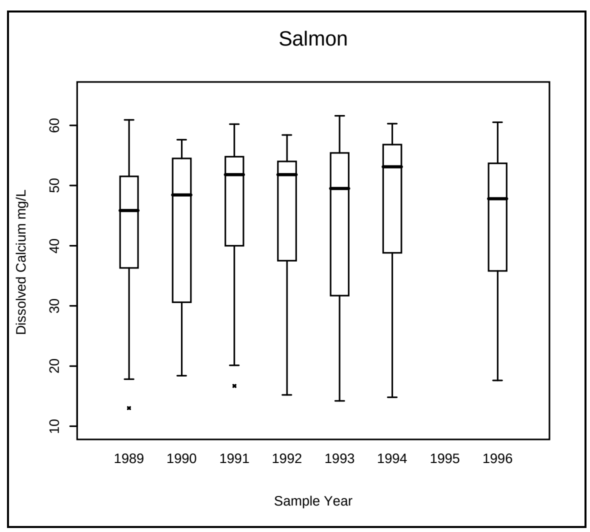


Figure 116. Annual summary of dissolved calcium in the Salmon River, 1989 - 1996.

Water Quality Criteria/Objectives

No trends were identified which would jeopardize any water uses in the Salmon River. Peak water hardness was regularly within the range for "poor but tolerable" drinking water.

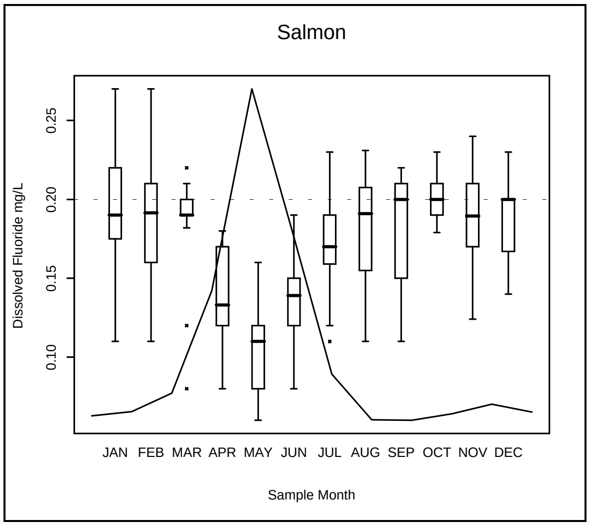


Figure 117. Seasonal summary of dissolved fluoride in the Salmon River. The solid line represents seasonal discharge patterns while the dashed line represents the BC MoELP water quality criterion for protection of aquatic life.

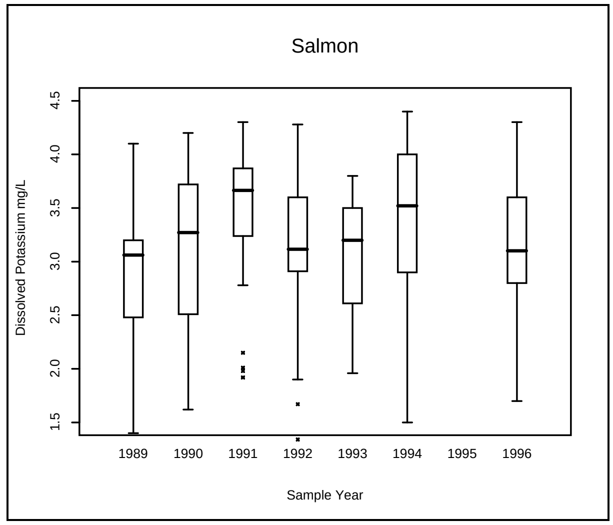


Figure 118. Annual summary of dissolved potassium in the Salmon River, 1989 - 1996

No trends were identified in dissolved sulphate or silica data by either statistical analysis methods.

All dissolved ions show strong seasonality, as evidenced by summary plots (Figure 113 and Figure 117), regression analyses (Table A6.14 in Appendix 6) and hysteresis diagrams (Table 30). Concentrations are low for only the duration of the short snow-melt driven freshet, after which the river quickly returns to a ground-water-supplied baseflow and the associated elevated dissolved ion concentrations.

Nutrients

Due to the specific water quality issues within the Salmon River watershed, particularly related to residential development and agriculture, a relatively larger range of nutrient variables are monitored at this site when compared to other locations in the Fraser Basin. Of the monitored set, those suitable for trend assessment included four dissolved nitrogen and three water-borne phosphorus variables.

While the overall interpretation of analyses of the nitrogen-related variables using non-parametric statistics showed no overall trend (i.e.: non-significant mSK test) , three (NO_x, dissolved nitrogen and Kjeldahl nitrogen) were significant by the Van Belle and Seasonal Kendall tests. This may imply a weak trend, which may be elucidated with additional data. Regression analysis of these data indicated negative quadratic trends in both dissolved nitrogen and ammonia nitrogen, however, the model is poorly determined (r^2 values of 0.14 and 0.33, respectively (Appendix 6)). Summary plots of the two data series do show changes in the median level which could be accounting for the observed regression results (Figure 119 and Figure 120).

Water Quality Criteria/Objectives

Analysis of nutrients did not indicate trends which would jeopardize any water use in the Salmon River. An increasing trend in total phosphorus should be followed for potential environmental significance.

Table 30. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion monitoring data in the Salmon River, 1985 - 1996.

Methods	**Dissolved Ions**				
	Dissolved calcium	Dissolved chloride	Dissolved fluoride	Dissolved magnesium	Hardness
Non-parametric	➔	➚	➔	➔	➔
Regression	↗	↗	∩	↗	↗
Hysteresis	╲	↻	╲	╲	╲
	Dissolved silica	Dissolved potassium	Dissolved sodium	Dissolved sulphate	
Non-parametric	➔	➔	➔	➔	
Regression	→	↗	↗	→	
Hysteresis	╲	╲	╲	↻	

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Similar to the nitrogen nutrient data sets, non-parametric analysis of the total phosphorus data showed both significant Van Belle and Seasonal Kendall tests, but not mSK. A linear increasing trend was revealed in total phosphorus by regression, with an r^2 of 0.73 (Table 31, Appendix 6). Analyses of 1988-1991 data (Shaw and El-Shaarawi 1995) suggested no trends, so these most recent results may be of some concern in the future if the pattern continues. No trends in orthophosphorus were identified in non-parametric analyses, although regression analysis showed a significant negative quadratic trend (Table 31). While

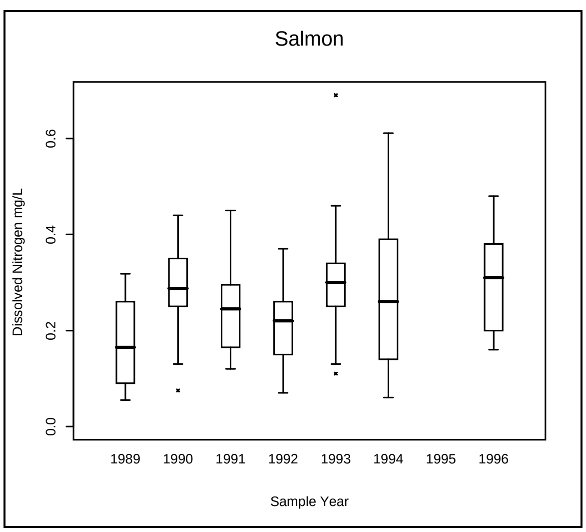


Figure 119. Annual summary of dissolved nitrogen in the Salmon River, 1989 - 1996.

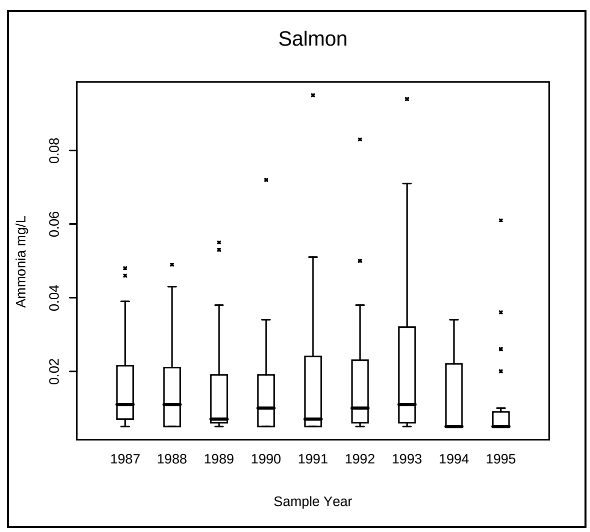


Figure 120. Annual summary of BC MoELP ammonia in the Salmon River, 1987 - 1995.

support for the model is weak (r^2 <0.10), the trend in median level is evident in an annual summary plot (Figure 114).

Hysteresis diagrams (Table 31) and regression analyses (Table A6.14 in Appendix 6) of the nutrients at this site indicated negative relationships with flow in the nitrogenous constituents, and positive correlations with the total phosphorus. The dramatic effect on nutrient levels of the spring freshet is well illustrated in monthly summary figures (Figure 121 and Figure 122).

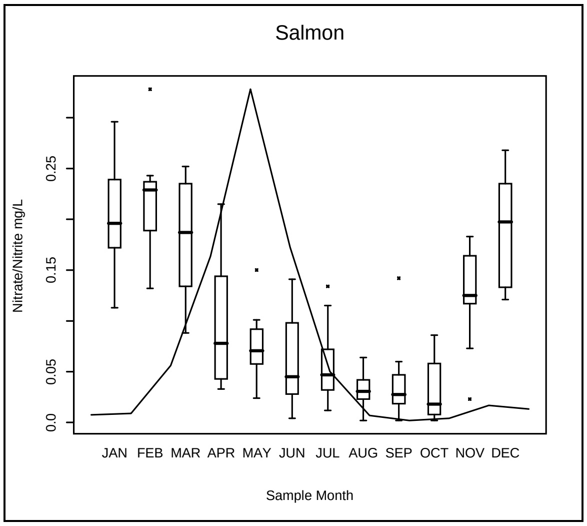


Figure 121. Seasonal summary of nitrate/nitrite in the Salmon River. The solid line represents the seasonal discharge pattern.

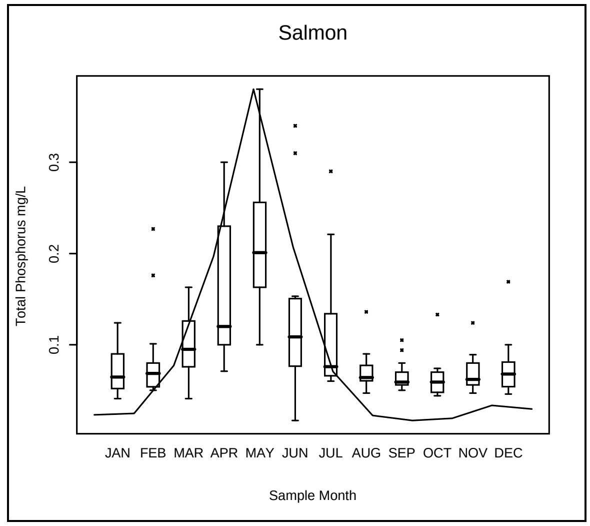


Figure 122. Seasonal summary of total phosphorus in the Salmon River. The solid line represents the seasonal discharge pattern.

Table 31. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks nutrient monitoring data in the Salmon River, 1985 - 1996.

Methods	Nutrients						
	Ammonia	Nitrate/ nitrite	Dissolved nitrogen	Kjeldahl nitrogen	Dissolved phosphorus	Ortho-phosphorus	Total phosphorus
Non-parametric	➔	➔	➔	➔	➔	➔	➔
Regression	∩	→	∩	→	→	∩	↗
Hysteresis							

→ - no trend
↗ - increasing linear trend
↘ - decreasing linear trend
∪ - positive quadratic trend
∩ - negative quadratic trend
➔ - no trend
⬈ - increasing linear trend
⬊ - decreasing linear trend

Metals

No trends were identified in total barium, manganese, selenium, strontium or vanadium data by either non-parametric or regression analyses. Non-parametric analyses indicated significant trends in these variables by both Van Belle and Seasonal Kendall tests, by not using either the mSK test nor in the regression analyses. Other metal constituents at this site likewise produced disparate non-parametric and regression trend results (Table 32).

Non-parametric analyses of total arsenic, chromium, cobalt, lithium, molybdenum and nickel data showed no trends (Table 32) perhaps due to the relatively short data record for these variables and high number of outliers. Regression analysis of total arsenic suggested a negative quadratic model, although the fit of the model was poor (r^2=0.10) (Appendix 6). Positive quadratic models fit to total nickel and chromium data (Figure 124 and Figure 123) by regression analyses were better supported, with r^2 values greater than 0.74.

Water Quality Criteria/Objectives

No trends in total metals would affect water uses in the Salmon River. Total chromium, manganese and iron regularly exceeded the maximum criteria for aquatic life due to suspended-sediment related metals.

Table 32. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals data in the Salmon River, 1985 - 1996.

	Total Metals					
Methods	**As**	**Ba**	**Cr**	**Co**	**Fe**	**Li**
Non-parametric	➔	➔	➔	➔	➔	➔
Regression	∩	→	∪	↘	→	∩
Hysteresis	⊬	↻	/	/	/	↻
	Mn	**Mo**	**Ni**	**Se**	**Sr**	**V**
Non-parametric	➔	➔	➔	➔	➔	➔
Regression	→	∪	∪	→	→	→
Hysteresis	↻	\	/	◸	\	/

➔ - no trend ⬈ - increasing linear trend ⬊ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

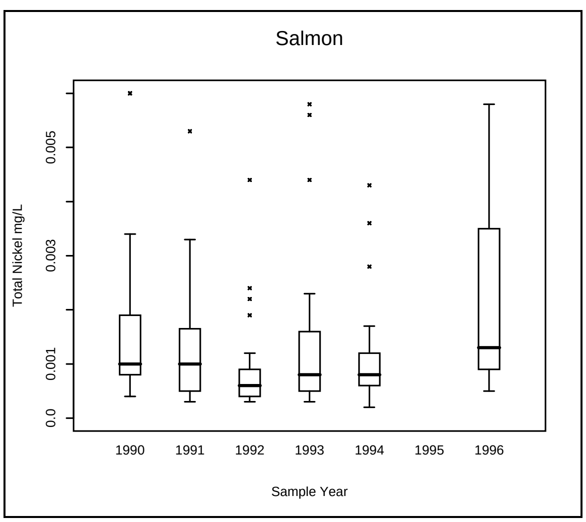


Figure 124. Annual summary of total nickel in the Salmon River, 1989 - 1994.

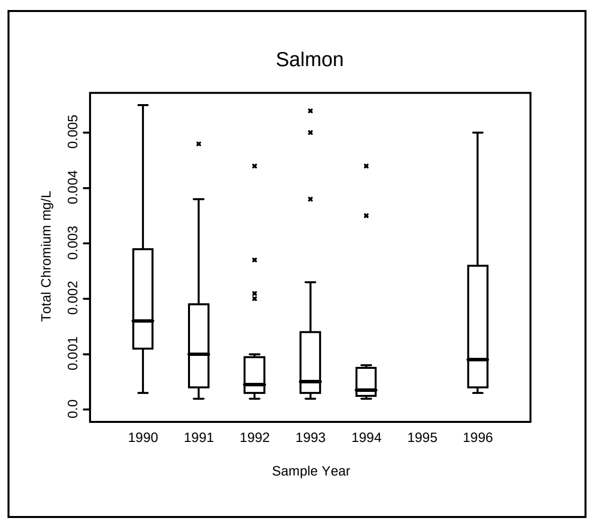


Figure 123. Annual summary of total chromium in the Salmon River, 1989 - 1996.

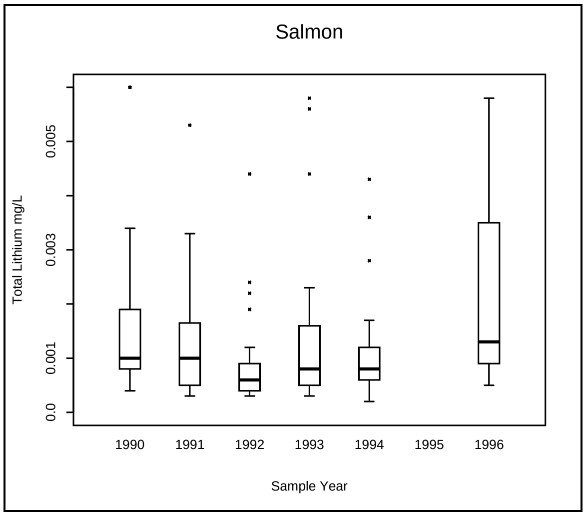


Figure 125. Annual summary of total lithium in the Salmon River, 1990 - 1996.

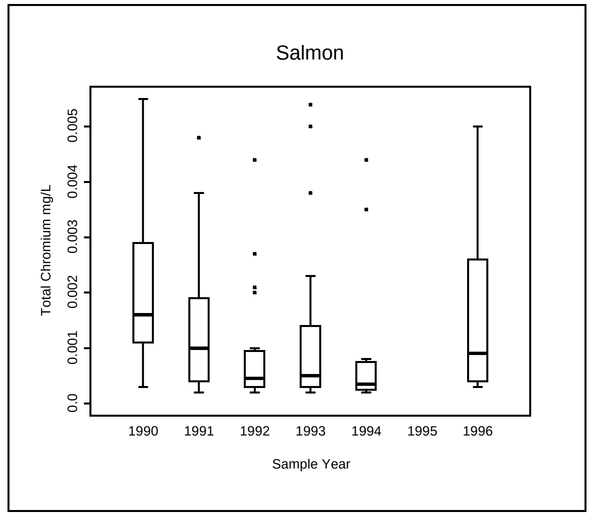


Figure 126. Annual summary of total cobalt in the Salmon River, 1990 - 1996.

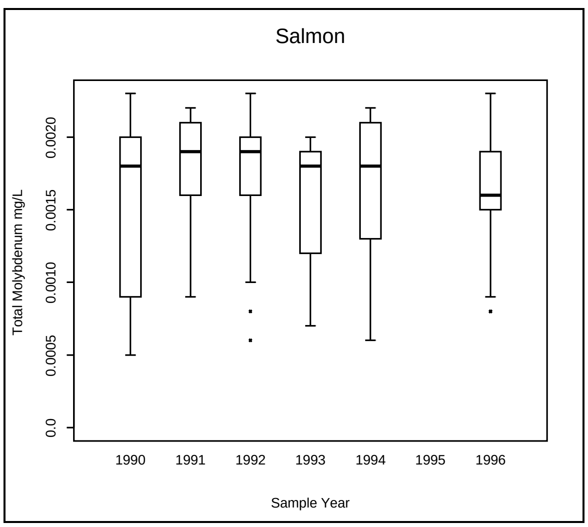


Figure 127. Annual summary of total molybdenum in the Salmon River, 1990 - 1996.

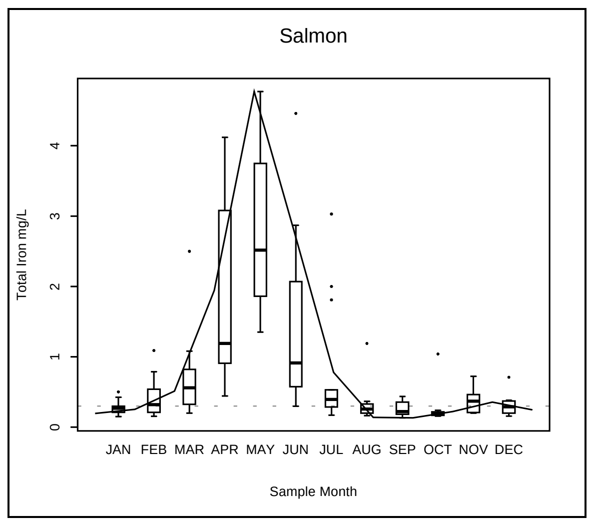


Figure 128. Seasonal summary of total iron in the Salmon River. The solid line represents seasonal discharge patterns while the dashed line represents the CCME/BC MoELP water quality criterion (0.30 mg/L) for protection of aquatic life.

Annual summary plots of total lithium, cobalt and molybdenum (Figure 125 – Figure 127) show little evidence of trend. As indicated elsewhere in this report, high variability of total metals data makes robust estimation of trend very difficult.

Strong seasonality is evident in all total metal constituents in the Salmon River (Table A6.14 in Appendix 6, Table 32 hysteresis diagrams). Levels increase dramatically as sediments are mobilized during spring freshet (Figure 128).

Microbials

Neither non-parametric nor regression analyses showed any significant trends in fecal coliform numbers, consistent with the same result found for 1988-1991(Shaw and El-Shaarawi 1995). A summary plot of fecal coliforms (Figure 129) confirm this result.

A positive association of fecal colifoms with flow in the Salmon River is evident in both hysteresis diagrams (Table 33) and regression analysis (Table A6.14 in Appendix 6). High fecal coliform levels in the basin are associated not only with the spring freshet, but also elevated in the late summer months (Figure 130). High fecal coliform numbers in the Salmon River may be attributed to both runoff from cattle grazing areas and unrestricted access of cattle to the main stream channel. The question of contamination from runoff is particularly acute during the spring freshet, when accumulated manure in winter feeding areas washes into the river with rain and meltwater flooding (B. Grace, BC MoELP, pers. comm.). A secondary cause of elevated coliform in the river may be septic drainage from residences along the river. Overall, the data exceed the recreational contact guideline (200 cfu/100ml) in about 20% of observations (Figure 131), with occasional values in excess of 1000 cfu/100ml.

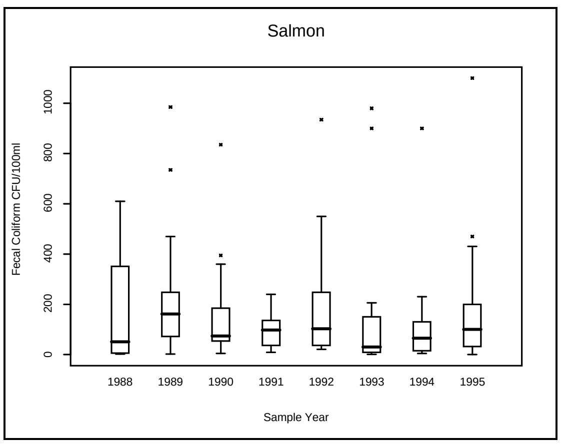


Figure 129. Annual summary of BC MoELP fecal coliform in the Salmon River, 1988 - 1995.

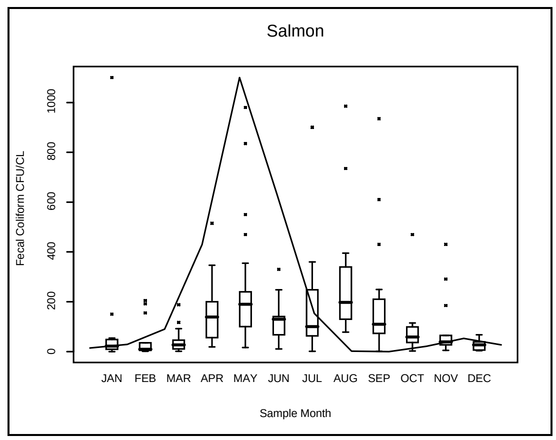


Figure 130. Seasonal summary of BC MoELP fecal coliform in the Salmon River. The solid line represents the seasonal discharge pattern.

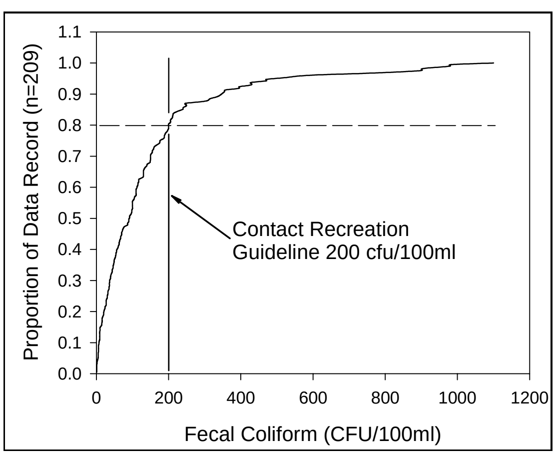


Figure 131. Summary of data distribution of fecal coliforms in the Salmon River, 1985-1996. Exactly 20% exceed the guideline for contact recreation.

Water Quality Criteria/Objectives

The water quality criterion for fecal coliform numbers for contact recreation (200 cfu/100ml) was frequently (41/209 observations) exceeded in the Salmon River.

Table 33. Summary of non-parametric tests, regression modelling and hysteresis pattern of BC Ministry of Environment, Lands and Parks microbial monitoring data in the Salmon River, 1985 - 1996.

Methods	Microbials
	Fecal coliform
Non-parametric	➔
Regression	→
Hysteresis	↙⬭

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

5.8 Thompson River

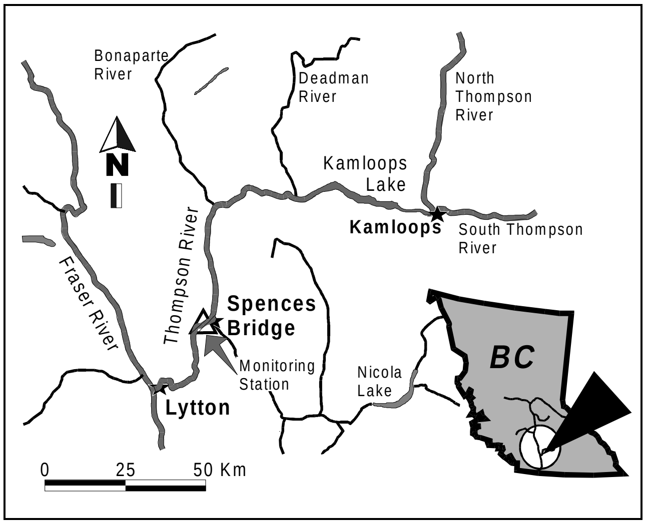


Figure 132. Location and surrounding area of the Environment Canada monitoring station on the Thompson River at Spences Bridge.

Data from the sampling site on the Thompson River near Spences Bridge (Figure 132) represents the integrated effects of natural and anthropogenic influences in both the North Thompson and the South Thompson rivers. The Thompson drains a basin area of 54,900 km^2, from the alpine ridges in the northern Cariboo Mountains to the interior sagebrush ecozone in the dry interior downstream of Kamloops.

Water in the Thompson River tends to be much less turbid, of lower ion content and somewhat warmer than is found at most of the other long-term monitoring sites in the basin (see spatial trends section). Flows are typical of an alpine drainage, with a strong spring freshet and summer flows supported by a combination of glacial melt and groundwater recharge. The upstream Kamloops Lake, which functions as a sedimentation basin through much of the year (Carmack *et al.* 1979) and moderates flow intensities downstream (Shaw and El-Shaarawi 1995), probably affects water quality at the monitoring site.

Within the drainage are a number of settlements. The largest is Kamloops, at the confluence of the North and South Thompson Rivers, where over the 10 year period of the water quality monitoring record the population increased 24%, from 61,773 in 1986 to 76,394 in 1996 (Statistics Canada).

The pulp and paper mill at Kamloops is the largest single discharge in the basin, and is probably the greatest anthropogenic influence on water quality in the basin. Operating since late 1965, the mill discharges a daily average of 182,000 m^3 of treated kraft mill effluent to the river through diffusers upstream of Kamloops Lake (Figure 133). Over the 1985 to 1996 period considered for water quality trends, several important process changes have been implemented in an effort to reduce the environmental effects of the effluents. The most significant of these was the change from elemental chlorine to chlorine dioxide in the bleaching process, moving from 50% to 100% substitution over 1991 to late 1992/93 (Hatfield 1995). This modification had the desired effect of reducing release of chlorinated organics, particularly dioxins and furans, but the effect was most evident in the monitoring program through declines in dissolved chloride.

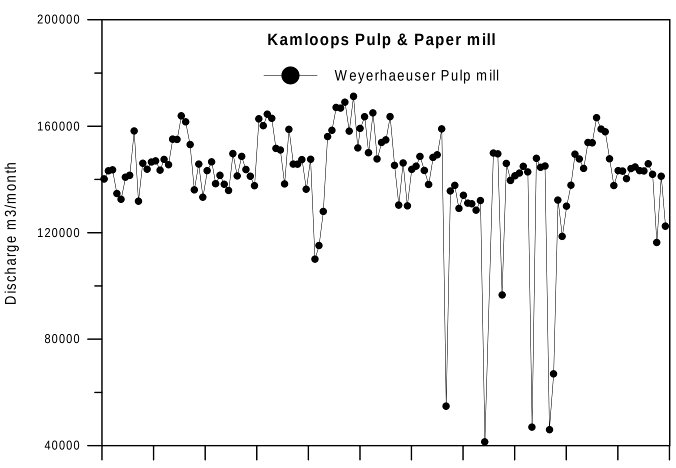


Figure 133. Average monthly effluent discharge volumes the Weyerhauser the pulp and paper mill in Kamloops, 1985 - 1996.

Other activities in the basin which may affect in-river water quality involve land-clearing, particularly timber harvesting and some agriculture. Some increased levels of suspended-sediment related constituents, such as non-filterable residue, total phosphorus, and turbidity might be expected (McDonald *et al.* 1991), although it may be difficult to detect effects when such activities are remote from the sampling site. Water quality monitoring was initiated at this site in 1985, and nearly complete biweekly or monthly data for analysis are available up to 1996 with the exception of an eight-month period during 1995 when no sampling was done as a result of a change in sampling personnel.

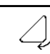
Physical Parameters

There were no significant trends in flow (Table 34), consistent with analyses of 1986-1991 data by Shaw and El-Shaarawi (1995).

Linear increasing trends were identified for specific conductivity, non-filterable residue and total alkalinity by both non-parametric and regression analyses (Table 34). This is a change from results of analysis of the 1986-1991 period, where, with the exception of a positive quadratic trend in total alkalinity, no trends were identified (Shaw and El-Shaarawi 1995). The increasing trend in conductivity is counter-intuitive, since concentrations of several of the major ions, particularly Cl and Na, are declining (See *Dissolved Ions* section, below). Related to the conductivity trend was the increasing trend, although weak, in filterable residue as determined by regression analysis (Table 34). Although the mSK test indicated no trend, both the Van Belle and Seasonal Kendall tests showed significant increasing trends.

Regression analyses suggested linear decreasing trends in water temperature or apparent colour (Table 34). Annual summary plots of these data (Figure 135 and Figure 134) show little evidence of the indicated trends. Strong seasonality is evident in all physical parameters measured at this site, related to either the mobilization of sediments at the onset of the spring freshet or to simple flow-dilution.

Table 34. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks physical monitoring data in the Thompson River, 1985 - 1996.

Methods	Physical Parameters			
	Flow	**Water temperature**	**Laboratory pH**	**Apparent colour**
Non-parametric	**→**	**→**	**→**	**→**
Regression	→	↘	NA	↘
Hysteresis				
	Specific conductivity	**Turbidity**	**Filterable residue**	**Non-filterable residue**
Non-parametric	**↗**	**→**	**→**	**↗**
Regression	↗	∪	↗	↗
Hysteresis				
	Total alkalinity			
Non-parametric	**↗**			
Regression	↗			
Hysteresis				

→ - no trend | **↗** - increasing linear trend | **↘** - decreasing linear trend
→ - no trend | ↗ - increasing linear trend | ↘ - decreasing linear trend
∪ - positive quadratic trend | ∩ - negative quadratic trend

Water Quality Criteria/Objectives

No trends in physical variables were identified which would affect water uses in the Thompson River.

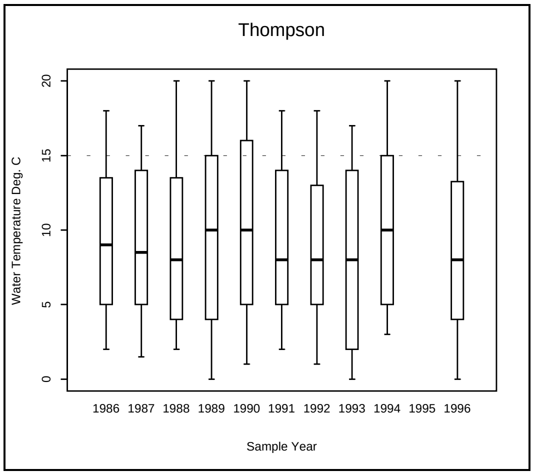


Figure 134 Seasonal summary of water temperature in the Thompson River. The dashed line shows a suggested maximum temperature for salmonid embryo survival (Nagpal 1994).

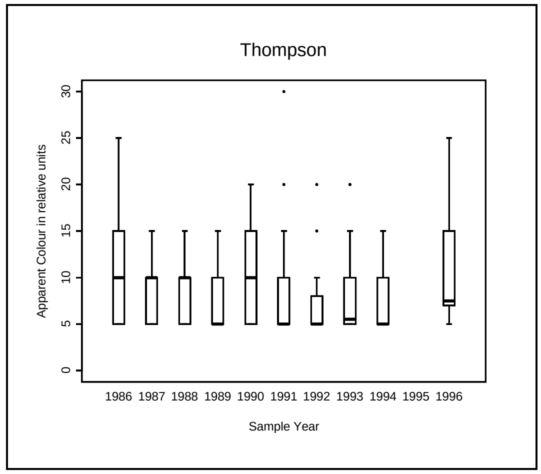


Figure 135. Annual summary of apparent colour in the Thompson River, 1986 - 1996.

Dissolved Ions

Silica was the only dissolved ion measured at the site for which no trends were evident. This may well be due to the necessary shortening of the data series because of analytical changes implemented in 1990. Possibly a more complete record may have shown a different result.

Linear decreasing trends detected in dissolved chloride and sodium data in both non-parametric and regression analyses are clearly evident in summary plots (Figure 138). Since chloride and sodium are found in high concentrations in both pulp and paper mill effluents and municipal waste waters (Norecol 1993), this decline might be attributed to improvements in the chemical quality of these discharges from Kamloops to the Thompson River. Intervention regression methods suggested that process changes implemented in 1991-1992 did have a significant effect on both chloride and sodium.

Linear increasing trends in dissolved magnesium and potassium were also detected by both non-parametric and regression modelling (Table 35).

Non-parametric analyses of dissolved calcium, hardness and sulphate indicated no trends. Regression modelling of these data, however, suggested a positive quadratic trend in dissolved calcium and linear increasing trends in both hardness and sulphate (Table 35). Calcium and sulphate summary plots show shifts in median concentration which, with the exception of 1996 data, tend to support the regression results (Figure 137 and Figure 136). Trend results for total hardness are not unexpected since this variable is calculated from magnesium and calcium concentrations, both of which showed increasing trends in either parametric or non-parametric analyses.

Water Quality Criteria/Objectives

The rate of increase detected for dissolved magnesium, potassium, sulphate, and hardness in the Thompson River is slight, and present levels are far below available water quality guidelines. Therefore it is unlikely that the trends will jeopardize any water uses in the near future.

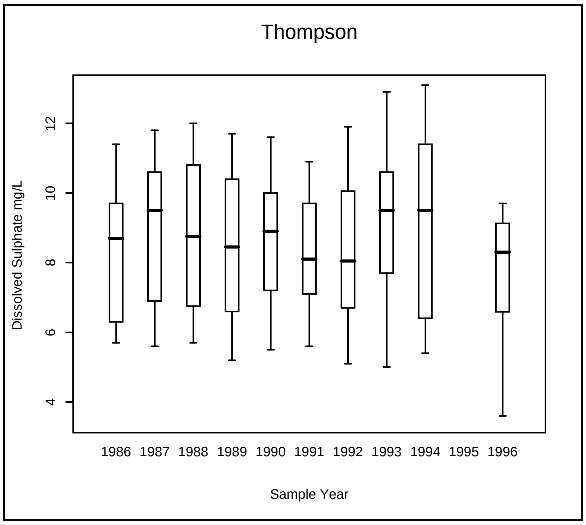


Figure 136. Annual summary of dissolved sulphate in the Thompson River, 1986 - 1996.

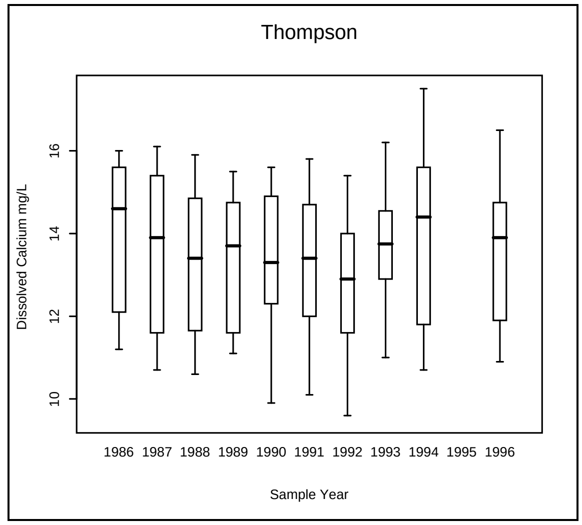


Figure 137. Annual summary of dissolved calcium in the Thompson River, 1986 - 1996.

As evident at the monitoring sites elsewhere in the basin, dissolved ion constituents in the Thompson River were negatively related to flow (Table A6.14 in Appendix 6, Table 35) and exhibited similar seasonal patterns (Figure 139).

Table 35. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada dissolved ion data in the Thompson River, 1985 - 1996.

Methods	Dissolved Ions			
	Dissolved calcium	**Dissolved chloride**	**Dissolved magnesium**	**Hardness**
Non-parametric	➔	➘	➚	➔
Regression	∪	↘	↗	↗
Hysteresis	↻	↻	↻	↻
	Dissolved silica	**Dissolved potassium**	**Dissolved sodium**	**Dissolved sulphate**
Non-parametric	➔	➚	➘	➔
Regression	→	↗	↘	↗
Hysteresis	⊿	↻	↻	↻

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

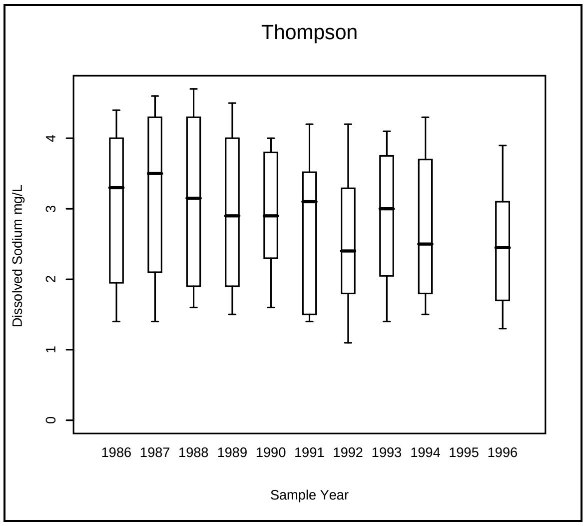


Figure 138. Annual summary of dissolved sodium in the Thompson River, 1986 - 1996.

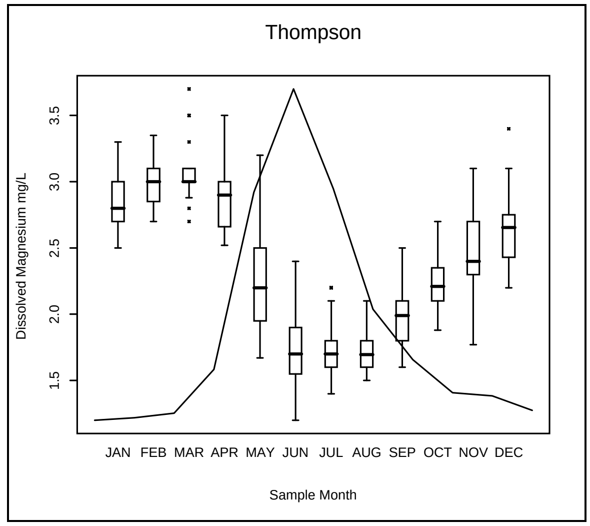


Figure 139. Seasonal summary of dissolved magnesium in the Thompson River. The solid line represents seasonal discharge pattern at the site.

Nutrients

There were no trends detected in the dissolved nitrogen data using either non-parametric or regression analyses (Table 36).

No trend in nitrate/nitrite was detected in non-parametric analysis, however a linear increasing trend was found in subsequent regression analysis (Table 36). The increase is evident as a slightly rising median level in an annual summary plot (Figure 140), which may be resulting from upstream discharges. Regression analyses of total and dissolved phosphorus data suggested positive quadratic models (Table 36), although in both cases the fit of the model to the data was relatively low (r^2<0.35, Appendix A6,

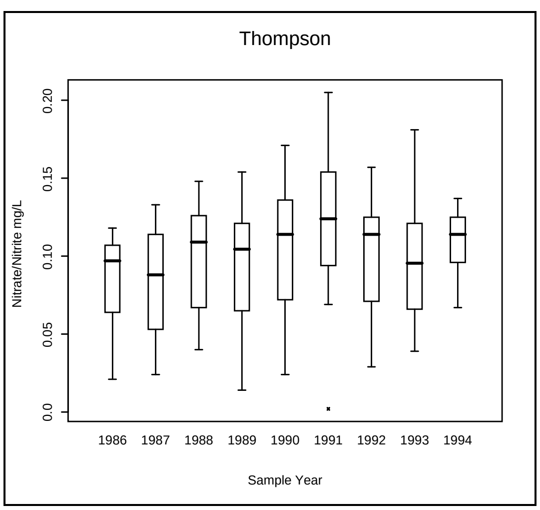


Figure 140. Annual summary of nitrate/nitrite in the Thompson River, 1986 - 1994.

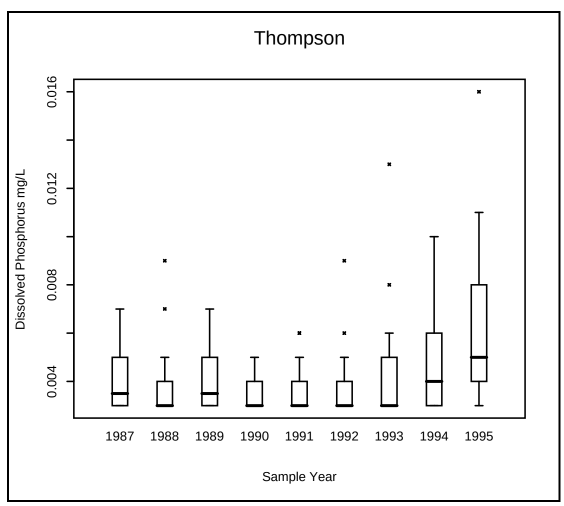


Figure 141. Annual summary of BC MoELP dissolved phosphorus in the Thompson River, 1987 - 1995.

Table 16). Non-parametric analyses, like those of the 1986-1991 data (Shaw and El-Shaarawi 1995), showed no trends. Annual summary plots for both variables show levels very near the detection limit and an increase in both median concentration and variability in the recent record (Figure 142 and Figure 141).

Water Quality Criteria/Objectives
No trends in nutrients would jeopardize water use in the Thompson River. Recent (1995-1996) increases in dissolved and total phosphorus may be of concern in future years should the pattern be sustained.

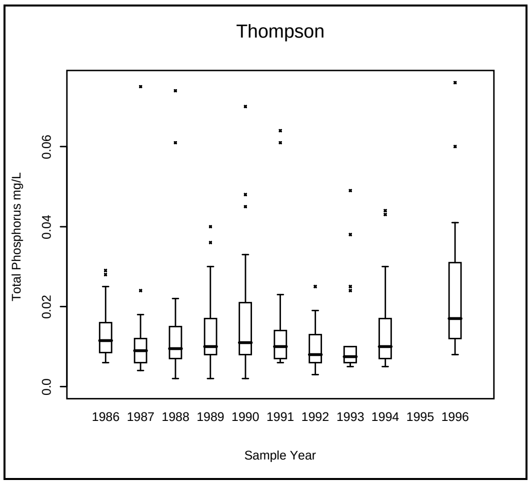


Figure 142. Annual summary of total phosphorus in the Thompson River, 1986 - 1996.

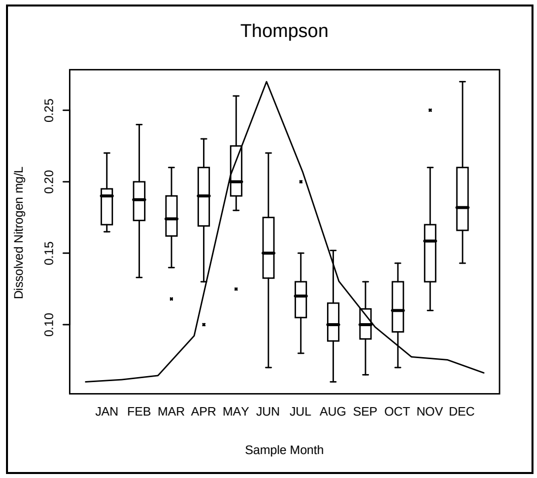
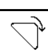
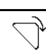


Figure 143. Seasonal summary of dissolved nitrogen in the Thompson River. The solid line represents the seasonal discharge pattern.

Strong seasonality is evident in dissolved N (Figure 140). Hysteresis diagrams and summary plot (Table 36, Figure 143) indicate the negative relationship between flow and dissolved nitrogen, while phosphorus constituents were positively correlated with flow, reflective of the close association between total phosphorus and suspended sediment.

Table 36. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada and BC Ministry of Environment, Lands and Parks nutrient monitoring in the Thompson River, 1985 - 1996.

Methods	Nutrients			
	Nitrate/ nitrite	**Dissolved nitrogen**	**Dissolved phosphorus**	**Total phosphorus**
Non-parametric	➔	➔	➔	➔
Regression	↗	→	∪	∪
Hysteresis				

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

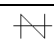
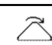
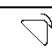
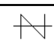
Total Metals

No trends were identified in either non-parametric or regression analyses of total lithium, nickel or strontium (Table 37).

Total arsenic, in contrast, showed a linear decreasing trend in both non-parametric and regression analyses. This pattern may be due to irregular values and occasional excursions in early portions of the record (<1991) which are not present in more recent data (Appendix A4, 26).
An increasing linear trend was detected in regression modelling but not non-parametric statistical analyses of total molybdenum. In an annual summary plot of the data, an increasing median molybdenum concentration is clearly visible (Figure 146). A similar increasing trend was seen at Hope and both trends may be a consequence of the use of Mo in gasoline. Confirmation will require more recent data to establish the consistency of the trend.

Likewise, declining trends were detected in total iron, aluminum, barium, chromium, manganese and vanadium by regression but not non-parametric analyses (Table 37, Figure 144). Frequent excursions are a common feature of total metals data, and are particularly evident in the total iron record (Figure 145).

Table 37. Summary of non-parametric tests, regression modelling and hysteresis patterns of Environment Canada total metals monitoring data in the Thompson River, 1985 - 1996.

	Total Metals					
Methods	**Al**	**As**	**Ba**	**Cr**	**Fe**	**Li**
Non-parametric	➔	➘	➔	➔	➔	➔
Regression	↘	↘	↘	↘	↘	→
Hysteresis						
	Mn	**Mo**	**Ni**	**Sr**	**V**	
Non-parametric	➔	➔	➔	➔	➔	
Regression	↘	↗	→	→	↘	
Hysteresis						

➔ - no trend ➚ - increasing linear trend ➘ - decreasing linear trend
→ - no trend ↗ - increasing linear trend ↘ - decreasing linear trend
∪ - positive quadratic trend ∩ - negative quadratic trend

Concentrations of most of the total metal variables were positively correlated with flow (Table A6.16 in Appendix 6, hysteresis diagrams Table 37), a result of mobilization of sediments at the onset of the spring freshet. Total strontium was the only metal which showed a negative correlation with flow (Figure 147), a finding consistent throughout the Fraser River Basin. Strontium may be high in groundwater, and this would seem a likely source for the measured concentrations in the Fraser River.

Water Quality Criteria/Objectives

No detected trends in total metals will affect water uses in the Thompson River. Concentrations of most metal variables, except for total molybdenum, were declining. Total aluminum, iron and chromium occasionally exceeded the maximum criteria for protection of aquatic life.

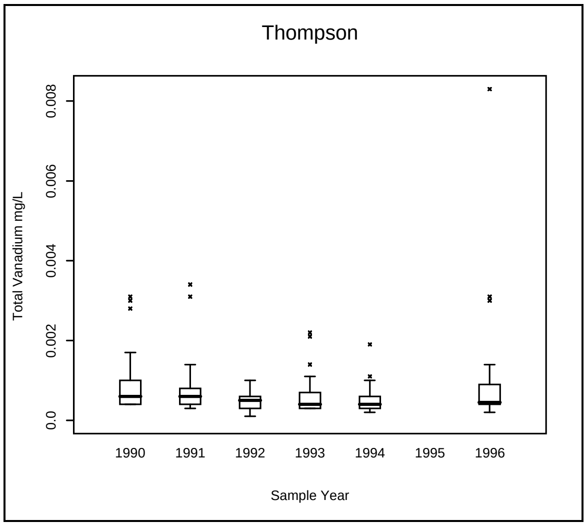


Figure 144. Annual summary of total vanadium in the Thompson River, 1990 - 1996.

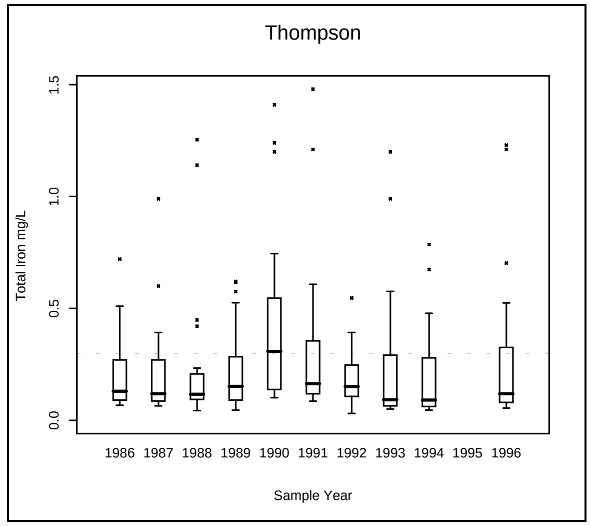


Figure 145. Annual summary of total iron in the Thompson River, 1986 - 1996. The dashed line represents the CCME/BC MoELP water quality criterion for protection of aquatic life.

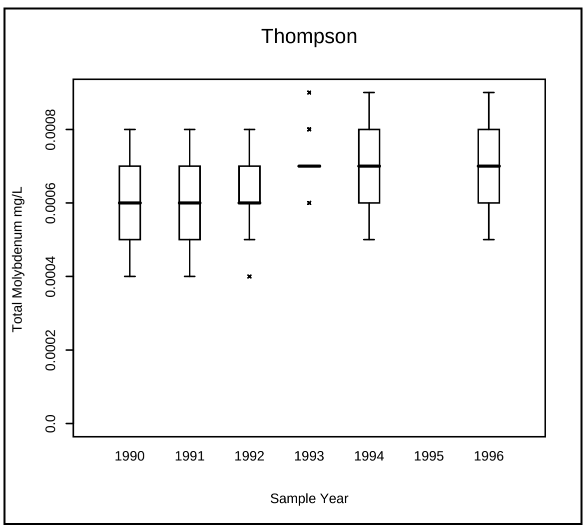


Figure 146. Annual summary of total molybdenum in the Thompson River, 1990 - 1996.

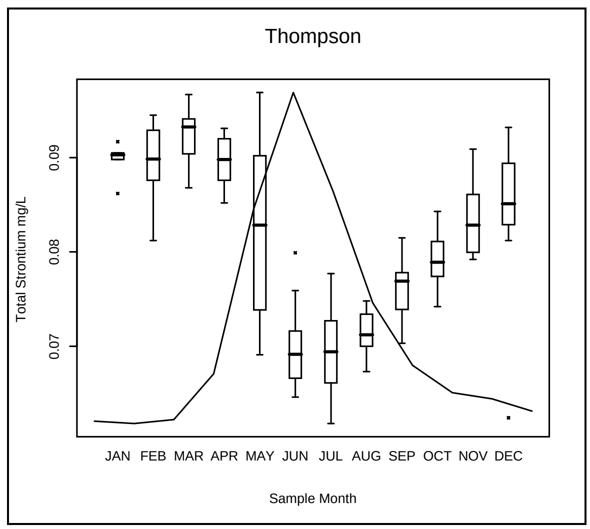


Figure 147. Seasonal summary of total strontium in the Thompson River. The solid line represents seasonal discharge pattern at the site.

5.9 Spatial Patterns

5.9.1 Physical Parameters

Spatial patterns in physical parameters in the Fraser River Basin may be grouped as those affected by dissolved components, which tend to exhibit and inverse relationship to flow, and those related to suspended components, which tend to be related to flow.

Flow in the Fraser mainstem increases steadily from the headwaters at Red Pass to the monitoring station at Hope (Figure 148) as the river receives the contributed flows of each of the major tributaries. The Thompson River in particular, because of its high volume, exerts a significant influence on measured water quality at Hope. The relatively low flow of the Salmon River in comparison to the other major tributaries is easily seen in a spatial summary plot (Figure 148).

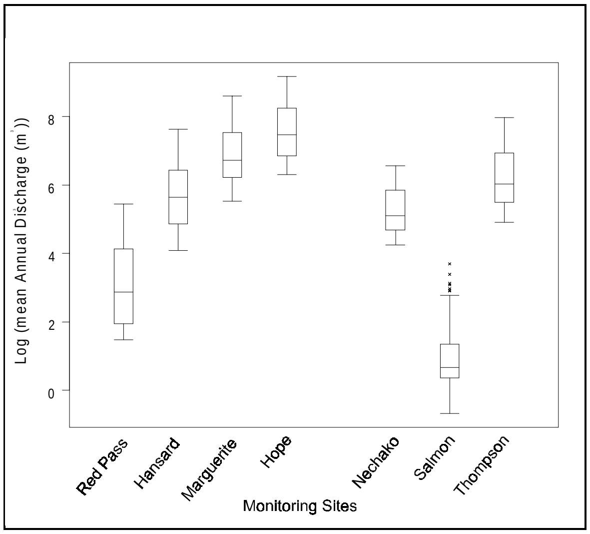


Figure 148. Spatial patterns in discharge at selected sites in the Fraser River Basin, 1985 - 1996.

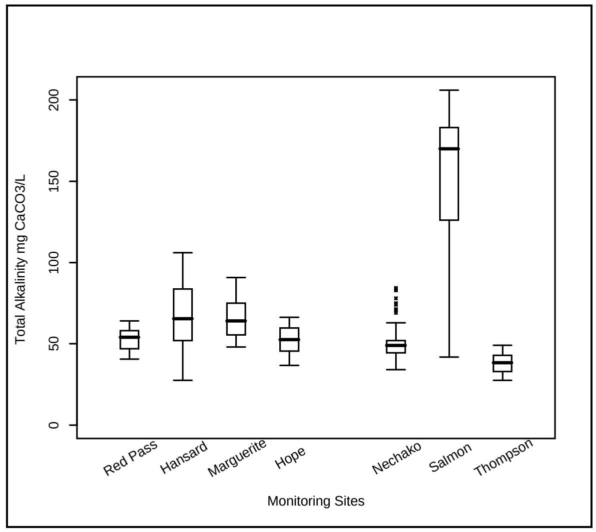


Figure 149. Spatial patterns of total alkalinity at selected sites in the Fraser River Basin, 1985 - 1996.

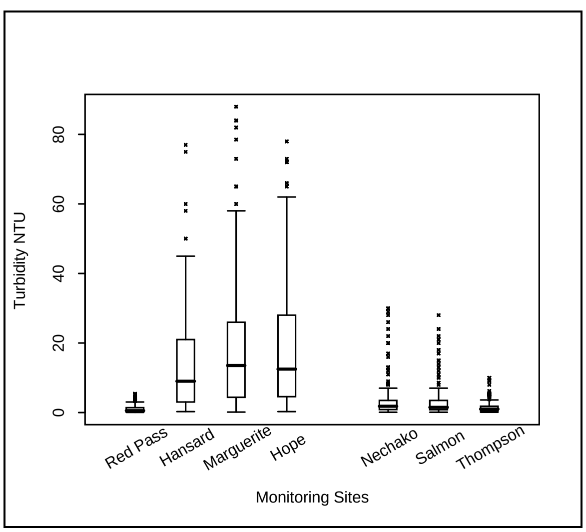


Figure 150. Spatial patterns of turbidity at selected sites in the Fraser River Basin, 1985 - 1996.

The pattern of dissolved variables is typified by total alkalinity (Figure 149). Total alkalinity increases from the headwaters to Hansard and declines downstream to Hope, probably due to dilution of the Fraser by confluence with the Thompson River. The relatively high contribution of groundwater to the instream flows of the Salmon River cause the elevated levels and large variability in both this constituent and other dissolved-ion related variables at that site. Identical spatial patterns are found for specific conductivity and laboratory pH in the Fraser River Basin.

The patterns in suspended-sediment related variables are exemplified in turbidity data through the basin (Figure 150). Turbidity is lowest at the headwater site (median 0.51 NTU). Median levels increase downstream to Marguerite (13.5 NTU), and remain relatively uniform to the monitoring site at Hope. Turbidity at the tributaries sites reflect the differences in surficial geology and flow regime. Turbidity tends to be much lower in these reaches than in the mainstem Fraser River, with relatively low median levels with less frequent excursions.

5.9.2 Dissolved Ions

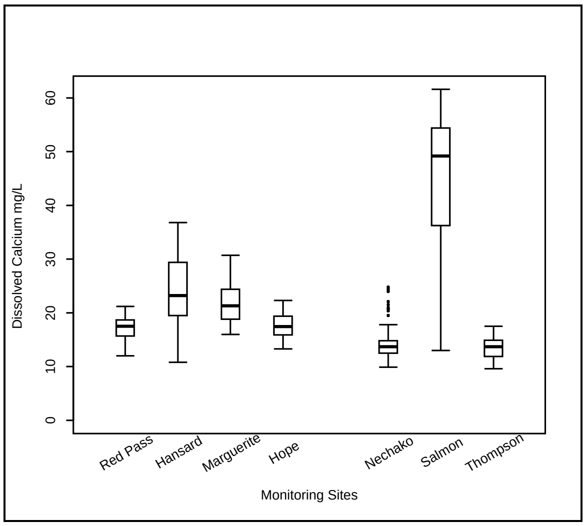


Figure 151. Spatial patterns of dissolved calcium at selected sites in the Fraser River Basin, 1985 - 1996.

Dissolved calcium increases from the headwaters to the Hansard monitoring station (Figure 151). The higher levels at this site (median 23.2 mg/L) result from the contributions from bedrock dissolution. Downstream of Hansard, the dilution by major tributaries, such as the Nechako River, results in lower median dissolved calcium at Marguerite (21.4 mg/L). Confluence with the Thompson River near Lytton further reduces median Fraser River calcium at Hope to 17.4 mg/L. Low instream flow and high contribution of groundwater is apparent in the Salmon River with median dissolved calcium levels of 49.5 mg/L.

Similar patterns are evident in other dissolved ions. Magnesium concentrations in the upper Fraser are also highest of the mainstem monitoring sites, declining from an overall median of 5.7 mg/L at Red Pass to 3.7 mg/L at Hope (Figure 152). Levels in the Salmon River (median 15.45 mg/L) are roughly three times as high as those in the upper reaches of the Fraser mainstem.

Chloride has long been used as a tracer of anthropogenic activity, since it is both a common component of effluents and relatively uninvolved in most environmental processes (Sherwood 1989). The spatial

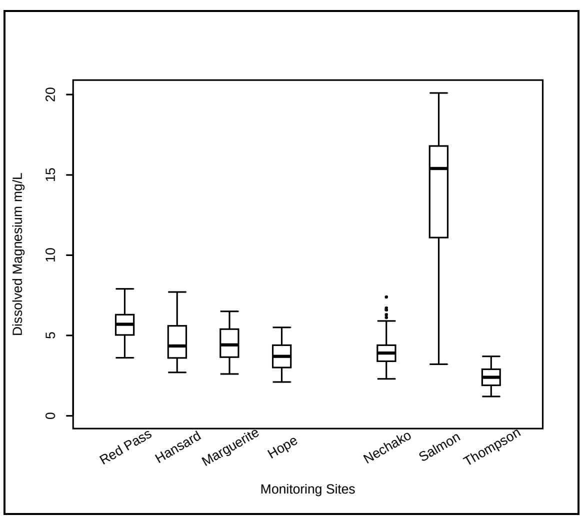


Figure 152. Spatial patterns of dissolved magnesium at selected sites in the Fraser River Basin, 1985 - 1996.

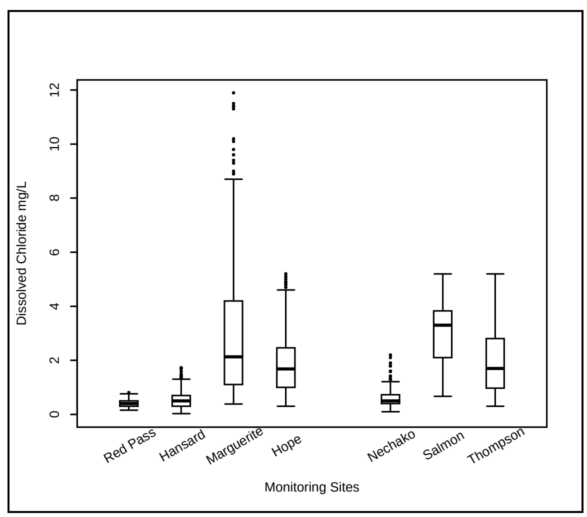
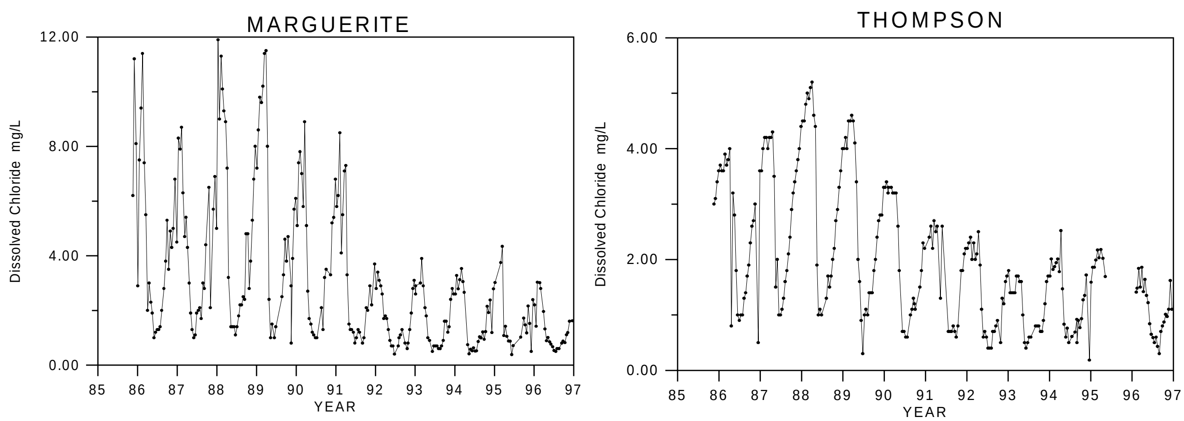


Figure 153. Spatial patterns of dissolved chloride at selected sites in the Fraser River Basin, 1985 - 1996.

summary of dissolved chloride concentrations in the Fraser River Basin (Figure 153) reflects patterns in both land-use and effluent discharges. With the exception of the high values detected in the Salmon River (median 3.3 mg/L), elevated chloride levels are found downstream of pulp and paper mills (Marguerite, Hope and the Thompson River). As indicated in trend analyses, dissolved chloride at these sites have declined greatly since 1991, a result of bleaching process changes at pulp and paper mills. The immediate and dramatic effect of these process changes is clearly illustrated in Figure 154.

Spatial patterns of dissolved potassium, silica and sodium are similar to those seen in other dissolved ions within the basin. Highest overall medians in the Fraser mainstem are observed at Hope for dissolved potassium (0.77 mg/L), dissolved silica (3.26 µg/L) and at Marguerite for dissolved sodium (3.7 mg/L).



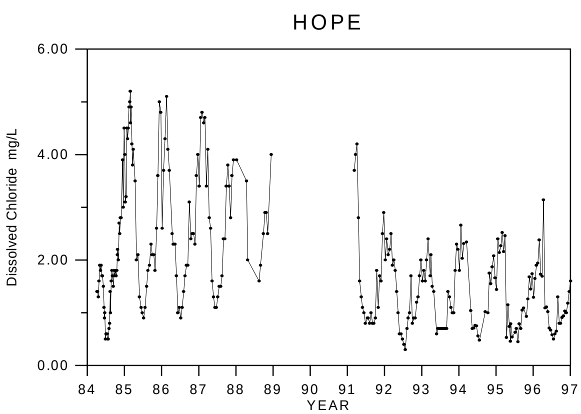


Figure 154. Time series of dissolved chloride at selected sites in the Fraser River Basin, 1985 - 1996. Pulp and paper mill process changes implemented during 1991 greatly reduced levels of this constituent at downstream monitoring stations.

5.9.3 Nutrients

Total phosphorus in the Fraser mainstem increases downstream from the headwaters at Moose Lake (Figure 155). Frequent outliers observed are likely related to particulate phosphorus associated with suspended sediment in the water column (compare with spatial trends for turbidity, Figure 150). The low total phosphorus levels at Red Pass are probably due to the absence of any significant upstream effluent discharges and the location at the outlet of Moose Lake. Of more concern may be the possible contribution of orthophosphorus by point-source effluents from Prince George and centres downstream. Studies of nutrient loading in the upper Fraser by French and Chambers (1995) showed that of the total P released in effluents to the Fraser River, more than 95% was in the dissolved form. While this was a small proportion of the measured total instream phosphorus concentration, the dissolved component is of much greater consequence to biological systems and is therefore of higher environmental significance.

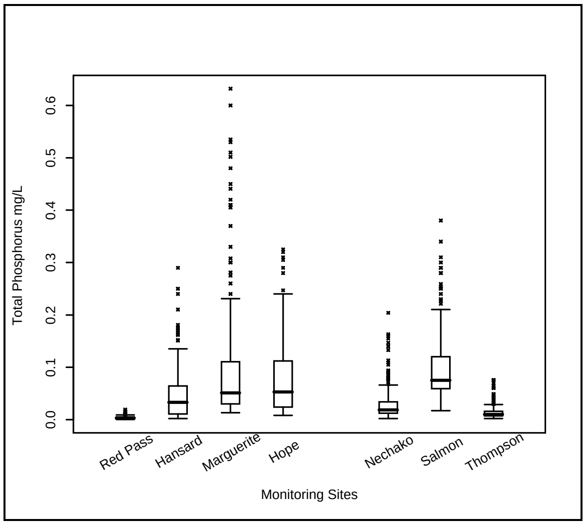


Figure 155. Spatial patterns of total phosphorus at selected sites in the Fraser River Basin, 1985 - 1996.

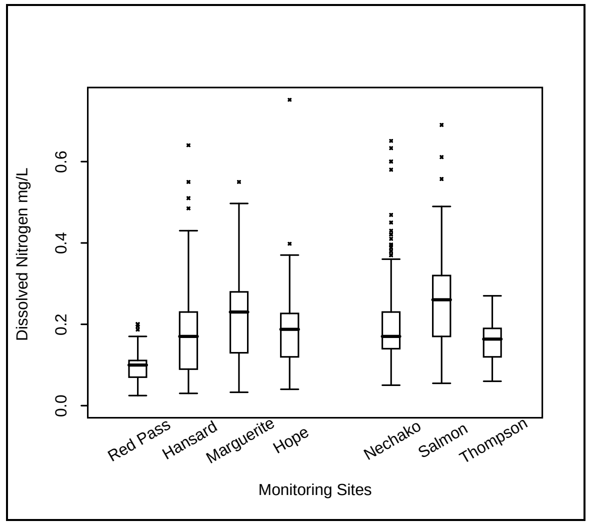


Figure 156. Spatial patterns of dissolved nitrogen at selected sites in the Fraser River Basin, 1985 - 1996.

Dissolved nitrogen in the Fraser River increases from a median concentration of 0.10 mg/L at Red Pass to 0.23 mg/L at Marguerite (Figure 156). Sources of dissolved nitrogen in the upper basin are probably natural, but the relatively elevated levels at Marguerite are doubtless due to municipal and industrial effluent discharges from Prince George and Quesnel. The relatively high measured concentrations in the Salmon River (to 0.69 mg/L) are probably resulting from both contamination by agricultural activities and high groundwater contributions to instream flows. Levels are, however, very low compared to waters affected by high-nutrient effluents, where concentrations may exceed 100 mg/L (McNeely *et al*. 1979).

Overall median concentrations were lowest on the Fraser mainstem at Red Pass for nitrate/nitrite (0.072 mg/L) and highest at Hansard (0.114 mg/L). Levels decrease slightly downstream at Marguerite and Hope.

5.9.4 Metals

Spatial summaries of data for aluminum, chromium and strontium are presented in Figure 157 to Figure 159. Frequent outliers are a common feature in the total metal data, since much of the measured metal is probably present as a native ore in suspended particulates. This is clearly the case in aluminum and chromium, where measured levels increase in the mainstem from upstream to downstream, in concert with increasing sediment load. The relationship with suspended sediments has also been discussed in results from each monitoring site.

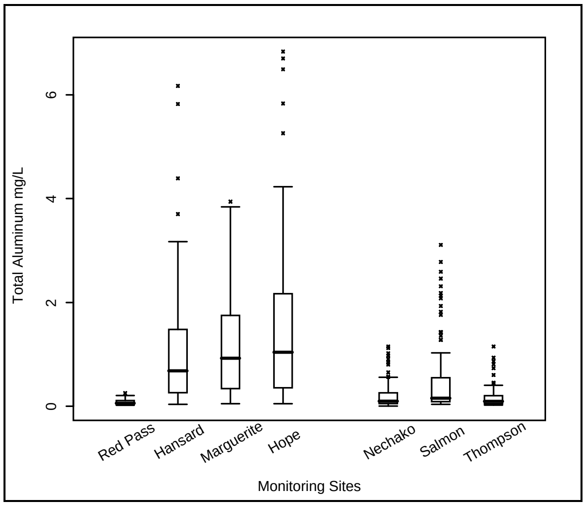


Figure 157. Spatial patterns of total aluminum at selected sites in the Fraser River Basin, 1985 - 1996.

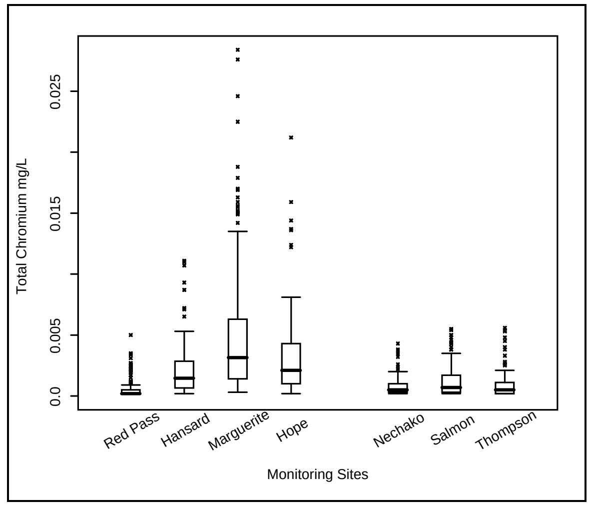


Figure 158. Spatial patterns of total chromium at selected sites in the Fraser River Basin, 1985 - 1996.

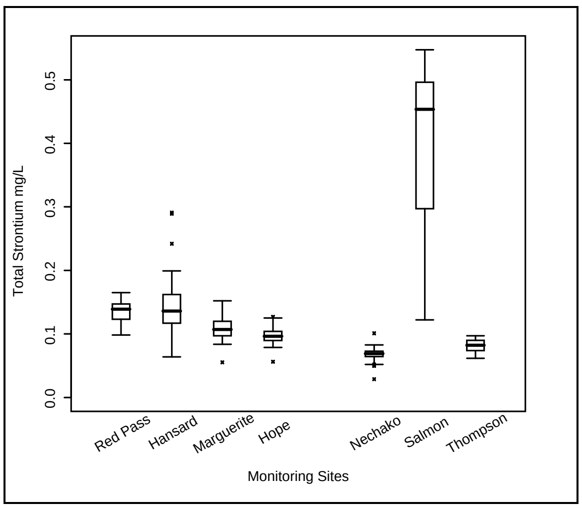


Figure 159. Spatial patterns of total strontium at selected sites in the Fraser River Basin, 1985 - 1996.

Some dissolved metals, such as strontium, exhibit a pattern more reflective of a variable primarily in a dissolved phase, probably derived from groundwater inputs. This is seen in a spatial summary of the data, showing a downstream decline in the mainstem, and significantly elevated levels in the Salmon River (Figure 159).

The environmental consequence of exceedences of total metals criteria is somewhat difficult to assess. Concentrations on which the criteria are based presume that the measured metal levels in water are in a dissolved phase, and hence bioavailable. In sediment-laden waters, such as the Fraser, only a very small fraction of the total metal is dissolved.

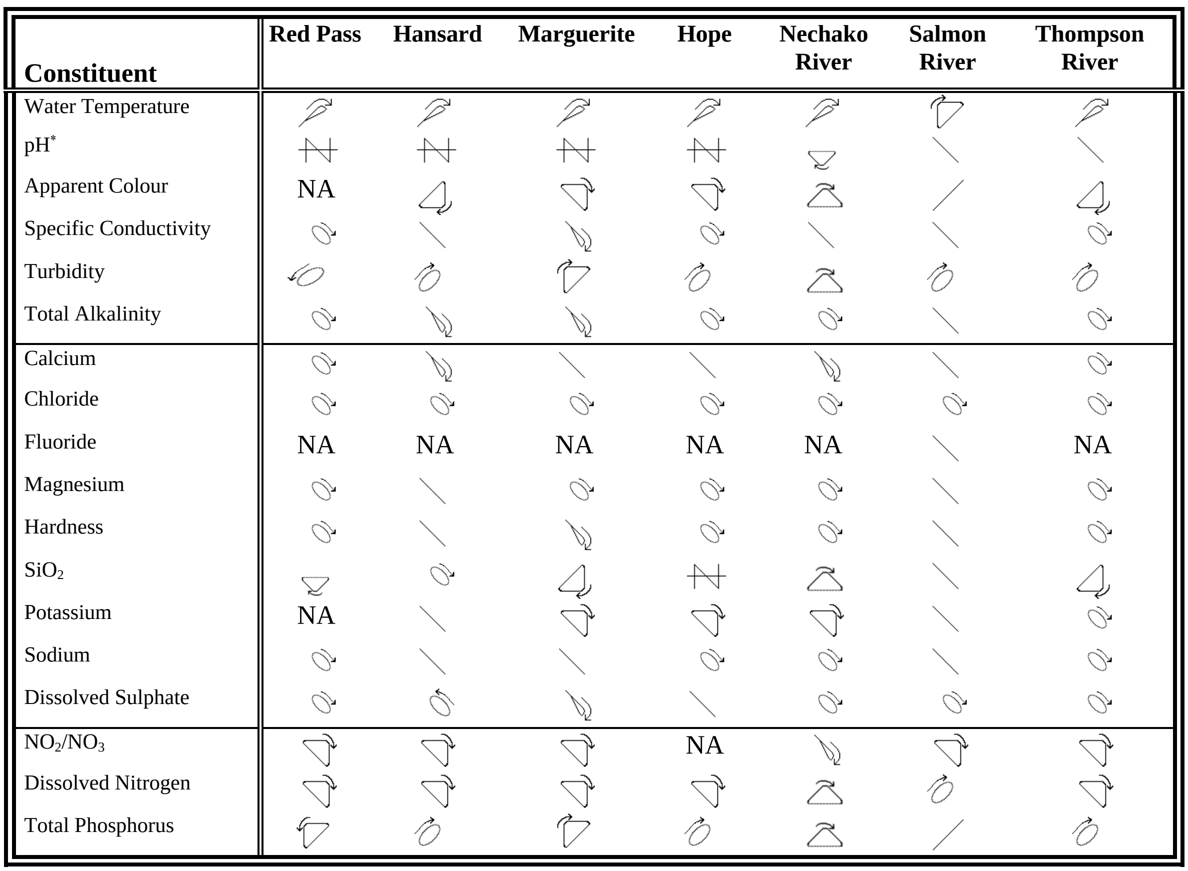
5.10 Hysteresis

Including hysteresis in the water quality constituent concentrations in this work was a contribution toward understanding processes contributing to seasonality and trend. Schematic representations of the patterns observed in this report are subjective, and offered as a first step toward functional approximation in future work on these trend data (Table 38 to Table 40).

Some constituents exhibit very strong and distinct patterns while others proved to be much more difficult to classify. Nevertheless, these tables reveal some interesting spatial patterns.

Of note are the patterns in the Salmon River which are consistently different from other stations analyzed. Most hysteresis relationships at this monitoring site are characterized by differing lag times between the peak flow and peak constituent concentrations in comparison to that at other sites. The Nechako River also exhibits some of these characteristics, although not to the extent observed in the Salmon River.

Table 38. Schematic summary diagrams of hysteresis patterns of Environment Canada physical, dissolved ion and nutrient water quality constituents in the Fraser River Basin.

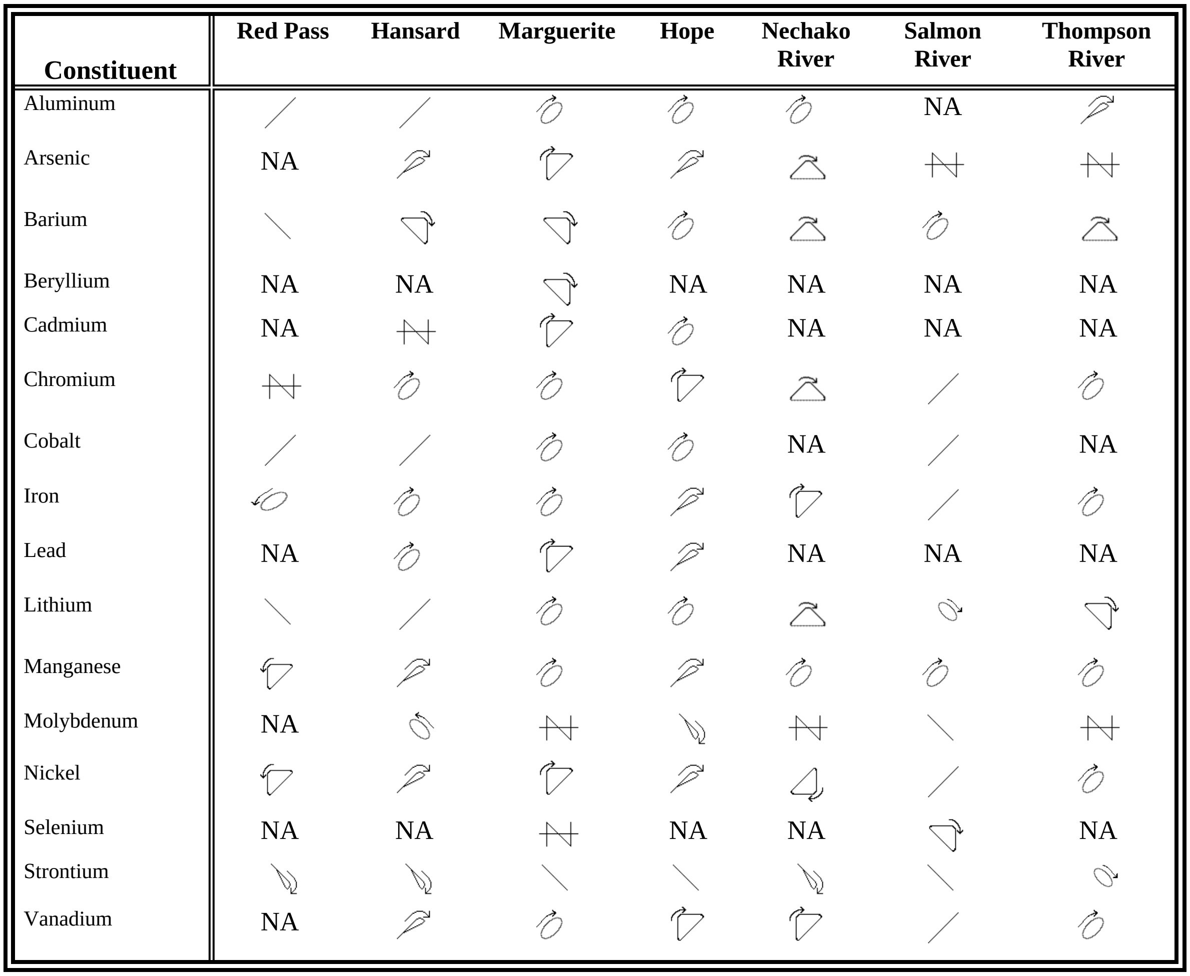


Constituent	Red Pass	Hansard	Marguerite	Hope	Nechako River	Salmon River	Thompson River
Water Temperature							
pH*							
Apparent Colour	NA						
Specific Conductivity							
Turbidity							
Total Alkalinity							
Calcium							
Chloride							
Fluoride	NA	NA	NA	NA	NA		NA
Magnesium							
Hardness							
SiO_2							
Potassium	NA						
Sodium							
Dissolved Sulphate							
NO_2/NO_3				NA			
Dissolved Nitrogen							
Total Phosphorus							

NA – Not Analyzed

 - pattern is not classifiable

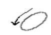
Table 39. Schematic summary diagrams of hysteresis patterns of EC metal water quality constituents in the Fraser River Basin.



Constituent	Red Pass	Hansard	Marguerite	Hope	Nechako River	Salmon River	Thompson River
Aluminum						NA	
Arsenic	NA						
Barium							
Beryllium	NA	NA		NA	NA	NA	NA
Cadmium	NA				NA	NA	NA
Chromium							
Cobalt					NA		NA
Iron							
Lead	NA				NA	NA	NA
Lithium							
Manganese							
Molybdenum	NA						
Nickel							
Selenium	NA	NA		NA	NA		NA
Strontium							
Vanadium	NA						

- pattern is not classifiable NA - Not Analyzed

Table 40. Schematic summary diagrams of hysteresis patterns of BC MoELP water quality constituents in the Fraser River Basin.

Constituent	Hansard	Stoner	Marguerite	Hope	Nechako River	Salmon River	Thompson River
Colour TAC		NA		NA	NA	NA	NA
Residue, Filterable		NA		NA		NA	
Residue, Non-filterable		NA		NA			
NH_3, Ammonia		NA		NA	NA		NA
Kjeldahl Nitrogen	NA	NA	NA	NA	NA		NA
Dissolved Phosphorus		NA		NA			
Orthophosphorus	NA	NA		NA	NA		NA
Absorb Organohalides	NA				NA	NA	NA
Fecal Coliform		NA	NA	NA	NA		NA

NA - Not Analyzed

 - pattern is not classifiable

6 General Summary and Recommendations

Present Water Quality

Overall, no particular water use would be compromised by water quality in the Fraser River Basin, as determined by measurements at the long-term monitoring stations considered in this report. Locally, single variables would be of concern for some uses, as, for example, the exceedences of microbial guidelines for drinking and recreation in the Salmon River. Other variables, in particular the total metals, frequently exceeded water quality guidelines and criteria for a number of potential water uses, and are considered in more detail below.

Although some monitored constituents exhibit increasing trends over the period of record, none were encroaching on any criteria/objectives for any water uses.

Summaries of the statistical trend analyses performed on the Environment Canada and BC MoELP data sets for the period of record are presented in Table 41 and Table 42. A visual comparison of parametric and non-parametric trend results between Shaw and El-Shaarawi (1995) and the present work (Table 43 and Table 44), shows a few key features:

- Reductions in chlorinated compounds in effluents from pulp and paper mills in the basin had favourable results in reducing adsorbable organohalides and dissolved chloride levels observed at downstream monitoring sites (Stoner, Marguerite, Hope and the Thompson River).

- Total metal water quality constituents throughout the basin exhibited either declining trends or no trends. The total metal measurements are affected strongly by particulate metals in suspended sediments, and show frequent excursions. While total metals measurements frequently exceeded available water quality guidelines for protection of aquatic life, the true environmental significance of these exceedences is difficult to assess. Guidelines and criteria are typically derived with the assumption that most of the total metals measured in a sample are in the dissolved phase, and hence bioavailable. This clearly is not the case for sites in the Fraser, and since the real partitioning between the dissolved and particulate phases is unknown, the environmental significance of the metals concentrations measured at the Fraser River Basin sites can not be properly assessed.

- Regression analysis of water quality constituents at the Nechako River monitoring station shows a preponderance of quadratic trends, relative to those indicated at other sites. Shaw and El-Shaarawi (1995) also reported numerous quadratic trends in the Nechako, and suggested that it be in part due to upstream flow regulation.

- Dissolved ion data at several sites showed increasing trends of various magnitudes. In the relatively unaffected upstream sites at Red Pass and Hansard, these increases probably result from natural, but as yet undetermined causes. The most consistent increasing trends, as determined in regression analyses, were in the Salmon River. Developments in the basin, agricultural activity and over- allocation of water with consequent reduction of instream flows may all be contributing factors. In the context of a threat to water use, these trends are minor and concentrations are not at levels which would compromise water uses. The trends are, however, suggestive of changes in the state of the ecosystem and should be followed for their value as environmental indicators rather than water-use management tools.

- Linear increases in non-filterable residue were found in all the Fraser River tributary stations. The patterns were indicated by both non-parametric and regression analyses in each case, suggesting that the result is well-supported by the available data. Here again, it is difficult to establish a cause but factors including development activity, timber harvest and agriculture could be investigated in the course of further work on the topic.

Table 41. Overall summary of trend analyses on Environment Canada water quality data, 1985-1995. Shaded boxes represent similar non-parametric and regression analyses.

Constituents	Red Pass	Hansard	Marguerite	Hope	Nechako River	Salmon River	Thompson River
Flow	➔ →	➔ →	➔ →	➔ →	➔ ↗	➔ →	➔ →
Water Temperature	➔ ∪	➔ ∪	➔ ∩	➚ ∩	➔ ↘	➔ →	➔ ↘
pH*	➔ →	➔ →	➔ ∪	➔ ∪	➔ ∪	➔ ↘	➔ NA
Apparent Colour	NA	➔ ↗	➔ →	➔ ∪	➔ →	➔ →	➔ ↘
Specific Conductivity	➚ ∩	➚ ↗	➔ ↗	➚ ↗	➚ ∪	➔ ↗	➚ ↗
Turbidity	➔ →	➔ →	➔ →	➔ →	➔ →	➚ ↗	➔ ∪
Total Alkalinity	➔ ↗	➔ →	➔ ↗	➚ ↗	➔ ∪	➔ ↗	➚ ↗
Calcium	➔ ↗	➔ ∪	➔ ∪	➔ ∪	➔ ∪	➔ ↗	➔ ∪
Chloride	➚ ∩	➔ →	➘ ↘	➘ ↘	➔ →	➚ ↗	➘ ↘
Fluoride	NA	NA	NA	NA	NA	➚ ∩	NA
Magnesium	➔ ↗	➚ ↗	➚ ↗	➚ ↗	➚ ∪	➔ ↗	➚ ↗
Hardness	➔ ↗	➚ ↗	➔ ∪	➔ ↗	➔ ∪	➔ ↗	➔ ↗
SiO_2	➔ ∪	➔ ∪	➔ ∪	➔ ∪	➔ ∪	➔ →	➔ →
Potassium	NA	➚ ↗	➚ ↗	➚ ↗	➚ ↗	➔ ↗	➚ ↗
Sodium	➔ ∩	➔ ↗	➔ →	➔ ∪	➚ ∪	➔ ↗	➘ ↘
Dissolved Sulphate	➚ ↗	➚ ↗	➚ ∩	➚ ∩	➔ ∩	➔ →	➔ ↗
NO_2/NO_3	➔ ↗	➔ ∩	➔ ↗	NA	➔ →	➔ →	➔ ↗
Dissolved Nitrogen	➔ →	➔ ∪	➔ ↗	➔ ∪	➔ ∪	➔ ∩	➔ →
Total Phosphorus	➔ →	➔ →	➔ →	➚ ↗	➔ →	➔ ↗	➔ ∪
Aluminum	➔ ↘	➔ ↘	➔ →	➔ ↘	➔ ↘	NA	➔ ↘
Arsenic	NA	➔ ∩	➔ ∩	➔ →	➔ ∩	➔ ∩	➘ ↘
Barium	➔ →	➔ ∪	➔ →	➔ ∪	➔ ∪	➔ →	➔ ↘
Beryllium	NA	NA	➔ →	NA	NA	NA	NA
Cadmium	NA	➔ ∪	➔ ↗	➔ →	NA	NA	NA
Chromium	➔ ↘	➔ ↘	➘ ↘	➔ ↘	➔ ↘	➔ ∪	➔ ↘
Cobalt	NA	➘ ↘	➔ ↘	➔ ∪	NA	➔ ↘	NA
Iron	➔ ∩	➔ →	➔ ∩	➔ →	➔ ∩	➔ →	➔ ↘
Lead	NA	➘ ↘	➘ ↘	➘ ↘	NA	NA	NA
Lithium	➔ ∩	➔ ↘	➘ ↘	➘ ↘	➔ →	➔ ∩	➔ →
Manganese	➔ →	➔ →	➔ →	➔ →	➔ →	➔ →	➔ ↘
Molybdenum	NA	➔ →	➚ ↗	➔ ∪	➔ →	➔ ∪	➔ ↗
Nickel	➔ ↗	➔ →	➔ ↘	➔ ∪	➔ ∪	➔ ∪	➔ →
Selenium	NA	NA	➘ ↘	NA	NA	➔ →	NA
Strontium	➔ →	➔ →	➔ ↘	➔ ↘	➔ →	➔ →	➔ →
Vanadium	NA	➔ ↘	➔ ↘	➔ ∪	➔ ↘	➔ →	➔ ↘

➚ - Increasing trend found by non-parametric tests
➘ - Decreasing trend found by non-parametric tests
➔ - No trend found by non-parametric tests
∩, ∪ - Quadratic trends found
↗ - Increasing linear trend found by regression methods
↘ - Decreasing linear trend found by regression methods
→ - No trend found by regression methods
NA – Constituent was not analyzed.

Table 42. Overall summary of trend analyses of BC MoELP water quality data, 1985-1995. Shaded boxes represent similar non-parametric and regression analyses.

Constituents	Hansard	Stoner	Marguerite	Hope	Nechako River	Salmon River	Thompson River
Colour TAC	➔ →	NA	➔ →	NA	NA	NA	NA
Residue, Filterable	➔ →	NA	➔ ↗	NA	➔ →	NA	➔ ↗
Residue, Non-filterable	➔ ∩	NA	➔ →	NA	⬈ ↗	⬈ ↗	⬈ ↗
NH_3, Ammonia	➔ →	NA	⬊ →	NA	NA	➔ ∩	NA
Kjeldahl Nitrogen	NA	NA	NA	NA	NA	➔ →	NA
Dissolved Phosphorus	➔ ↗	NA	➔ →	NA	➔ →	➔ →	➔ ∪
Orthophosphorus	NA	NA	⬈ ∩	NA	NA	➔ ∩	NA
Absorbable Organohalides	NA	➔ ↘	⬊ ↘	⬊ ↘	NA	NA	NA
Fecal Coliform	➔ →	NA	➔ ∪	NA	NA	➔ →	NA

⬈ - Increasing trend found by non-parametric tests
⬊ - Decreasing trend found by non-parametric tests
➔ - No trend found by non-parametric tests
∩, ∪ - Quadratic trends found
↗ - Increasing linear trend found by regression methods
↘ - Decreasing linear trend found by regression methods
→ - No trend found by regression methods
NA – Constituent was not analyzed.

Table 43. Concordance table for regression modelling of 1985-1991 vs. 1985-1996 Environment Canada data in the Fraser River Basin.

Constituent	Red Pass		Hansard		Marguerite		Hope		Nechako		Salmon		Thompson	
	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996
Flow	➔	→	➔	→	➔	→	➔	→	➔	↗	➔	→	➔	→
Water Temperature	➔	∪	➔	∪	➔	∩	➔	∩	➔	↘	➔	→	➔	↘
Apparent Colour	➔	NA	➔	↗	➔	→	➔	∪	➔	→	➔	→	➔	↘
Specific Conductivity	➔	∩	➚	↗	➚	↗	➔	↗	➔	∪	➔	↗	➔	↗
Turbidity	➔	→	➘	→	➔	→	➔	→	➔	→	➘	↗	➔	∪
Total Alkalinity	➔	↗	∪	→	➔	↗	➔	↗	➔	∪	➔	↗	∪	↗
Calcium	➔	↗	∪	∪	➘	∪	➘	∪	∪	∪	➚	↗	∪	∪
Chloride	➔	∩	∪	→	➔	↘	➚	↘	∪	→	➚	↗	∩	↘
Magnesium	➔	↗	➚	↗	➚	↗	➔	↗	∪	∪	➚	↗	∪	↗
Hardness	➘	↗	∪	↗	➔	∪	➔	↗	➔	∪	➚	↗	∪	↗
Potassium	➔	NA	➚	↗	➚	↗	➔	↗	∪	↗	➚	↗	➚	↗
Sodium	➔	∩	➚	↗	➚	→	➚	∪	∪	∪	➚	↗	➔	↘
Dissolved Sulphate	➔	↗	➔	↗	➚	∩	➚	∩	∪	∩	➚	→	➔	↗
NO_2/NO_3	➚	↗	➔	∩	➚	↗	➔	NA	➔	→	➔	→	➔	↗
Dissolved Nitrogen	➔	→	➔	∪	➔	↗	➘	∪	∪	∪	∪	∩	∪	→
Total Phosphorus	➔	→	➔	→	➔	→	➔	↗	➔	→	➔	↗	➔	∪
Arsenic	➔	NA	➚	∩	➚	∩	➔	→	➚	∩	➔	∩	➚	↘
Iron	➔	∩	➔	→	➔	∩	➔	→	➔	∩	➔	→	➔	↘
Manganese	➔	→	➘	→	➔	→	➔	→	➔	→	➘	→	➔	↘

➚ - Increasing trend found in 1985 - 1991
➘ - Decreasing trend found in 1985 - 1991
➔ - No trend found in 1985 - 1991
↗ - Increasing linear trend found in 1985 - 1996
↘ - Decreasing linear trend found in 1985 - 1996
→ - No trend found in 1985 - 1996
∪, ∩ - Quadratic trends found
NA – Constituent was not analyzed.

Table 44. Concordance table for non-parametric testing of 1985-1991 vs. 1985-1996 Environment Canada data in the Fraser River Basin.

CONSTITUENT	Red Pass		Hansard		Marguerite		Hope		Nechako River		Salmon River		Thompson River	
	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996	1985 - 1991	1985 - 1996
Flow	➔	→	➔	→	➔	→	➔	→	➔	↗	➔	→	➔	→
Water Temperature	➘	→	➔	→	➔	→	➔	↗	➔	→	➔	→	➔	↘
Apparent Colour	➔	**NA**	➚	↗	➚	→	➔	→	➔	→	➔	↗	➔	→
Specific Conductivity	➚	↗	➔	↗	➔	→	➔	↗	➔	↗	➔	→	➔	↗
Turbidity	➔	→	➔	→	➔	→	➔	→	➔	→	➔	↗	➔	→
Total Alkalinity	➚	→	➔	→	➔	→	➔	↗	➔	→	➔	→	➔	↗
Calcium	➔	↗	➘	→	➘	↘	➔	↘	➘	→	➔	→	➘	→
Chloride	➔	↗	➔	↗	➔	↘	➚	↘	➔	→	➔	↗	➘	↘
Magnesium	➔	↗	➔	↗	➔	↗	➔	↗	➔	↗	➔	↗	➔	↗
Hardness	➔	↗	➘	↗	➔	→	➔	→	➔	→	➔	↘	➘	→
Potassium	➔	**NA**	➚	↗	➚	↗	➔	↗	➔	↗	➔	→	➚	↗
Sodium	➚	↗	➔	↗	➔	→	➔	→	➔	↗	➔	↗	➘	↘
Dissolved Sulphate	➔	↗	➔	↗	➚	↗	➔	↗	➔	→	➔	→	➔	→
NO_2/NO_3	➚	↗	➚	↗	➚	↗	➚	**NA**	➔	→	➚	↗	➚	↗
Dissolved Nitrogen	➔	→	➔	↗	➔	↗	➘	→	➔	→	➔	↗	➔	↗
Total Phosphorus	➔	→	➔	→	➔	→	➔	↗	➔	→	➔	↗	➔	→
Arsenic	➔	**NA**	➔	→	➚	→	➔	↘	➔	→	➔	→	➔	↘
Iron	➚	→	➔	→	➚	→	➔	→	➚	→	➔	↗	➔	→
Manganese	➔	→	➔	↘	➔	→	➔	→	➔	→	➔	→	➔	↘

➚ - Increasing trend found in 1985 - 1991
➘ - Decreasing trend found in 1985 - 1991
➔ - No trend found in 1985 - 1991
NA – Constituent was not analyzed.

↗ - Increasing linear trend found in 1985 - 1996
↘ - Decreasing linear trend found in 1985 - 1996
→ - No trend found in 1985 - 1996

Recommendations

This report is an updated analysis of long-term trends in water quality in the Fraser River Basin. The first effort by Shaw and El-Shaarawi (1995) made recommendations which have generally been addressed in the present report. The following suggestions are intended to further strengthen future analyses of long-term trends in the Fraser River Basin.

1.Efforts should be made to monitor sites which identify the effects of particular activities.

In particular, the monitoring station at Stoner on the Fraser mainstem should be included in the regular monitoring program since the location would isolate the effects of discharges from Prince George from those at Quesnel. A full variable suite would have to be included, expanding on the single parameter (AOX) measured presently.

2.A separate hysteresis study would be beneficial for future analyses.

In this report we have attempted to lay a foundation for interpreting the constituent-discharge relationships throughout the basin. An extension of this analysis, by incorporating the patterns in the existing simple water quality model, would improve future trend analyses.

3.*Continue statistical analyses of long-term trends in the Fraser River Basin at the current rate of once every five years.*

The present work covers 10 years of data for most constituents, which is considered the minimum data range for conducting the statistical methods. As more data become available, the ability of these statistical methods to detect underlying trends should increase.

For ease of interpretation and economy of presentation, this analysis should be restricted to the modified Seasonal Kendall test with subsequent Sen's Slope estimates. In but a few instances, a significant trend detected with this test was associated with significant results in the Van Belle tests and the Seasonal Kendall Tau. As such, this would be an appropriate single test for future analyses. Coupled with Sen's Slope estimator, these two measures would probably provide the necessary robust detection and estimation of monotonic trend.

The regression model employed in this work provides valuable information to supplement the non-parametric tests and should be retained in future assessments. Careful data screening before and after analysis should be conducted to reduce the influence of outliers in parameter estimation. Methods for estimating error intervals about model parameters should also be investigated to measure the confidence in the results.

4.The existing water quality network should be maintained, and if possible, expanded.

In an era of diminishing resources, hard decisions about programs and priorities are often necessary. The existing water quality network in the Fraser River Basin, and elsewhere in British Columbia, is the longest existing water quality dataset in the province and is an important resource and starting point for aquatic environmental research. The network exists as a monitor of long-term change and influence of developments. Additional small watershed drainages should be included to examine watershed-level changes and their effects on water quality.

5.The information-content of some variables should be evaluated and the monitoring suite modified accordingly.

The value of some variables, particularly the suite of total metals measurements, should be re-assessed. The extreme variability of these variables, the close relationship with suspended sediments and the difficulty of meaningful interpretation greatly limit the value of these measures. At the very least, studies of partitioning between particulate and dissolved phases should be considered. Ideally, a move should be considered to the measurement of dissolved metals, which are the biologically relevant fraction of the total metals levels in water.

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Appendices

Appendix 1: Water Quality Variable Codes and Associated Detection Limits for Environment Canada and BC MELP Water Quality Data

Appendix 2: Data Screening Results Showing Variables Selected for Further Analysis

Appendix 3: Statistical Summary Tables of Water Quality Data from Monitoring Sites

Appendix 4: Time-Series Plots of Environment Canada Water Quality Data from each Site

Appendix 5: Time-Series Plots of BC Ministry of Environment, Lands and Parks Water Quality Data from each Site

Appendix 6: Tabulated Statistical Results of Non-Parametric and Regression Modelling Analyses

APPENDIX 1

Parameter codes and detection limits for
Environment Canada and B.C. Ministry of
Environment, Lands and Parks water chemistry analyses.

Environment Canada Parameter Codes and Associated Detection Limits

Physicals

Physicals	Method Code	Detection Limit	Units
Air Temp	97060S	-	
Water Temp	02061S	-	
Apparent Colour	02011L	5	colour
Conductivity	02041L	0.2	µS/cm
Laboratory pH	10301L	-	
Turbidity	02073L	0.05	NTU
Residue, Non-Filterable	10401L	10	mg/L
Residue, Fixed Non-Filterable	10501L	10	mg/L
Residue, Filterable	10451L	10	mg/L
Residue, Fixed Filterable	10551L	10	mg/L
Alkalinity	10101L	0.5	mg/L

Dissolved Ions

	< Aug 1, 1987			Aug 1, 1987-Jan 31, 1990			>= Feb 1, 1990		
	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units
Calcium	20103L	0.05	mg/L	20103L	0.05	mg/L	20321L	100	µg/L
Magnesium	12101E	(a)*	-	12102L	0.01	mg/L	12321L	100	µg/L
Hardness	10603L	1	mg/L	10602E	(b)*	-	10602E	(b)*	-

	< Nov 1, 1989			>= Nov 1, 1989 - Sept 30, 1993			>= Oct 1, 1993		
	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units
Potassium	19103L	0.02	mg/L	19301L	0.001	mg/L	19111	0.1	mg/L
Sodium	11103L	0.02	mg/L	11321L	200	µg/L			

				Dec 1, 1992 - Mar 31, 1994			>= Apr 1, 1994		
	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units
Chloride	17206L	0.05	mg/L						
Fluoride	09105L	0.05	mg/L	09105L	0.02	mg/L	324	0.01	mg/L
Silicon	14105L	0.02	mg/L						
Sulphate	16306L	0.02	mg/L						

Nutrients

Nutrients	Method Code	Detection Limit	Units
Nitrogen: NO2/NO3	07110L	0.005	mg/L
Nitrogen: Total Dissolved	07651L	25	µg/L
Phosphorus, Total	15406L	2	µg/L

Total Metals

	Aug 1, 1984-Feb 13, 1990 (AA TOTAL)			> Feb 13, 1990 (ICP TOTAL)			Present	
	Method Code	Detection Limit	Units	Method Code	Detection Limit	Units	Detection Limit	Units
Aluminum	13003P	50	µg/L	13009P	0.001	mg/L	0.002	mg/L
Arsenic	33008L	0	µg/L	33008L	0.02	µg/L	0.0001	mg/L
Barium	56001P	0.1	mg/L	56009P	0.001	mg/L	0.0002	mg/L
Beryllium	-	-	-	04010P	0.05	µg/L	0.05	µg/L
Cadmium	48002P	1	µg/L	48009P	0.001	mg/L	0.0001	mg/L
Chromium	24003P	2	µg/L	24009P	0.002	mg/L	0.0002	mg/L
Cobalt	-	-	-	27009P	0.002	mg/L	0.0001	mg/L
Copper	29005P	1	µg/L	29009P	0.001	mg/L	0.0002	mg/L
Iron	26004P	50	µg/L	26009P	0.002	mg/L	0.0004	mg/L
Lead	82002P	1	µg/L	82009P	0.01	mg/L	0.0005	mg/L
Lithium	-	-	-	03009P	0.1	mg/L	0.0001	mg/L
Manganese	25004P	1	µg/L	25010P	0.001	mg/L	0.0001	mg/L
Mercury	80011P	0.05	µg/L	80011P	0.05	µg/L	0.005	µg/L
Molybdenum	42002P	0.2	µg/L	42009P	0.004	mg/L	0.0001	mg/L
Nickel	28002P	1	µg/L	28009P	0.002	mg/L	0.0002	mg/L
Selenium	34008P	0.03	µg/L	34008P	0.03	µg/L	0.0001	mg/L
Strontium	-	-	-	38009P	0.002	mg/L	0.0001	mg/L
Vanadium	-	-	-	23009P	0.002	mg/L	0.0001	mg/L
Zinc	30005P	1	µg/L	30009P	0.002	mg/L	0.0002	mg/L

(a)* - Calculated from the values of the Total hardness (determined by EDTA titration) and dissolved calcium :

Mg = (Total Hardness*0.01998 - Ca*0.0499) * 12.16

(b)* - Calculated from concentrations of dissolved calcium and dissolved magnesium :

Hardness = Ca*2.497 - Mg*4.118

BC Environment Parameter Codes and Associated Detection Limits

Physicals

	Parameter Code	Work Route	Detection Limit	Units
Specific Conductivity	0011	1160	1	µS/cm
Colour Tac	1310	1310	1	TAC
pH	0004	1220	0.1	pH units
Turbidity	0015	1150	0.1	NTU
Residue, Non-Filterable	0008	1070/1072	4	mg/L
Residue, Fixed Non-Filterable	0009	1050	4	mg/L
Residue, Filterable	7	1030	4	mg/L
Residue. Fixed Filterable	0006	1020	4	mg/L
Residue, Total	0005	1031	14	mg/L
Alkalinity, Total	0102	1210	0.5	mg/L
Alkalinity, 4.5/4.2	D102	1212	0.5	mg/L

Dissolved Ions

	Parameter Code	Work Route	Detection Limit	Units
Calcium	Ca-D	0031	0.01	mg/L
Chloride	1104	1330	0.5	mg/L
Fluoride, dissolved	1106	1341	0.1	mg/L
Magnesium	Mg-D	0031	0.02	mg/L
Potassium, dissolved	K-D	0031	0.4	mg/L
Silica Reactive, dissolved	Si-D	0031	0.03	mg/L
Sodium, Dissolved	Na-D	0031	0.01	mg/L
Sulphate, dissolved	1121	1400	1	mg/L

Nutrients

	Parameter Code	Work Route	Detection Limit	Units
Nitrogen, Ammonia	1108	1351	0.005	mg/L
Nitrogen, NO2/NO3 dissolved	1109	1350	0.02	mg/L
Nitrogen, Kjeldahl dissolved	1113	136A	0.04	mg/L
Nitrogen, Total Kjeldahl	0113	136A	0.04	mg/L
Nitrogen, dissolved	1114	CALC	0.04	mg/L
Ortho-Phosphorus	1118	1380	0.003	mg/L
Phosphorus, dissolved	P--D	139A	0.003	mg/L
Phosphorus, total	P--T	139A	0.003	mg/L

Metals

	Parameter Code	Work Route	Detection Limit	Units
Aluminum	Al-T	0040	0.02	mg/L
Arsenic	As-T	0181	0.001	mg/L
Barium	Ba-T	0042	0.001	mg/L
Cadmium	Cd-T	0040	0.01	mg/L
Chromium	Cr-T	0040	0.01	mg/L
Cobalt	Co-T	0040	0.1	mg/L
Copper	Cu-T	0040	0.01	mg/L
Iron	Fe-T	0040	0.01	mg/L
Lead	Pb-T	0040	0.1	mg/L
Manganese	Mn-T	0040	0.01	mg/L
Molybdenum	Mo-T	0040	0.01	mg/L
Nickel	Ni-T	0040	0.05	mg/L
Vanadium	V-T	0040	0.01	mg/L
Zinc	Zn-T	0040	0.01	mg/L

Microbials

	Parameter Code	Work Route	Detection Limit	Units
Total Coliform (CFU/Cl)	0451	2480	0	CFU/cL
Total Coliform (MPN)	0451	2492	0	MPN/cL
Fecal Coliform (CFU/Cl)	0450	2480	0	CFU/cL
Fecal Coliform (MPN)	0450	2492	0	MPN/cL
Fecal Streptococcus	0454	2480	0	CFU/cL
E. Coli	0147	6013	2	CFU/cL
Enterococcus	0148	6014	2	CFU/cL

Organics

	Parameter Code	Work Route	Detection Limit	Units
Phenols	0117	0550	0.002	mg/L
Adsorb Organohalides	AOX-	DM01	0.01	mg/L

APPENDIX 2

Summary tables for water quality monitoring data considered in this report at sites in the Fraser River basin. Data ranges for analyses performed on subsets of the complete data range are indicated by numbered superscripts. They reference the following date ranges:

$\mathbf{A}^{1}$: 1991 – 1996
$\mathbf{A}^{2}$: 1988 – 1994
$\mathbf{A}^{3}$: 1990 – 1996
$\mathbf{A}^{4}$: 1989 – 1996
$\mathbf{A}^{5}$: 1986 – 1993
$\mathbf{A}^{6}$: 1987 – 1996
$\mathbf{A}^{7}$: 1986 – 1994
$\mathbf{A}^{8}$: 1988 – 1995
$\mathbf{A}^{9}$: 1991 – 1994
$\mathbf{A}^{10}$: 1987 – 1994

A2 - 1. Summary table for Environment Canada data collected from main stem sites considered in this report on the Fraser River Basin.

A2 - 2. Summary table for Environment Canada data collected from tributary sites considered in this report on the Fraser River basin.

A2 - 3. Summary table for BC Ministry of Environment, Lands, and Parks data collected from main stem sites considered in this report on the Fraser River basin.

A2 - 4. Summary table for BC Ministry of Environment, Lands, and Parks data collected from tributary sites considered in this report on the Fraser River basin.

Environment Canada Adequacy Summary Table For Mainstem Monitoring Sites in the Fraser River Basin

	VARIABLE	Red Pass							Hansard							Marguerite							Hope					
		Total Values = 251							Total Values = 242							Total Values = 252							Total Values = 275					
		Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing	
		#	%	#	%	#	%		#	%	#	%	#	%		#	%	#	%	#	%		#	%	#	%	#	%
	Physicals																											
1	Air Temp	0	0	0	0	2	1	NA	0	0	0	0	18	7	NA	0	0	0	0	2	1	NA	0	0	0	0	2	1
2	Water Temp	1	0	0	0	2	1	A	0	0	0	0	24	10	A	0	0	1	0	4	2	A	0	0	0	0	4	1
3	Apparent Colour	0	0	94	37	1	0	NA	0	0	15	6	1	0	A	1	0	11	4	1	0	A	0	0	14	5	0	0
4	Conductivity	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	1	0	A	0	0	0	0	0	0
5	Laboratory pH	35	14	0	0	1	0	A[3]	0	0	0	0	0	0	A[3]	68	27	0	0	2	1	A[3]	59	21	0	0	0	0
6	Turbidity	0	0	1	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	2	1	A	0	0	0	0	0	0
7	Residue Non-Filterable	0	0	129	51	82	33	NA	0	0	0	0	179	74	NA	0	0	11	4	175	69	NA	0	0	8	3	163	59
8	Residue Fixed Non-Filterable	0	0	1	0	137	55	NA	0	0	0	0	179	74	NA	0	0	18	7	175	69	NA	0	0	22	8	163	59
9	Residue Filterable	0	0	1	0	137	55	NA	0	0	0	0	179	74	NA	0	0	0	0	175	69	NA	0	0	0	0	163	59
10	Residue Fixed Filterable	0	0	1	0	137	55	NA	0	0	0	0	179	74	NA	0	0	0	0	175	69	NA	0	0	1	0	163	59
11	Alkalinity, Total	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	1	0	A	0	0	0	0	0	0
	Dissolved Ions																											
12	Calcium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	2	1	A	0	0	0	0	0	0
13	Chloride	0	0	1	0	1	0	A	0	0	2	1	0	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0
14	Fluoride	0	0	101	40	1	0	A[1]	0	0	25	10	0	0	A[1]	0	0	19	8	0	0	A[4]	0	0	1	0	0	0
15	Magnesium	0	0	0	0	25	10	A	0	0	0	0	41	17	A	0	0	0	0	2	1	A	0	0	0	0	0	0
16	Hardness	0	0	0	0	25	10	A	0	0	0	0	41	17	A	0	0	0	0	2	1	A	0	0	0	0	0	0
17	Potassium	0	0	15	6	1	0	NA	0	0	0	0	0	0	A	0	0	0	0	2	1	A	0	0	0	0	0	0
18	Silicon	0	0	0	0	1	0	A[1]	0	0	0	0	0	0	A[1]	0	0	0	0	2	1	A[1]	0	0	0	0	0	0
19	Sodium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	2	1	A	0	0	0	0	0	0
20	Sulphate	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	1	0	A	0	0	0	0	0	0
	Nutrients																											
21	Nitrogen: NO2/3	0	0	1	0	57	23	A[2]	0	0	0	0	43	18	A	0	0	0	0	48	19	A[5]	0	0	0	0	52	19
22	Nitrogen: Dissolved	0	0	0	0	156	62	A	0	0	0	0	237	98	A	1	0	0	0	2	1	A	0	0	0	0	4	1
23	Phosphorus, Total	0	0	40	16	1	0	A	0	0	1	0	2	1	A	0	0	0	0	4	2	A	0	0	0	0	0	0
	Total Metals																											
24	Aluminum	15	6	0	0	86	34	A[3]	22	9	0	0	101	42	A[1]	25	10	0	0	105	42	A[1]	0	0	0	0	140	51
25	Arsenic	0	0	89	35	19	8	NA	0	0	4	2	14	6	A	0	0	1	0	18	7	A	0	0	0	0	6	2
26	Barium	0	0	0	0	86	34	A[3]	0	0	0	0	101	42	A[3]	0	0	0	0	105	42	A[3]	0	0	0	0	140	51
27	Beryllium	0	0	130	52	86	34	NA	0	0	77	32	106	44	NA	0	0	68	27	105	42	A[3]	0	0	61	22	140	51
28	Cadmium	0	0	180	72	9	4	NA	0	0	26	11	9	4	A	2	1	84	33	10	4	A[6]	0	0	145	53	5	2
29	Chromium	0	0	42	17	85	34	A[3]	0	0	2	1	79	33	A[3]	2	1	0	0	80	32	A[6]	0	0	0	0	104	38
30	Cobalt	0	0	8	3	86	34	NA	0	0	0	0	101	42	A[3]	0	0	1	0	105	42	A[3]	0	0	0	0	140	51
31	Copper	0	0	1	0	40	16	NA	0	0	0	0	8	3	NA	4	2	0	0	10	4	NA	0	0	1	0	5	2
32	Iron	0	0	0	0	40	16	A	0	0	0	0	8	3	A	4	2	0	0	10	4	A	0	0	0	0	5	2
33	Lead	0	0	143	57	40	16	NA	0	0	26	11	8	3	A	2	1	44	17	11	4	A	0	0	74	27	5	2
34	Lithium	0	0	0	0	86	34	A[3]	0	0	0	0	101	42	A[3]	0	0	0	0	105	42	A[3]	0	0	0	0	140	51
35	Manganese	0	0	17	7	9	4	A[4]	0	0	0	0	7	3	A	4	2	1	0	10	4	A	0	0	3	1	3	1
36	Mercury	26	10	81	32	72	29	NA	4	2	44	18	58	24	NA	28	11	54	21	71	28	NA	0	0	63	23	71	26
37	Molybdenum	0	0	62	25	86	34	NA	0	0	23	10	101	42	A[3]	0	0	8	3	105	42	A[3]	0	0	0	0	104	38
38	Nickel	0	0	0	0	85	34	A[3]	0	0	0	0	80	33	A[3]	0	0	0	0	85	33	A[3]	0	0	0	0	104	38
39	Selenium	0	0	153	61	19	8	NA	0	0	58	24	14	6	NA	0	0	51	20	18	7	A	0	0	52	19	6	2
40	Strontium	0	0	0	0	86	34	A[3]	0	0	0	0	101	42	A[3]	0	0	1	0	105	42	A[3]	0	0	0	0	140	51
41	Vanadium	0	0	62	25	86	34	NA	0	0	1	0	101	42	A[3]	0	0	2	1	105	42	A[3]	0	0	0	0	140	51
42	Zinc	0	0	7	3	9	4	NA	0	0	0	0	9	4	NA	4	2	0	0	12	5	NA	0	0	2	1	5	2

A : Adequate for further analysis

NA : Not adequate for further analysis

Environment Canada Adequacy Summary Table For Tributary Monitoring Sites in the Fraser River basin

	VARIABLE	Nechako River Total Values = 222							Thompson River Total Values = 245							Salmon River Total Values = 199							Sumas River Total Values = 92						
		Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing		Adequacy	Flagged		Censored		Missing		Adequacy
		#	%	#	%	#	%		#	%	#	%	#	%		#	%	#	%	#	%		#	%	#	%	#	%	
	Physicals																												
1	Air Temp	0	0	0	0	3	1	NA	0	0	0	0	0	0	NA	1	1	0	0	3	2	NA	0	0	0	0	3	3	NA
2	Water Temp	0	0	0	0	13	6	A	0	0	0	0	0	0	A	0	0	0	0	4	2	A	0	0	0	0	4	4	NA
3	Apparent Colour	0	0	7	3	1	0	A	0	0	22	9	0	0	A	0	0	19	10	0	0	A	0	0	2	2	0	0	NA
4	Conductivity	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	1	1	A	0	0	0	0	0	0	NA
5	Laboratory pH	64	29	0	0	1	0	A[3]	69	28	0	0	0	0	A[3]	18	9	0	0	0	0	A[3]	24	26	0	0	0	0	NA
6	Turbidity	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	1	1	0	0	A	0	0	0	0	0	0	NA
7	Residue Non-Filterable	0	0	6	3	197	89	NA	0	0	3	1	234	96	NA	0	0	0	0	189	95	NA	0	0	39	42	16	17	NA
8	Residue Fixed Non-Filterable	0	0	10	5	199	90	NA	0	0	4	2	234	96	NA	0	0	0	0	189	95	NA	0	0	47	51	29	32	NA
9	Residue Filterable	0	0	0	0	199	90	NA	0	0	0	0	234	96	NA	0	0	0	0	189	95	NA	0	0	0	0	30	33	NA
10	Residue Fixed Filterable	0	0	0	0	199	90	NA	0	0	0	0	234	96	NA	0	0	0	0	189	95	NA	0	0	1	1	29	32	NA
11	Alkalinity, Total	0	0	0	0	2	1	A	0	0	0	0	0	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	NA
	Dissolved Ions																												
12	Calcium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	1	1	0	0	0	0	A	0	0	0	0	0	0	NA
13	Chloride	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	1	1	0	0	A	0	0	0	0	0	0	NA
14	Fluoride	0	0	7	3	0	0	A	0	0	6	2	0	0	A	0	0	0	0	0	0	A	0	0	0	0	13	14	NA
15	Magnesium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	A	2	2	0	0	0	0	NA
16	Hardness	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	1	1	A	0	0	0	0	0	0	NA
17	Potassium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	NA
18	Silicon	0	0	0	0	0	0	A[1]	0	0	0	0	0	0	A[1]	0	0	0	0	0	0	A[1]	0	0	0	0	59	64	NA
19	Sodium	0	0	0	0	1	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	A	0	0	0	0	1	1	NA
20	Sulphate	0	0	2	1	0	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	A	0	0	0	0	0	0	NA
	Nutrients																												
21	Nitrogen: NO2/3	2	1	27	12	45	20	A[5]	0	0	1	0	35	14	A[7]	5	3	4	2	39	20	A[2]	8	9	0	0	13	14	NA
22	Nitrogen: Dissolved	1	0	0	0	3	1	A	0	0	0	0	7	3	A	2	1	0	0	0	0	A	9	10	0	0	1	1	NA
23	Phosphorus, Total	0	0	0	0	0	0	A	0	0	2	1	1	0	A	0	0	0	0	0	0	A	0	0	1	1	0	0	NA
	Total Metals																												
24	Aluminum	17	8	0	0	107	48	A[1]	23	9	0	0	108	44	A[1]	24	12	0	0	47	24	NA	6	7	0	0	58	63	NA
25	Arsenic	0	0	0	0	32	14	A	0	0	36	15	25	10	A	0	0	0	0	34	17	A	0	0	0	0	7	8	NA
26	Barium	0	0	0	0	107	48	A[3]	0	0	0	0	108	44	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
27	Beryllium	0	0	77	35	107	48	NA	0	0	119	49	108	44	NA	0	0	95	48	47	24	NA	0	0	24	26	58	63	NA
28	Cadmium	0	0	130	59	9	4	NA	0	0	175	71	8	3	NA	0	0	82	41	10	5	NA	0	0	46	50	4	4	NA
29	Chromium	0	0	0	0	43	19	A[3]	0	0	10	4	81	33	A[3]	0	0	6	3	47	24	A[3]	0	0	0	0	58	63	NA
30	Cobalt	0	0	7	3	107	48	NA	0	0	16	7	108	44	NA	0	0	1	1	47	24	A[3]	0	0	0	0	58	63	NA
31	Copper	3	1	0	0	9	4	NA	1	0	16	7	8	3	NA	1	1	0	0	10	5	NA	0	0	1	1	4	4	NA
32	Iron	2	1	0	0	9	4	A	1	0	0	0	8	3	A	0	0	0	0	10	5	A	0	0	0	0	4	4	NA
33	Lead	0	0	101	45	9	4	NA	0	0	128	52	8	3	NA	0	0	94	47	10	5	NA	0	0	25	27	4	4	NA
34	Lithium	0	0	0	0	107	48	A[3]	0	0	0	0	108	44	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
35	Manganese	0	0	5	2	9	4	A	1	0	10	4	8	3	A	0	0	0	0	10	5	A	0	0	0	0	4	4	NA
36	Mercury	21	9	51	23	59	27	NA	33	13	120	49	50	20	NA	33	17	46	23	52	26	NA	11	12	32	35	20	22	NA
37	Molybdenum	0	0	0	0	107	48	A[3]	0	0	0	0	108	44	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
38	Nickel	0	0	0	0	85	38	A[3]	0	0	38	16	46	19	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
39	Selenium	0	0	53	24	32	14	NA	0	0	51	21	25	10	NA	0	0	2	1	34	17	A	0	0	9	10	10	11	NA
40	Strontium	0	0	0	0	107	48	A[3]	0	0	0	0	108	44	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
41	Vanadium	0	0	0	0	107	48	A[3]	0	0	1	0	108	44	A[3]	0	0	0	0	47	24	A[3]	0	0	0	0	58	63	NA
42	Zinc	3	1	3	1	10	5	NA	0	0	6	2	9	4	NA	0	0	3	2	10	5	NA	1	1	0	0	4	4	NA

A : Adequate for further analysis

NA : Not adequate for further analysis

BC Ministry of Environment, Lands, and Parks Adequacy Summary Table For Mainstem Monito

	VARIABLE	Hansard					Stoner					Marguerite					Hope				
		Total Values = 230					Total Values = 158					Total Values = 235					Total Values = 185				
		Censored		Missing		Adequacy	Censored		Missing		Adequacy	Censored		Missing		Adequacy	Censored		Missing		Adequacy
		#	%	#	%		#	%	#	%		#	%	#	%		#	%	#	%	
	Physicals																				
1	Specific Conductivity	0	0	137	60	NA	0	0	112	71	NA	0	0	133	57	NA	0	0	109	59	NA
2	Colour TAC	13	6	17	7	A	0	0	121	77	NA	7	3	56	24	A	1	1	172	93	NA
3	pH	0	0	161	70	NA	0	0	104	66	NA	0	0	128	54	NA	0	0	89	48	NA
4	Turbidity	0	0	228	99	NA	0	0	153	97	NA	0	0	227	97	NA	0	0	138	75	NA
5	Residue Non-Filterable	28	12	20	9	A[8]	1	1	153	97	NA	0	0	23	10	A[8]	0	0	109	59	NA
6	Residue Fixed Non-Filterable	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
7	Residue Filterable	3	1	38	17	A[8]	0	0	122	77	NA	0	0	52	22	A[8]	0	0	114	62	NA
8	Residue Fixed Filterable	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
9	Residue Total	0	0	230	100	NA	0	0	122	77	NA	0	0	235	100	NA	0	0	185	100	NA
10	Alkalinity (phenolpht.)	2	1	228	99	NA	0	0	158	100	NA	0	0	232	99	NA	0	0	183	99	NA
11	Alkalinity, Total	0	0	228	99	NA	0	0	144	91	NA	0	0	232	99	NA	0	0	183	99	NA
12	Alkalinity 4.5/4.2	0	0	228	99	NA	0	0	158	100	NA	0	0	232	99	NA	0	0	184	99	NA
	Dissolved Ions																				
13	Calcium	0	0	190	83	NA	0	0	122	77	NA	0	0	204	87	NA	0	0	143	77	NA
14	Chloride	2	1	225	98	NA	0	0	115	73	NA	0	0	191	81	NA	0	0	182	98	NA
15	Fluoride, dissolved	3	1	227	99	NA	0	0	144	91	NA	0	0	232	99	NA	0	0	182	98	NA
16	Magnesium	0	0	188	82	NA	0	0	122	77	NA	0	0	204	87	NA	0	0	143	77	NA
17	Potassium, dissolved	0	0	227	99	NA	0	0	158	100	NA	0	0	232	99	NA	0	0	182	98	NA
18	Silica Reactive, dissolved	0	0	228	99	NA	0	0	158	100	NA	0	0	232	99	NA	0	0	182	98	NA
19	Sodium, dissolved	0	0	228	99	NA	0	0	117	74	NA	0	0	232	99	NA	0	0	182	98	NA
20	Sulphate, dissolved	0	0	228	99	NA	0	0	144	91	NA	0	0	232	99	NA	0	0	182	98	NA
	Nutrients																				
21	Nitrogen, Ammonia	98	43	68	30	A[8]	8	5	112	71	NA	79	34	51	22	A[8]	38	21	108	58	NA
22	Nitrogen, NO2/3 dissolved	0	0	228	99	NA	0	0	117	74	NA	0	0	206	88	NA	0	0	178	96	NA
23	Nitrogen, Kjeldahl	0	0	228	99	NA	0	0	143	91	NA	0	0	232	99	NA	0	0	183	99	NA
24	Nitrogen, Total Kjeldahl	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
25	Nitrogen, dissolved	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
26	Ortho-Phosphorus	134	58	68	30	NA	2	1	139	88	NA	75	32	58	25	A[8]	36	19	109	59	NA
27	Phosphorus, dissolved	88	38	69	30	A[8]	1	1	117	74	NA	29	13	52	22	A[8]	6	3	109	59	NA
28	Phosphorus, Total	1	0	227	99	NA	0	0	144	91	NA	0	0	232	99	NA	0	0	182	98	NA
	Total Metals																				
29	Aluminum	0	0	119	52	NA	0	0	133	84	NA	1	0	122	52	NA	0	0	91	49	NA
30	Arsenic	1	0	228	99	NA	1	1	137	87	NA	0	0	232	99	NA	0	0	175	95	NA
31	Barium	0	0	229	100	NA	0	0	123	78	NA	0	0	235	100	NA	0	0	185	100	NA
32	Cadmium	42	18	189	82	NA	0	0	122	77	NA	0	0	204	87	NA	0	0	143	77	NA
33	Chromium	41	18	170	74	NA	1	1	122	77	NA	6	3	195	83	NA	0	0	143	77	NA
34	Cobalt	42	18	188	82	NA	2	1	122	77	NA	13	6	204	87	NA	14	8	143	77	NA
35	Copper	34	15	189	82	NA	2	1	122	77	NA	26	11	204	87	NA	36	19	143	77	NA
36	Iron	0	0	188	82	NA	0	0	122	77	NA	0	0	204	87	NA	0	0	143	77	NA
37	Lead	41	18	188	82	NA	36	23	132	84	NA	29	12	204	87	NA	41	22	143	77	NA
38	Manganese	5	2	188	82	NA	0	0	122	77	NA	2	1	204	87	NA	3	2	143	77	NA
39	Mercury	0	0	229	100	NA	10	6	144	91	NA	2	1	233	99	NA	0	0	183	99	NA
40	Molybdenum	29	13	188	82	NA	2	1	121	77	NA	19	8	204	87	NA	35	19	143	77	NA
41	Nickel	42	18	188	82	NA	2	1	122	77	NA	28	12	204	87	NA	39	21	143	77	NA
42	Vanadium	0	0	188	82	NA	2	1	122	77	NA	0	0	204	87	NA	0	0	143	77	NA
43	Zinc	21	9	188	82	NA	2	1	122	72	NA	14	6	204	87	NA	21	11	143	77	NA
	Microbials																				
44	Total Coliform (CFU/Cl)	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
45	Total Coliform (MPN)	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
46	Fecal Coliform (CFU/Cl)	21	9	74	32	A[4]	0	0	154	97	NA	9	4	53	23	A[4]	0	0	144	78	NA
47	Fecal Coliform (MPN)	7	3	206	90	NA	4	3	138	87	NA	3	1	215	91	NA	2	1	158	85	NA
48	Fecal Streptococcus	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
49	E. Coli	0	0	230	100	NA	2	1	148	94	NA	1	0	227	97	NA	0	0	185	100	NA
50	Enterococcus	0	0	230	100	NA	0	0	158	100	NA	0	0	235	100	NA	0	0	185	100	NA
	Organics																				
51	Phenols	14	6	206	90	NA	9	6	124	78	NA	1	0	204	87	NA	0	0	185	100	NA
52	Adsorb Organohalides (AOX)	25	11	196	85	NA	5	3	55	35	A[9]	15	6	98	42	A[1]	18	10	60	32	A[1]

A : Adequate for further analysis NA : Not adequate for further analysis

BC Ministry of Environment, Lands, and Parks Adequacy Summary Table

	VARIABLE	Nechako River Total Values = 205					Salmon River Total Values = 299					Thompson River Total Values = 276				
		Censored		Missing		Adequacy	Censored		Missing		Adequacy	Censored		Missing		Adequacy
		#	%	#	%		#	%	#	%		#	%	#	%	
	Physicals															
1	Specific Conductivity	0	0	118	58	NA	0	0	235	79	NA	0	0	149	54	NA
2	Colour TAC	0	0	203	99	NA	0	0	299	100	NA	0	0	274	99	NA
3	pH	0	0	120	59	NA	0	0	228	76	NA	0	0	131	47	NA
4	Turbidity	0	0	202	99	NA	0	0	288	96	NA	0	0	271	98	NA
5	Residue Non-Filterable	49	24	18	9	A[8]	14	5	45	15	A[6]	62	22	61	22	A[10]
6	Residue Fixed Non-Filterable	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
7	Residue Filterable	0	0	33	16	A[8]	0	0	160	54	NA	0	0	63	23	A[8]
8	Residue Fixed Filterable	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
9	Residue Total	0	0	205	100	NA	0	0	247	83	NA	0	0	276	100	NA
10	Alkalinity (phenolpht.)	0	0	202	99	NA	0	0	299	100	NA	0	0	274	99	NA
11	Alkalinity, Total	0	0	202	99	NA	0	0	298	100	NA	0	0	274	99	NA
12	Alkalinity 4.5/4.2	0	0	202	99	NA	0	0	299	100	NA	0	0	274	99	NA
	Dissolved Ions															
13	Calcium	0	0	196	96	NA	0	0	283	95	NA	0	0	272	99	NA
14	Chloride	0	0	202	99	NA	1	0	273	91	NA	0	0	267	97	NA
15	Fluoride, dissolved	0	0	202	99	NA	0	0	298	100	NA	0	0	273	99	NA
16	Magnesium	0	0	168	82	NA	0	0	283	95	NA	0	0	272	99	NA
17	Potassium, dissolved	0	0	202	99	NA	0	0	297	99	NA	0	0	272	99	NA
18	Silica Reactive, dissolved	0	0	202	99	NA	0	0	299	100	NA	0	0	273	99	NA
19	Sodium, dissolved	0	0	205	100	NA	0	0	285	95	NA	0	0	267	97	NA
20	Sulphate, dissolved	0	0	202	99	NA	0	0	269	90	NA	0	0	263	95	NA
	Nutrients															
21	Nitrogen, Ammonia	115	56	22	11	NA	77	26	47	16	A[4]	113	41	63	23	NA
22	Nitrogen, NO2/3 dissolved	0	0	202	99	NA	0	0	253	85	NA	0	0	268	97	NA
23	Nitrogen, Kjeldahl	0	0	202	99	NA	0	0	60	20	A[6]	1	0	268	97	NA
24	Nitrogen, Total Kjeldahl	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
25	Nitrogen, dissolved	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
26	Ortho-Phosphorus	4	2	199	97	NA	4	1	40	13	A[6]	40	14	172	62	NA
27	Phosphorus, dissolved	27	13	32	16	A[8]	3	1	41	13	A[6]	71	26	65	24	A[6]
28	Phosphorus, Total	0	0	202	99	NA	0	0	215	72	NA	0	0	266	96	NA
	Total Metals															
29	Aluminum	1	0	105	51	NA	0	0	290	97	NA	0	0	268	97	NA
30	Arsenic	0	0	201	98	NA	0	0	292	98	NA	3	1	273	99	NA
31	Barium	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
32	Cadmium	0	0	196	96	NA	0	0	283	95	NA	0	0	273	99	NA
33	Chromium	1	0	194	95	NA	0	0	283	95	NA	0	0	272	99	NA
34	Cobalt	10	5	196	96	NA	0	0	283	95	NA	4	1	272	99	NA
35	Copper	32	16	168	82	NA	11	4	283	95	NA	1	0	272	99	NA
36	Iron	0	0	168	82	NA	0	0	283	95	NA	0	0	272	99	NA
37	Lead	0	0	168	82	NA	0	0	283	95	NA	2	1	272	99	NA
38	Manganese	8	4	168	82	NA	0	0	283	95	NA	1	0	272	99	NA
39	Mercury	0	0	203	99	NA	0	0	299	100	NA	0	0	274	99	NA
40	Molybdenum	0	0	168	82	NA	0	0	283	95	NA	3	1	272	99	NA
41	Nickel	32	16	168	82	NA	0	0	283	95	NA	2	1	272	99	NA
42	Vanadium	0	0	168	82	NA	0	0	283	95	NA	0	0	272	99	NA
43	Zinc	24	12	168	82	NA	10	3	283	95	NA	4	1	272	99	NA
	Microbials															
44	Total Coliform (CFU/CI)	0	0	205	100	NA	1	0	270	90	NA	0	0	276	100	NA
45	Total Coliform (MPN)	0	0	205	100	NA	0	0	299	100	NA	0	0	276	100	NA
46	Fecal Coliform (CFU/CI)	26	13	76	37	NA	1	0	86	29	A[4]	3	1	249	90	NA
47	Fecal Coliform (MPN)	11	5	175	85	NA	4	1	250	84	NA	1	0	275	100	NA
48	Fecal Streptococcus	0	0	205	100	NA	0	0	297	99	NA	0	0	276	100	NA
49	E. Coli	0	0	205	100	NA	15	5	223	75	NA	3	1	260	94	NA
50	Enterococcus	0	0	205	100	NA	1	0	288	96	NA	0	0	270	98	NA
	Organics															
51	Phenols	23	11	152	74	NA	0	0	298	100	NA	0	0	276	100	NA
52	Adsorb Organohalides (AOX)	0	0	205	100	NA	0	0	299	100	NA	3	1	254	92	NA

A : Adequate for further analysis   NA : Not adequate for further analysis

APPENDIX 3

Data summary tables for water quality monitoring
data considered in this report at sites in the Fraser River basin

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A3 - 1. Environment Canada data summary table for mainstem sites considered in this report on the Fraser River Basin.

A3 – 2. Environment Canada data summary table for tributary sites considered in this report on the Fraser River Basin.

A3 - 3. BC Ministry of Environment, Lands, and Parks data summary table for sites considered in this report on the Fraser River Basin.

Environment Canada Data Summary Table For Mainstem Monitoring Sites in the Fraser River Basin

	VARIABLE	Red Pass				Hansard				Marguerite				Hope			
		Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
	Physicals																
1	Air Temp	-28	3	2.387	24	-27	8	7.141	30.5	-31	8	8.458	32	-2	11.5	11.98	34.5
2	Water Temp	-1	4	5.04	15	-3	7	8.085	25	-2	4	5.69	20	0	8.75	9.151	24
3	Apparent Colour	3	5	5.284	15	5	15	19.79	85	5	30	34.12	120	5	20	25.8	80
4	Conductivity	93	137.5	134.5	160	102	154	158.5	254	108	154	156.2	230	95.2	128	130	172
5	Laboratory pH	6.9	7.98	7.941	8.22	6.7	7.95	7.808	8.29	7.3	8	7.965	8.3	7	7.9	7.858	8.2
6	Turbidity	0.05	0.51	1.025	5.4	0.3	9	13.67	77	0.15	13.5	18.02	88	0.28	12.5	18.25	78
7	Residue Non-Filterable	1	10	8.899	21	10	56	72.469	342	10	25.5	86.481	661	10	28	73.528	665
8	Residue Fixed Non-Filterable	1	10	10.649	179	10	49.5	62.016	323	10	19	78.208	628	10	23	66.192	642
9	Residue Filterable	10	85	85.912	191	10	104	113.219	272	24	102	134.987	318	31	86	104.748	266
10	Residue Fixed Filterable	10	60	65.544	165	10	73	74.625	232	13	66	89.74	258	10	54	65.39	222
11	Alkalinity, Total	40.6	54	52.76	64	41.4	66.7	68.38	106	48	64	65.63	90.7	40	52.6	52.7	66.3
	Dissolved Ions																
12	Calcium	12	17.55	17.2	21.2	15.6	23.2	24.46	36.8	16	21.4	21.73	30.7	13.3	17.5	17.7	22.3
13	Chloride	0.16	0.4	0.419	0.81	0.03	0.5	0.5688	1.73	0.38	2.2	3.133	11.9	0.3	1.715	2	5.2
14	Fluoride	0.01	0.03	0.035	0.11	0.01	0.04	0.037	0.09	0.01	0.05	0.048	0.12	0.01	0.05	0.047	0.08
15	Magnesium	3.61	5.7	5.651	7.9	2.7	4.35	4.625	7.7	2.6	4.4	4.486	6.5	2.1	3.7	3.687	5.5
16	Hardness	45.7	67.2	66.23	84.9	50.1	74.35	80	123	52.4	71.4	72.65	102.3	43.8	59	59.34	77.5
17	Potassium	0.1	0.2	0.215	0.5	0.2	0.5	0.487	0.9	0.3	0.61	0.6542	1.35	0.4	0.77	0.765	1.16
18	Silicon	0.84	1.355	1.353	1.83	1.2	2.3	2.356	4.87	1.68	3	3.17	6.27	1.91	3.26	3.323	5.68
19	Sodium	0.4	0.8	0.7406	1.2	0.4	1.1	1.164	2.4	0.8	3.7	4.029	9.9	1.2	3.1	3.247	5.9
20	Sulphate	7.4	13.2	13.14	18.8	3	11.8	11.86	21.1	2.5	9	9.027	15.5	4.3	9.1	9.102	15
	Nutrients																
21	Nitrogen: NO2/3	0.002	0.072	0.066	0.124	0.026	0.114	0.111	0.268	0.008	0.1	0.095	0.211	0.01	0.094	0.096	0.613
22	Nitrogen: Dissolved	0.025	0.1	0.093	0.2	0.03	0.17	0.175	0.64	0.033	0.23	0.221	0.55	0.04	0.188	0.182	0.752
23	Phosphorus, Total	0.0002	0.003	0.004	0.001	0.002	0.032	0.048	0.302	0.013	0.051	0.099	0.632	0.008	0.052	0.078	0.325
	Total Metals																
24	Aluminum	0.022	0.059	0.079	0.253	0.036	0.797	0.915	4.39	0.05	0.939	1.174	3.94	0.049	1.1	1.54	6.83
25	Arsenic	0.0001	0.0001	0.0001	0.0017	0.0001	0.0004	0.0005	0.003	0.0001	0.0006	0.0008	0.0037	0.0001	0.0007	0.0009	0.0042
26	Barium	0.011	0.013	0.013	0.015	0.0087	0.017	0.02	0.054	0.015	0.024	0.028	0.075	0.014	0.023	0.025	0.049
27	Beryllium	0.05	0.05	0.05	0.09	0.05	0.05	0.07	0.25	0.05	0.05	0.07	0.25	0.05	0.05	0.066	0.26
28	Cadmium	0.0001	0.0001	0.0002	0.004	0.0001	0.0001	0.0002	0.0016	0.0001	0.0002	0.0003	0.0014	0.0001	0.0002	0.0002	0.0009
29	Chromium	0.0002	0.0002	0.0006	0.005	0.0002	0.002	0.003	0.013	0.0003	0.003	0.005	0.028	0.0002	0.002	0.003	0.0212
30	Cobalt	0.0001	0.0002	0.0002	0.0006	0.0001	0.0008	0.001	0.0061	0.0001	0.0002	0.001	0.005	0.0001	0.0009	0.001	0.0033
31	Copper	0.0002	0.0009	0.005	0.122	0.0004	0.003	0.007	0.084	0.0006	0.004	0.007	0.059	0.0004	0.004	0.004	0.0141
32	Iron	0.002	0.055	0.085	0.414	0.007	1.47	2.079	16.6	0.136	1.715	2.884	20.5	0.015	1.49	2.043	9.53
33	Lead	0.0002	0.0002	0.0006	0.021	0.0001	0.0013	0.0018	0.0096	0.0002	0.001	0.002	0.0096	0.0002	0.001	0.001	0.009
34	Lithium	0.0015	0.002	0.002	0.0024	0.0007	0.003	0.004	0.019	0.0001	0.003	0.003	0.011	0.0011	0.002	0.002	0.0061
35	Manganese	0.002	0.006	0.007	0.015	0.002	0.036	0.045	0.286	0.005	0.043	0.07	0.348	0.005	0.036	0.05	0.36
36	Mercury	0.005	0.01	0.015	0.138	0.005	0.01	0.016	0.08	0.005	0.01	0.017	0.091	0.005	0.02	0.019	0.08
37	Molybdenum	0.0001	0.0001	0.0001	0.0015	0.0001	0.0002	0.0002	0.0009	0.0001	0.0005	0.0005	0.001	0.0003	0.0006	0.0006	0.001
38	Nickel	0.0003	0.0015	0.0016	0.003	0.0002	0.002	0.003	0.016	0.0006	0.003	0.004	0.0219	0.0004	0.003	0.004	0.0187
39	Selenium	0.0001	0.0001	0.0001	0.0007	0.0001	0.0001	0.0001	0.0011	0.0001	0.0001	0.0002	0.0006	0.0001	0.0001	0.0002	0.0015
40	Strontium	0.098	0.136	0.136	0.165	0.0896	0.136	0.143	0.291	0.084	0.108	0.11	0.152	0.0786	0.096	0.098	0.127
41	Vanadium	0.0001	0.0001	0.0001	0.0008	0.0001	0.001	0.001	0.0053	0.0001	0.002	0.004	0.017	0.0001	0.003	0.003	0.01
42	Zinc	0.0002	0.0009	0.001	0.0057	0.0003	0.005	0.011	0.183	0.0009	0.006	0.01	0.054	0.0008	0.006	0.008	0.05

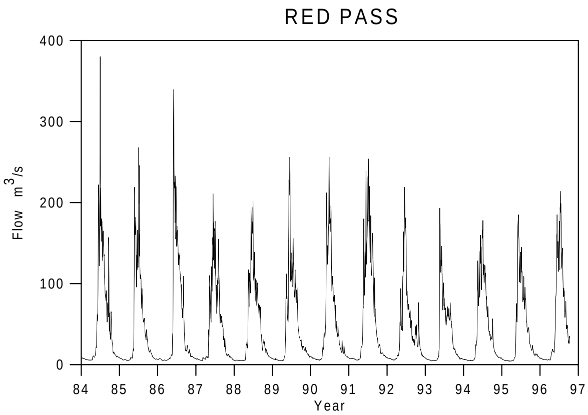
Environment Canada Data Summary Table For Tributary Monitoring Sites in the Fraser River Basin

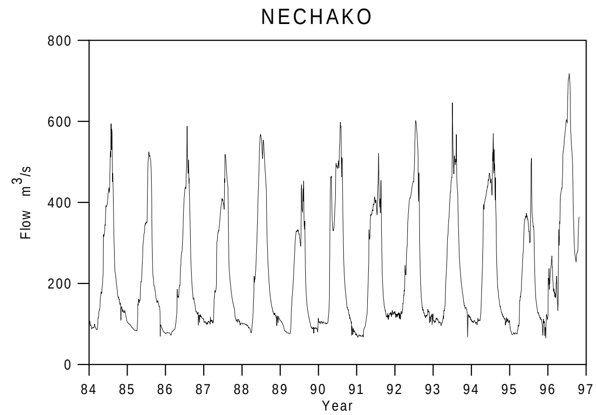
	VARIABLE	Nechako				Salmon				Thompson				Sumas			
		Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
	Physicals																
1	Air Temp	-24	10	10.4	32	-18	10	11.01	31	-16	10	11.57	33	-6	12	12	28
2	Water Temp	-2	7	7.949	25.7	0	7	8.207	24	0	8	9.21	20	0	9.5	9.92	19
3	Apparent Colour	2.5	10	15.43	80	5	10	18.87	100	5	7.75	8.798	30	5	30	29.429	100
4	Conductivity	77	107	109.2	175	102	409	360.3	517	69.6	108	103.6	130	187	284	284.297	336
5	Laboratory pH	7.1	7.845	7.807	8.22	7.56	8.2	8.183	8.52	6.9	7.82	7.803	8.24	7.5	7.765	7.79	9.5
6	Turbidity	0.1	1.8	3.664	30	0.1	1.5	3.539	28	0.1	1	1.515	10	0.4	4.2	9.395	205
7	Residue Non-Filterable	10	19	27.32	89	Not analyzed at this site				10	15	19.727	57	5	10	24.473	420
8	Residue Fixed Non-Filterable	10	10	21.913	86	Not analyzed at this site				10	10	15.727	53	63	196	203.3	387
9	Residue Filterable	61	109	125.957	229	Not analyzed at this site				47	91	94.182	178	5	10	15.024	190
10	Residue Fixed Filterable	17	78	74.652	163	Not analyzed at this site				14	45	49.545	128	10	125.5	131	300
11	Alkalinity, Total	34.1	49	49.57	84.3	41.8	170	152.2	214	27.5	39	38.19	49.1	64.9	104	103.6	127
	Dissolved Ions																
12	Calcium	9.9	13.7	13.95	24.8	13	49.5	44.68	67	9.6	13.8	13.56	17.5	8.7	21.4	20.815	26.6
13	Chloride	0.1	0.5	0.649	2.2	0.67	3.3	3.011	5	0.185	1.72	2.004	5.2	6.32	14.7	14.65	20.47
14	Fluoride	0.01	0.05	0.053	0.13	0.06	0.18	0.168	0.27	0.02	0.05	0.059	0.14	0.049	0.051	0.06	0.13
15	Magnesium	2.3	3.9	3.964	7.4	3.21	15.45	13.78	21.1	1.2	2.5	2.42	3.7	14.5	17.4	18.04	24.7
16	Hardness	35.1	50	50.51	78	45.68	189	168.4	254	30.2	44.8	43.79	56.3	96.5	126	126.729	153
17	Potassium	0.4	0.7	0.739	1.6	1.34	3.225	3.141	4.4	0.57	0.9	0.881	1.2	1.57	2.4	2.874	7.3
18	Silicon	1.96	2.72	2.905	6.08	8.21	11.4	11.27	14.5	1.86	2.735	2.768	3.97	6.47	10.5	10.473	12.6
19	Sodium	1.6	2.4	2.446	4.1	3.5	13.25	12.06	16.9	1.1	3.1	2.944	4.7	4.4	9.5	9.462	13
20	Sulphate	2.6	4.4	4.542	7.7	5.9	40.25	35.44	62	5	8.8	8.723	13.1	9	13.7	14.069	31.7
	Nutrients																
21	Nitrogen: NO2/3	0.002	0.013	0.032	0.334	0.002	0.088	0.106	0.328	0.002	0.107	0.097	0.205	0.14	2.275	2.408	4.51
22	Nitrogen: Dissolved	0.05	0.17	0.204	0.651	0.055	0.26	0.258	0.69	0.06	0.164	0.156	0.27	1.6	2.673	2.819	5.84
23	Phosphorus, Total	0.002	0.018	0.031	0.204	0.017	0.074	0.1	0.38	0.002	0.01	0.015	0.076	0.002	0.111	0.126	0.46
	Total Metals																
24	Aluminum	0.002	0.104	0.235	1.15	0.036	0.105	0.486	3.11	0.024	0.093	0.169	1.15	0.014	0.164	0.652	6.9
25	Arsenic	0.0002	0.0004	0.0005	0.0017	0.0006	0.001	0.001	0.0018	0.0001	0.0001	0.0002	0.0004	0.0003	0.0009	0.0009	0.003
26	Barium	0.0087	0.019	0.021	0.0513	0.0193	0.027	0.027	0.0462	0.0077	0.011	0.012	0.0205	0.026	0.035	0.039	0.103
27	Beryllium	0.05	0.05	0.051	0.1	0.05	0.05	0.062	0.31	0.05	0.05	0.051	0.09	0.05	0.05	0.054	0.13
28	Cadmium	0.0001	0.0001	0.0002	0.002	0.0001	0.0001	0.0002	0.0016	0.0001	0.0001	0.0002	0.0011	0.0001	0.0002	0.0004	0.0018
29	Chromium	0.0002	0.0005	0.0009	0.0043	0.0002	0.0007	0.001	0.0055	0.0002	0.0005	0.0009	0.0056	0.0003	0.002	0.008	0.083
30	Cobalt	0.0001	0.0001	0.0003	0.0012	0.0001	0.0003	0.0005	0.0023	0.0001	0.0001	0.0002	0.001	0.0002	0.0007	0.002	0.026
31	Copper	0.0002	0.002	0.006	0.095	0.0007	0.002	0.005	0.0715	0.0001	0.0001	0.0002	0.001	0.0007	0.002	0.028	1.05
32	Iron	0.0006	0.201	0.441	2.958	0.133	0.36	0.813	4.77	0.0303	0.141	0.251	1.48	0.101	1.12	1.18	3.13
33	Lead	0.0002	0.0007	0.001	0.019	0.0002	0.0002	0.0008	0.009	0.0002	0.0006	0.0009	0.021	0.0002	0.001	0.002	0.017
34	Lithium	0.0003	0.0005	0.0006	0.0012	0.0019	0.005	0.005	0.0085	0.0005	0.001	0.001	0.0017	0.002	0.004	0.004	0.013
35	Manganese	0.0001	0.017	0.025	0.121	0.0248	0.047	0.055	0.154	0.002	0.006	0.009	0.0355	0.009	0.08	0.087	0.356
36	Mercury	0.005	0.011	0.021	0.53	0.005	0.008	0.045	0.106	0.005	0.01	0.013	0.071	0.007	0.02	0.022	0.117
37	Molybdenum	0.0009	0.002	0.002	0.0031	0.0005	0.002	0.002	0.0023	0.0004	0.0007	0.0007	0.0009	0.0003	0.0006	0.0005	0.0009
38	Nickel	0.0002	0.001	0.001	0.0059	0.0002	0.0009	0.001	0.006	0.0002	0.0007	0.0009	0.0034	0.007	0.014	0.046	0.472
39	Selenium	0.0001	0.0001	0.0002	0.0012	0.0001	0.0005	0.0005	0.001	0.0001	0.0001	0.0001	0.0009	0.0001	0.0002	0.0002	0.0006
40	Strontium	0.0521	0.069	0.069	0.101	0.122	0.454	0.398	0.57	0.0618	0.084	0.082	0.0969	0.083	0.127	0.133	0.437
41	Vanadium	0.0001	0.0006	0.001	0.0051	0.0014	0.003	0.004	0.0126	0.0001	0.0005	0.0007	0.0034	0.0001	0.0009	0.002	0.018
42	Zinc	0.0002	0.002	0.004	0.028	0.0002	0.002	0.003	0.02	0.0002	0.001	0.003	0.062	0.0009	0.004	0.009	0.265

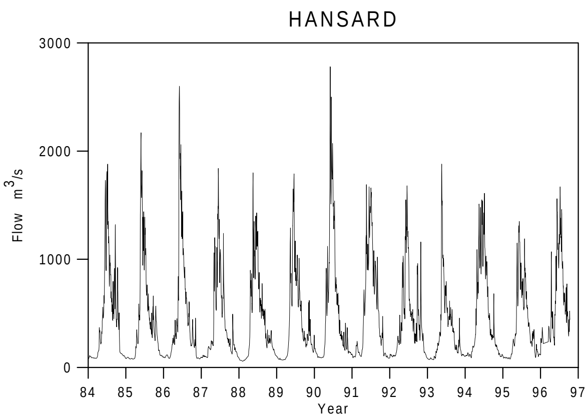
	VARIABLE	Hansard				Stoner				Marguerite				Hope				Nechako				Salmon				Thompson			
		Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
	Physicals																												
1	Colour TAC	1	5	7.082	33	3	16.5	18.162	46	1	14	15.96	54	1	12	12.625	24	20	21.5	21.5	23	Not analyzed at this site				4	7	7	10
2	Residue Non-Filterable	1	25	43.64	334	4	6	7.8	13	1	38	72.32	549	1	26.5	46.566	380	1	4	10.25	88	1	7	22.57	255	1	4	4.873	30
3	Residue Filterable	38	102	101.9	194	64	92	99.216	137	68	104	108	184	48	88	88.028	124	40	76	76.32	126	4	254	229.231	336	44	70	69.03	122
	Nutrients																												
4	Nitrogen, Ammonia	0.005	0.005	0.007	0.041	0.005	0.011	0.016	0.05	0.005	0.005	0.011	0.041	0.005	0.005	0.007	0.021	0.005	0.005	0.006	0.023	0.005	0.008	0.016	0.143	0.005	0.005	0.006	0.058
5	Nitrogen, Kjeldahl	0.04	0.045	0.045	0.05	0.12	0.265	0.245	0.32	0.01	0.205	0.22	0.41	0.09	0.145	0.145	0.2	0.11	0.2	0.237	0.4	0.08	0.2	0.247	1.36	0.04	0.1	0.112	0.21
6	Ortho-Phosphorus	0.003	0.003	0.004	0.03	0.003	0.004	0.007	0.036	0.003	0.003	0.005	0.017	0.003	0.003	0.004	0.008	0.003	0.003	0.004	0.007	0.006	0.035	0.036	0.069	0.001	0.001	0.084	0.12
7	Phosphorus, dissolved	0.003	0.003	0.004	0.024	0.003	0.007	0.009	0.04	0.003	0.007	0.008	0.02	0.003	0.005	0.006	0.019	0.003	0.005	0.006	0.016	0.018	0.04	0.043	0.104	0.003	0.003	0.004	0.016
	Microbials																												
8	Fecal Coliform (CFU/CI)	0	4	7.368	56	5	195	267	1200	0	40	92.27	1100	1	31	44.581	210	0	3	12.738	422	0	90	143.6	1100	1	3	8.065	120
	Organics																												
9	Adsorb Organohalides (AOX)	0.01	0.01	0.01	0.02	0.01	0.04	0.057	0.3	0.01	0.04	0.052	0.31	0.01	0.02	0.03	0.14	Not analyzed at this site				Not analyzed at this site				0.01	0.03	0.025	0.04

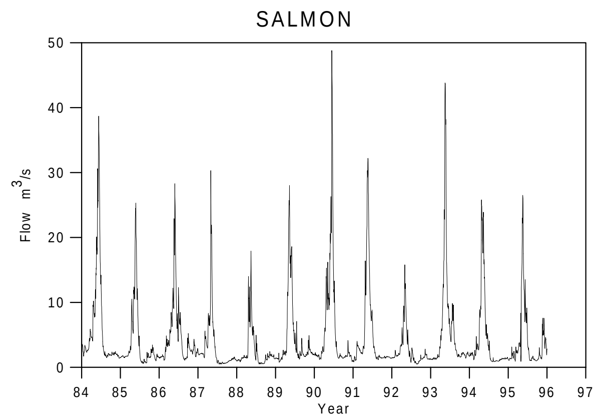
APPENDIX 4

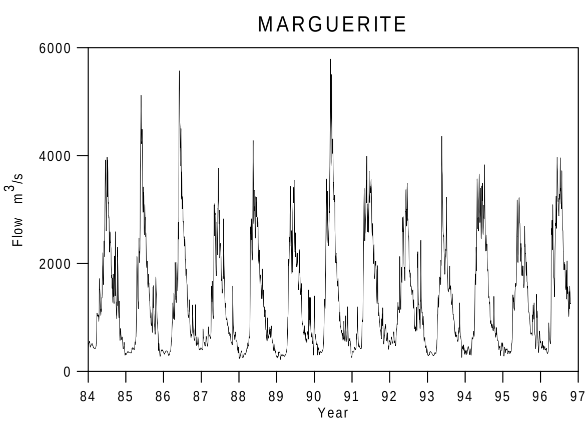
Time series plots of Environment Canada water quality monitoring data for constituents considered in this report at selected sites in the Fraser River basin.

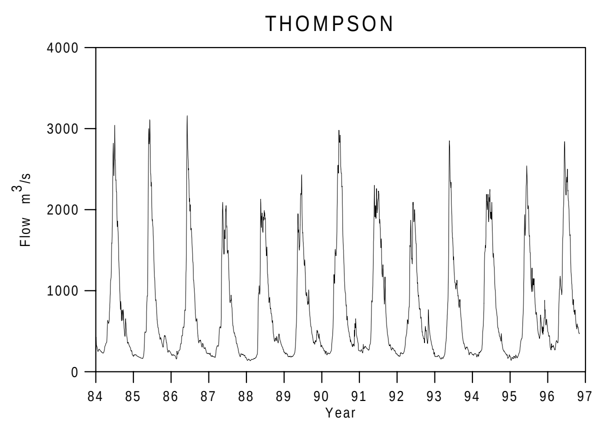

RED PASS
Flow m3/s
Year

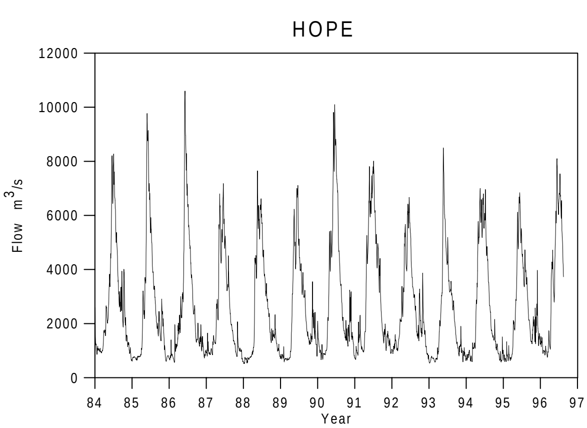

NECHAKO
Flow m3/s
Year

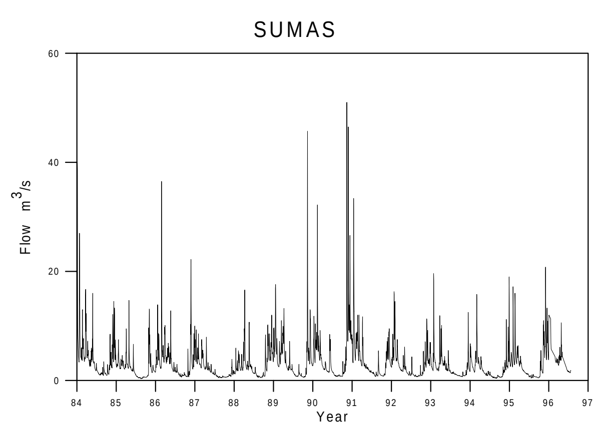

HANSARD
Flow m3/s
Year


SALMON
Flow m3/s
Year

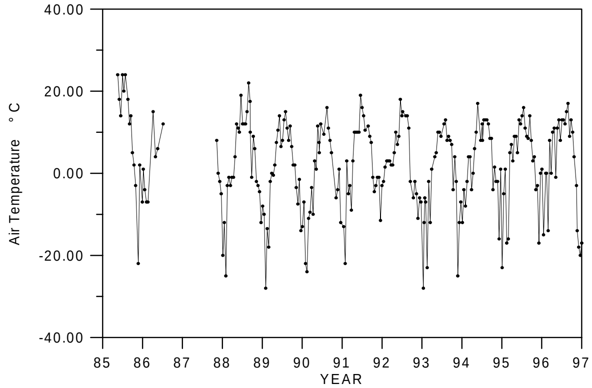

MARGUERITE
Flow m3/s
Year


THOMPSON
Flow m3/s
Year

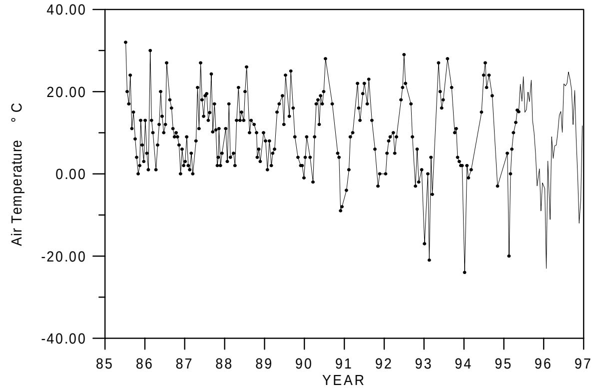

HOPE
Flow m3/s
Year


SUMAS
Flow m3/s
Year

RED PASS



NECHAKO



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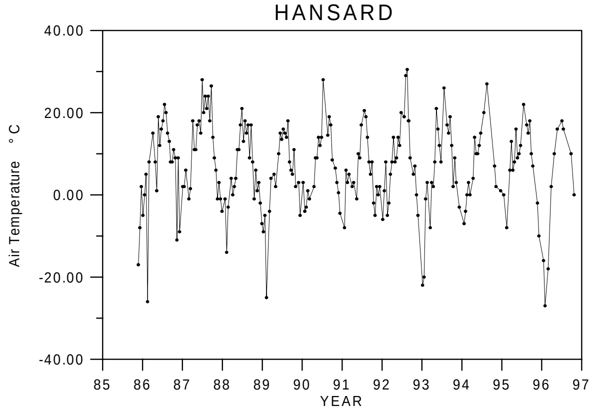
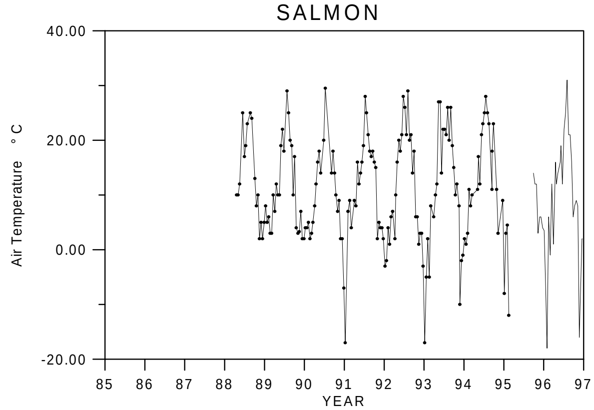
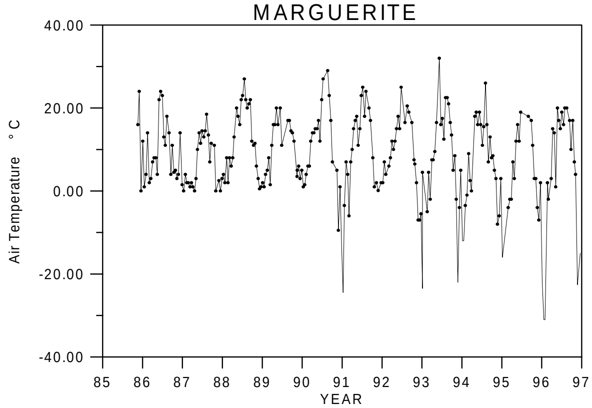


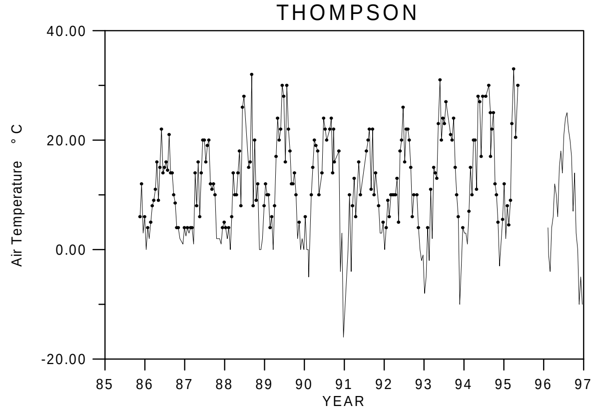
SALMON



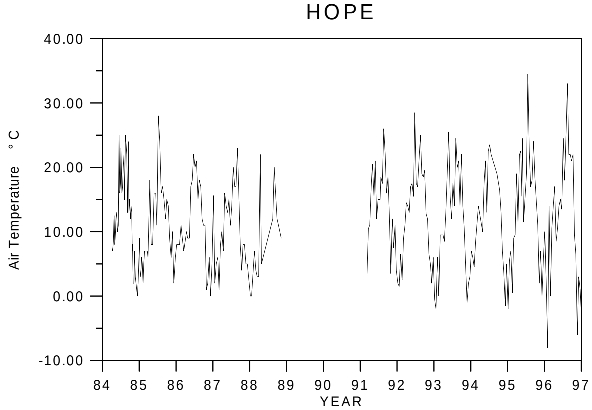
MARGUERITE



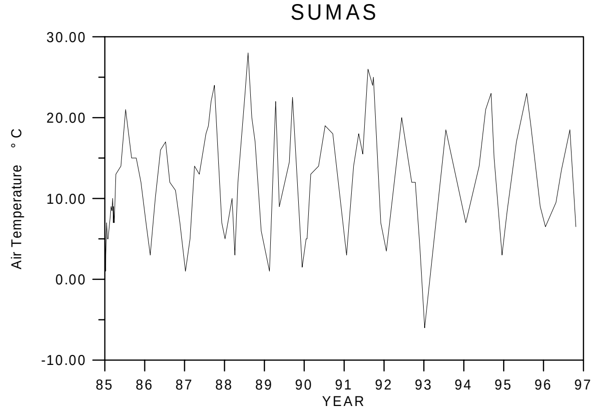
THOMPSON

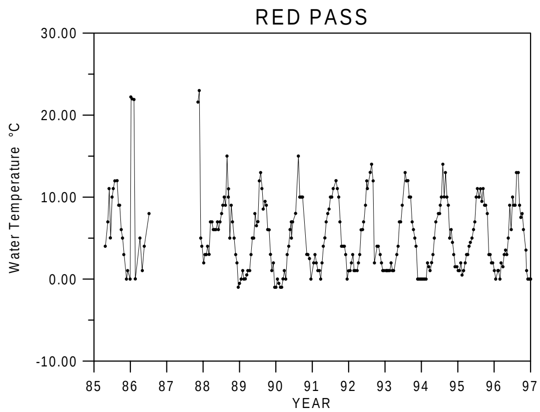


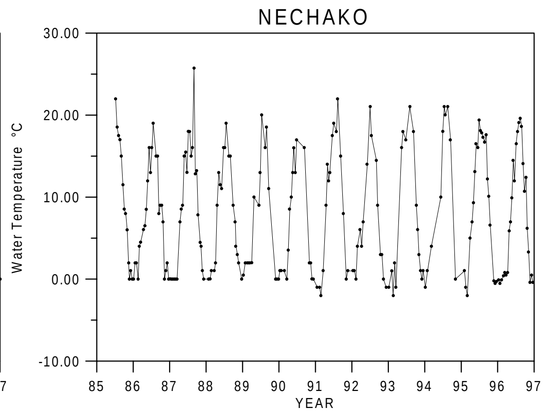
HOPE

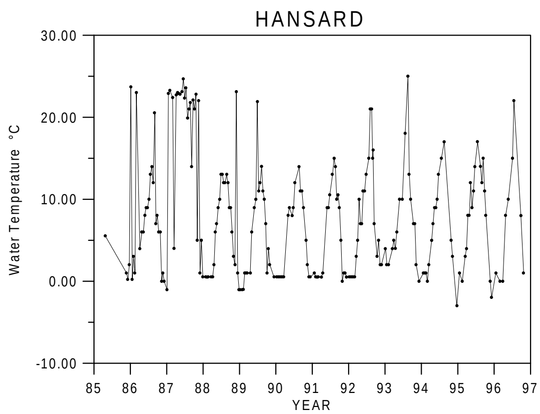


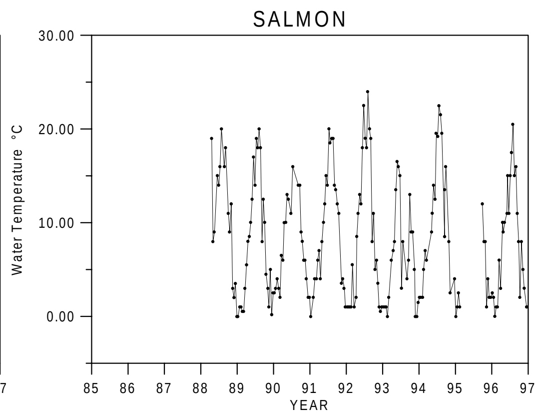
SUMAS

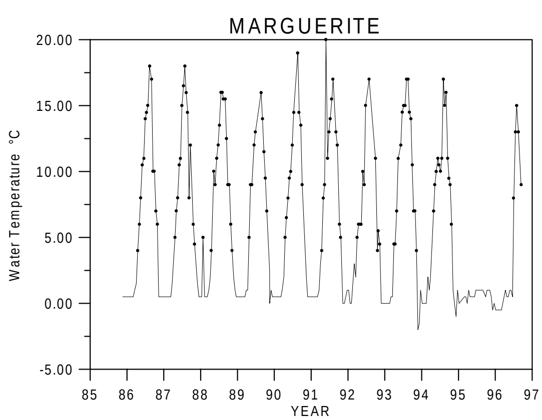


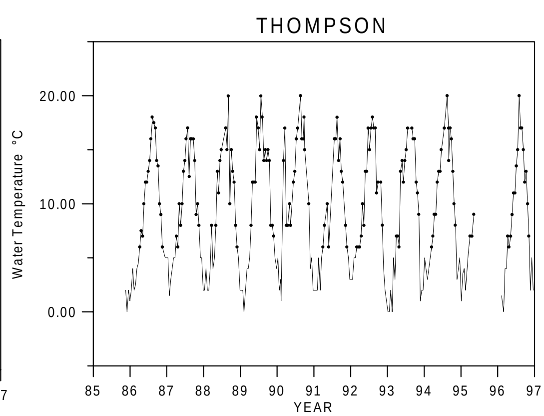

RED PASS
Water Temperature °C
YEAR

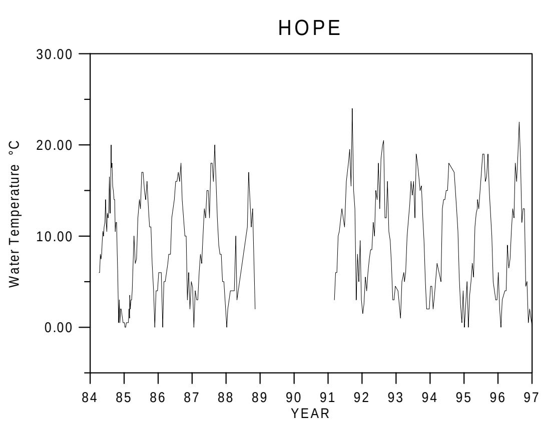

NECHAKO
Water Temperature °C
YEAR

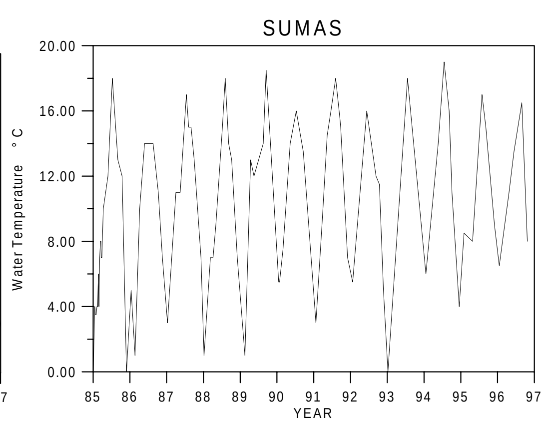

HANSARD
Water Temperature °C
YEAR


SALMON
Water Temperature °C
YEAR

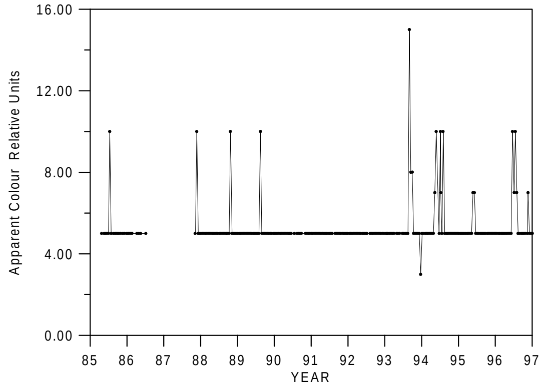

MARGUERITE
Water Temperature °C
YEAR


THOMPSON
Water Temperature °C
YEAR

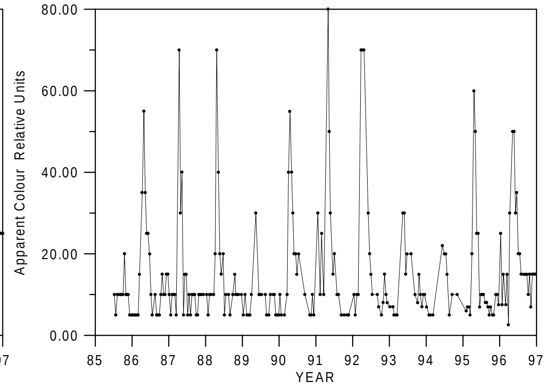

HOPE
Water Temperature °C
YEAR


SUMAS
Water Temperature °C
YEAR

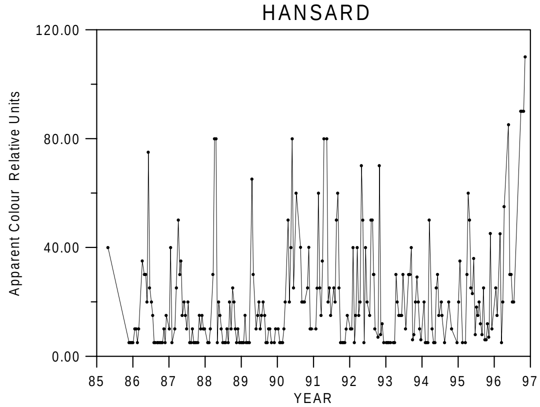
RED PASS



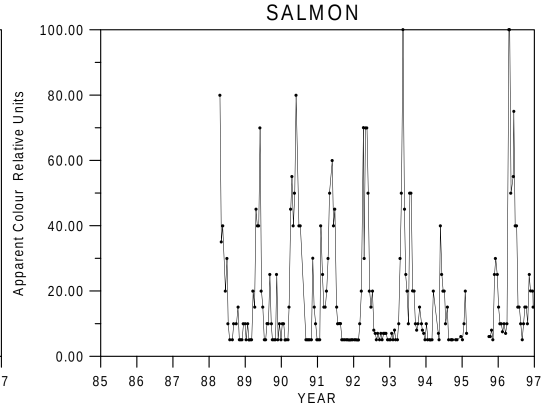
NECHAKO



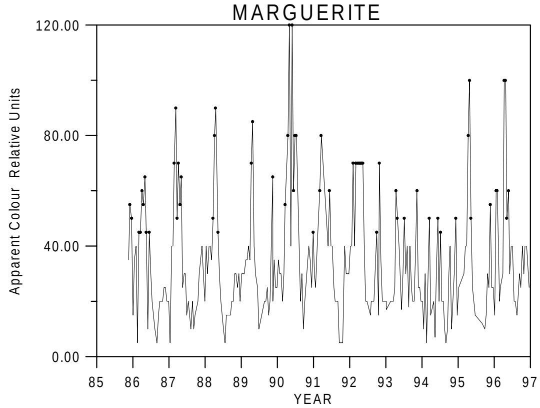
HANSARD



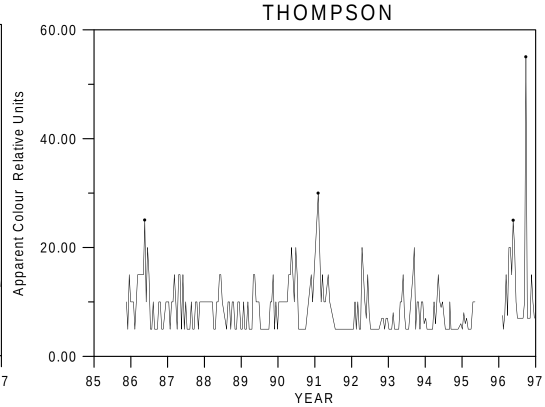
SALMON



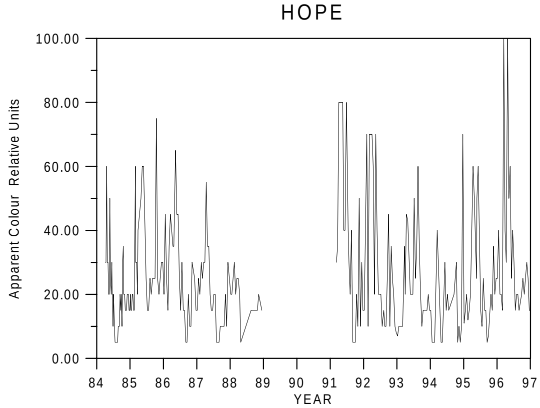
MARGUERITE



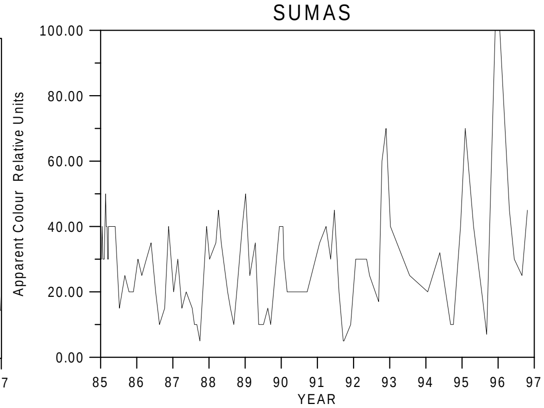
THOMPSON

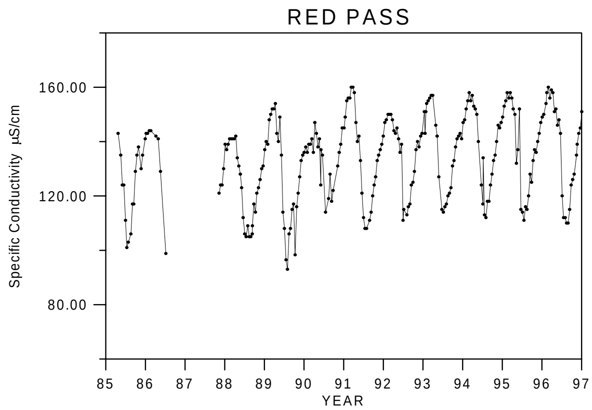


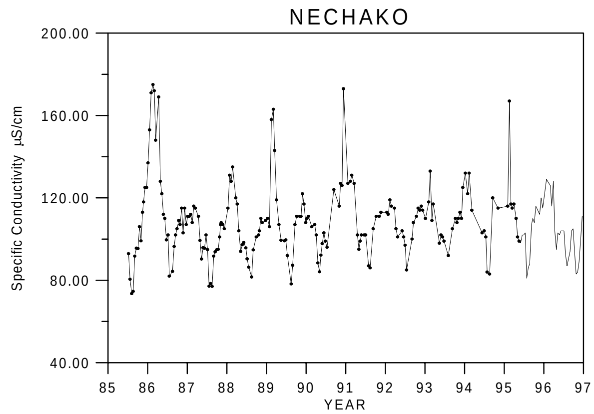
HOPE

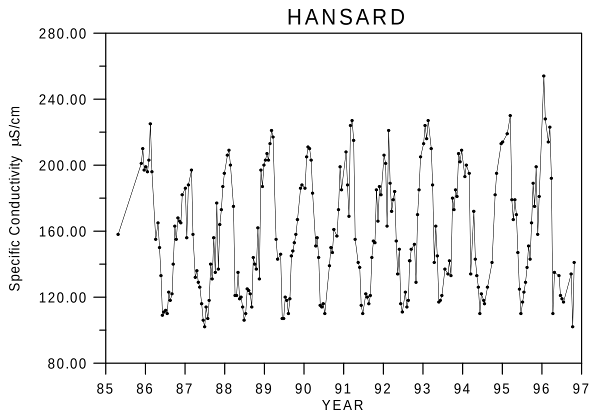


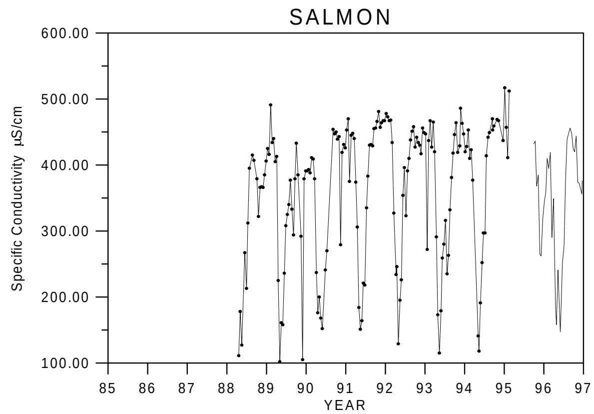
SUMAS

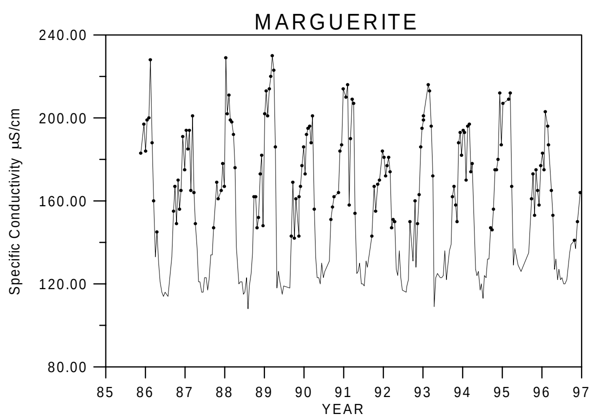


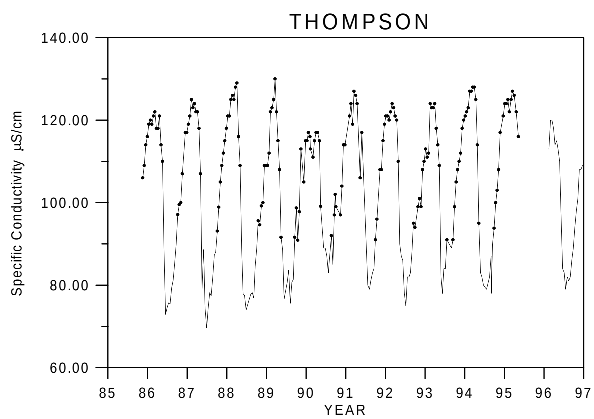

RED PASS
Specific Conductivity µS/cm
80.00
120.00
160.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

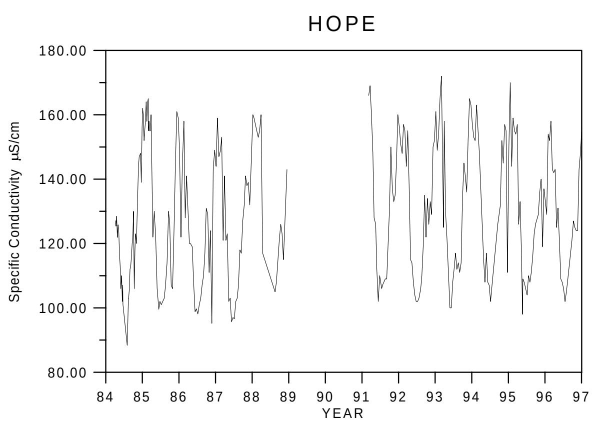

NECHAKO
Specific Conductivity µS/cm
40.00
80.00
120.00
160.00
200.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

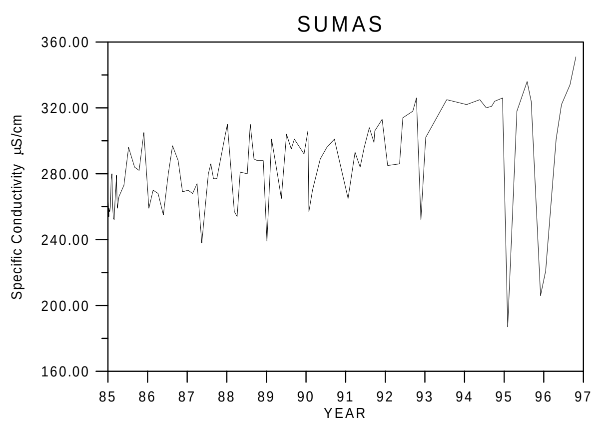

HANSARD
Specific Conductivity µS/cm
80.00
120.00
160.00
200.00
240.00
280.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

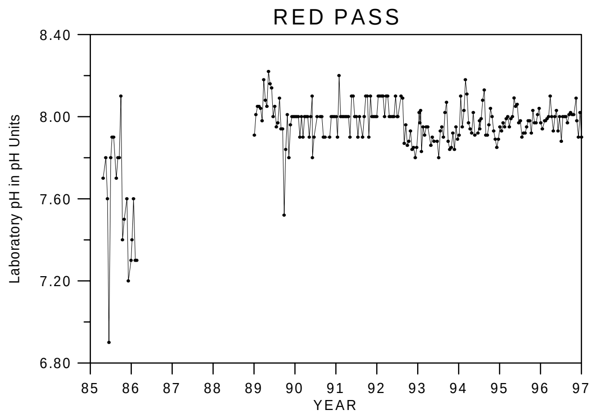

SALMON
Specific Conductivity µS/cm
100.00
200.00
300.00
400.00
500.00
600.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

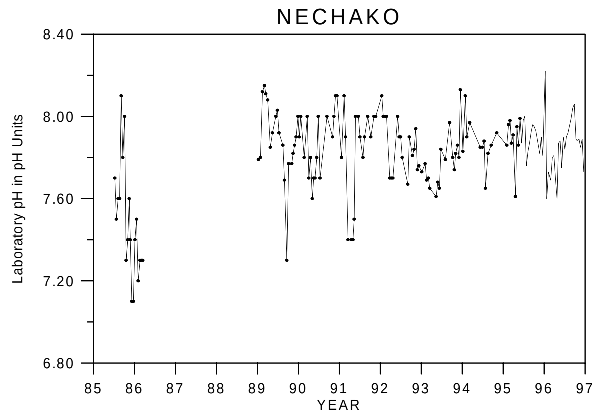

MARGUERITE
Specific Conductivity µS/cm
80.00
120.00
160.00
200.00
240.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

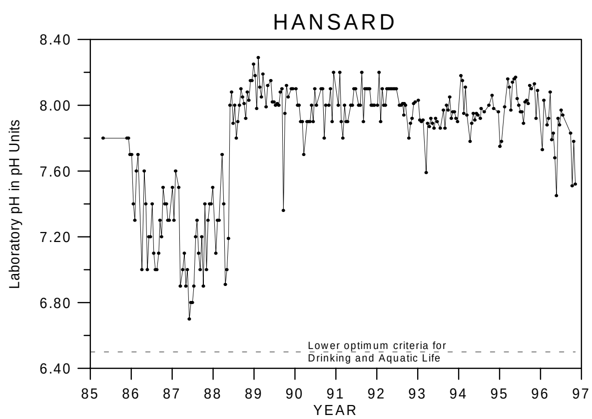

THOMPSON
Specific Conductivity µS/cm
60.00
80.00
100.00
120.00
140.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

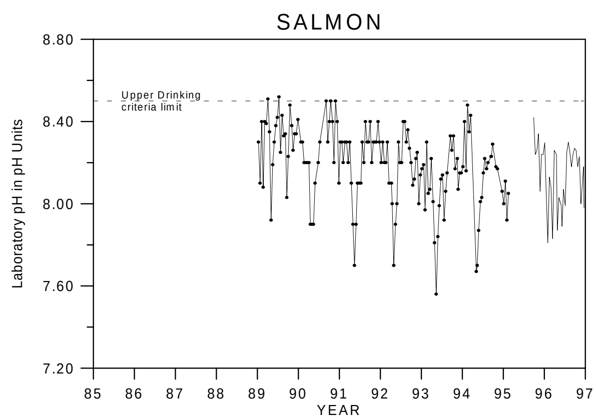

HOPE
Specific Conductivity µS/cm
80.00
100.00
120.00
140.00
160.00
180.00
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

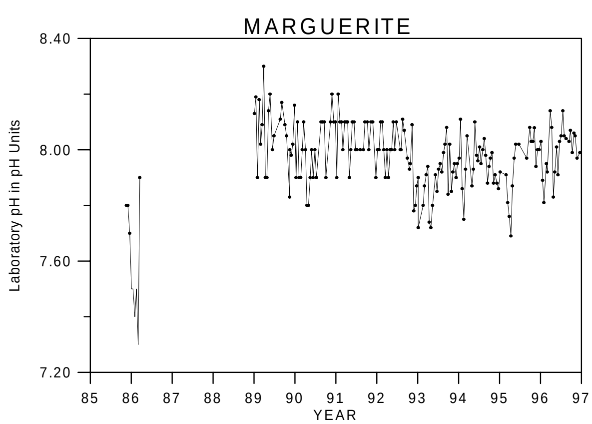

SUMAS
Specific Conductivity µS/cm
160.00
200.00
240.00
280.00
320.00
360.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

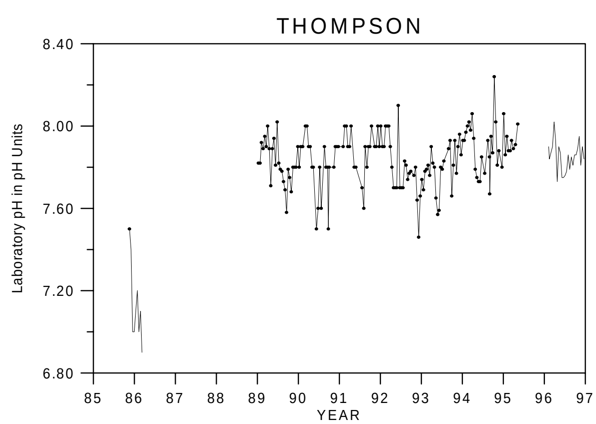

RED PASS
Laboratory pH in pH Units
YEAR

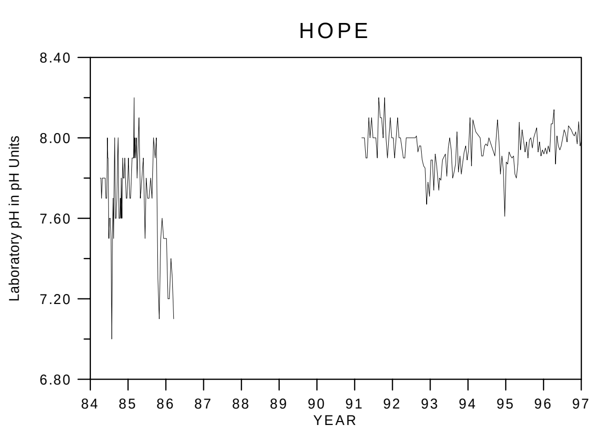

NECHAKO
Laboratory pH in pH Units
YEAR

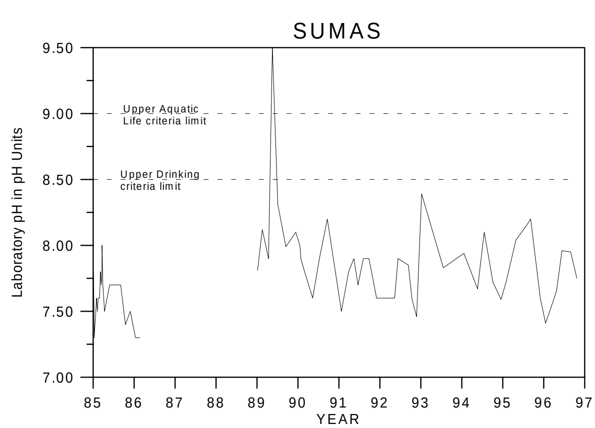

HANSARD
Laboratory pH in pH Units
Lower optimum criteria for
Drinking and Aquatic Life
YEAR

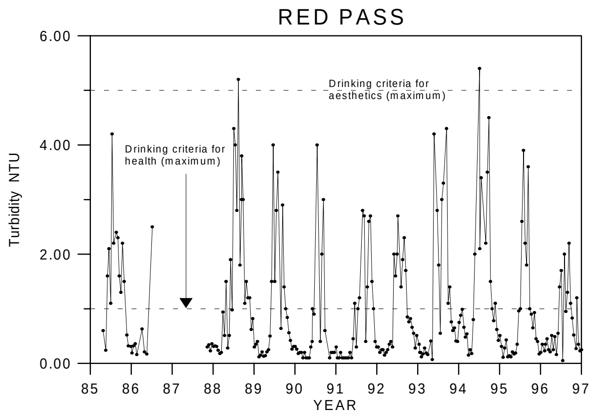

SALMON
Laboratory pH in pH Units
Upper Drinking
criteria limit
YEAR

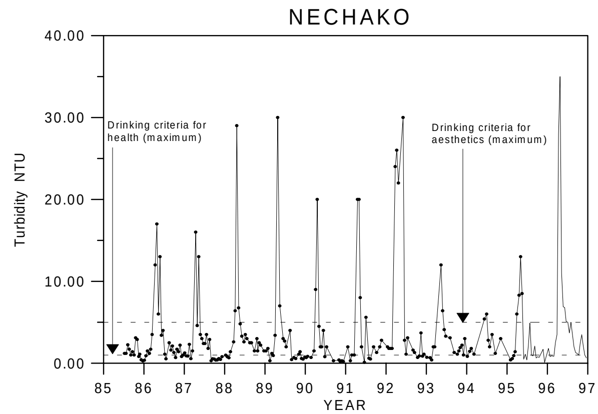

MARGUERITE
Laboratory pH in pH Units
YEAR

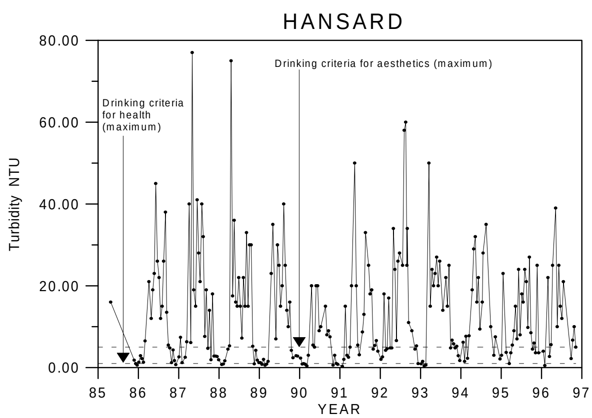

THOMPSON
Laboratory pH in pH Units
YEAR

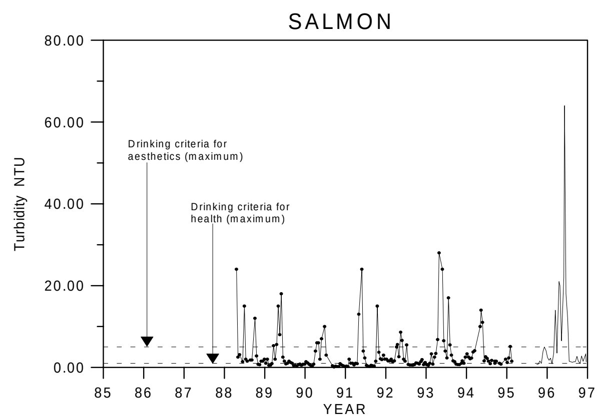

HOPE
Laboratory pH in pH Units
YEAR

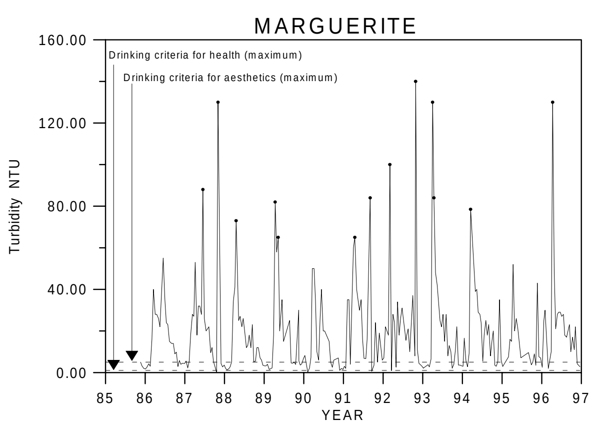

SUMAS
Laboratory pH in pH Units
Upper Aquatic
Life criteria limit
Upper Drinking
criteria limit
YEAR

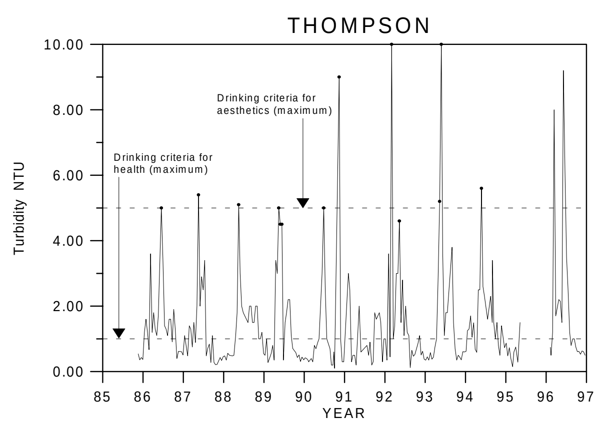

RED PASS
Drinking criteria for aesthetics (maximum)
Drinking criteria for health (maximum)
Turbidity NTU
YEAR

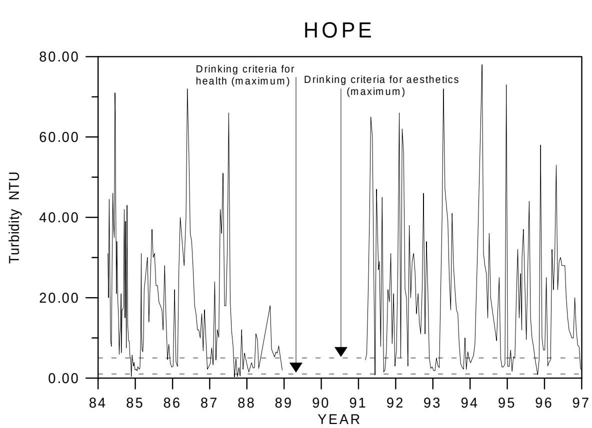

NECHAKO
Drinking criteria for health (maximum)
Drinking criteria for aesthetics (maximum)
Turbidity NTU
YEAR

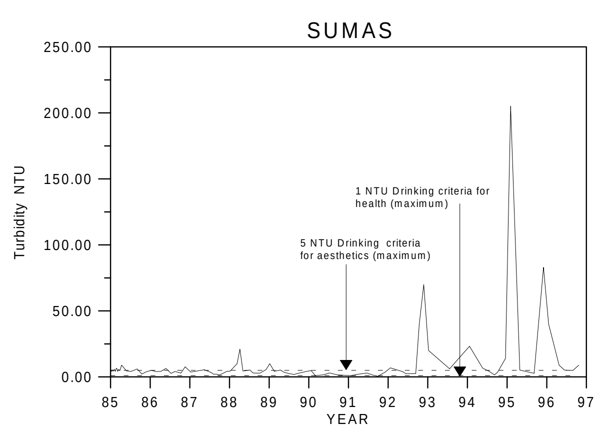

HANSARD
Drinking criteria for aesthetics (maximum)
Drinking criteria for health (maximum)
Turbidity NTU
YEAR

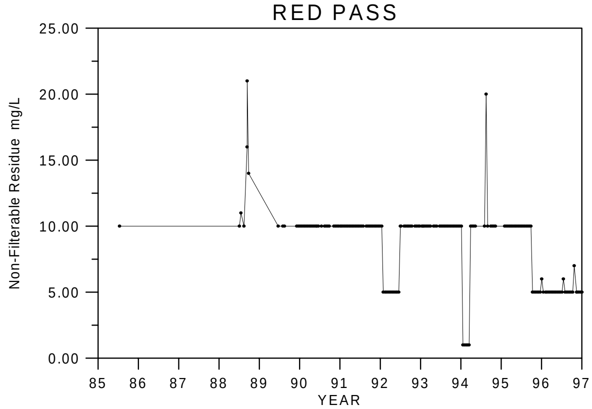

SALMON
Drinking criteria for aesthetics (maximum)
Drinking criteria for health (maximum)
Turbidity NTU
YEAR

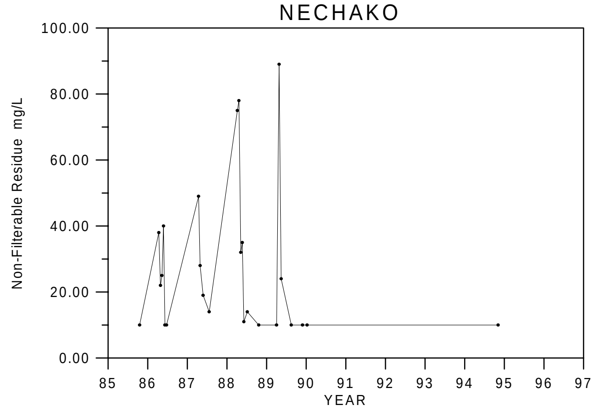

MARGUERITE
Drinking criteria for health (maximum)
Drinking criteria for aesthetics (maximum)
Turbidity NTU
YEAR

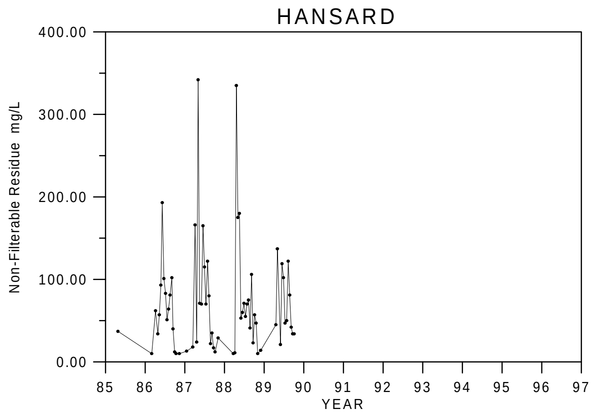

THOMPSON
Drinking criteria for aesthetics (maximum)
Drinking criteria for health (maximum)
Turbidity NTU
YEAR


HOPE
Drinking criteria for health (maximum)
Drinking criteria for aesthetics (maximum)
Turbidity NTU
YEAR

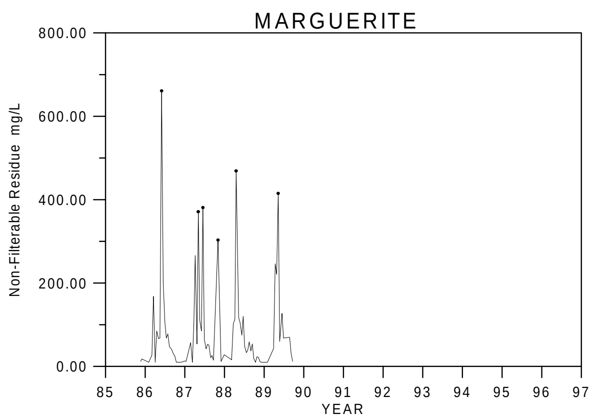

SUMAS
1 NTU Drinking criteria for health (maximum)
5 NTU Drinking criteria for aesthetics (maximum)
Turbidity NTU
YEAR

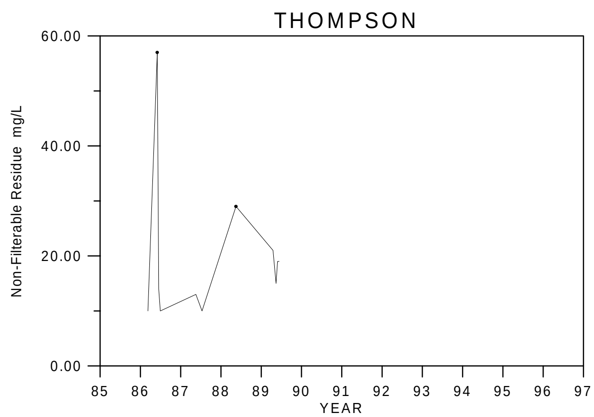


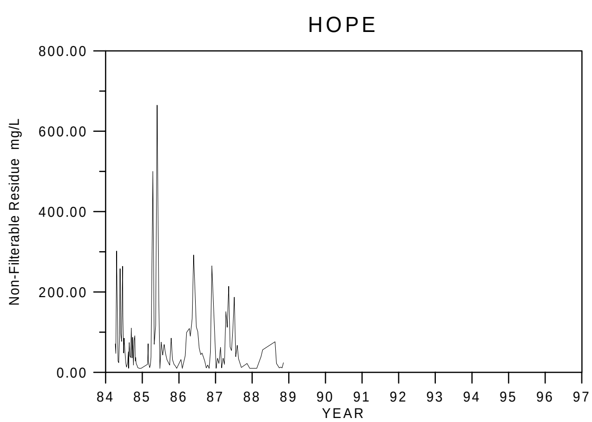


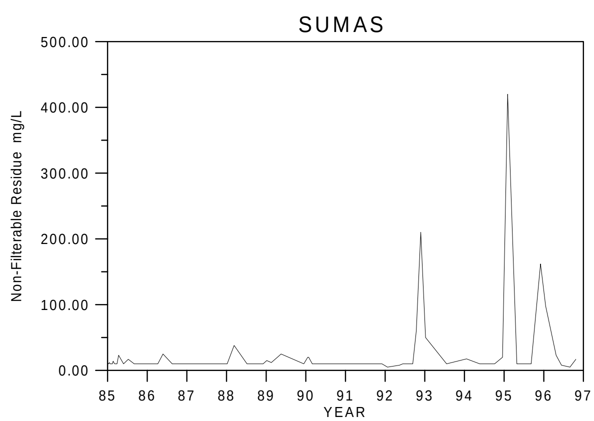


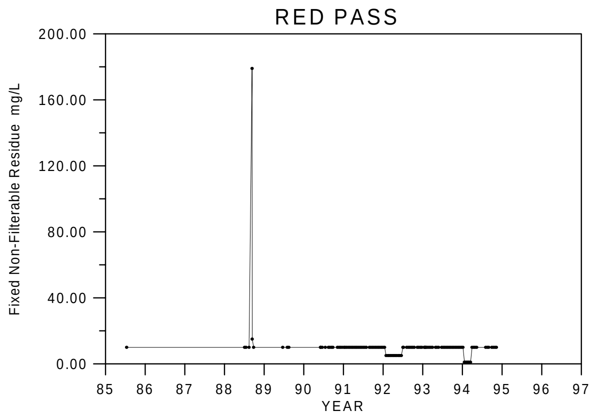
Non-Filterable Residue was not sampled significantly at the Salmon River monitoring station (one value).

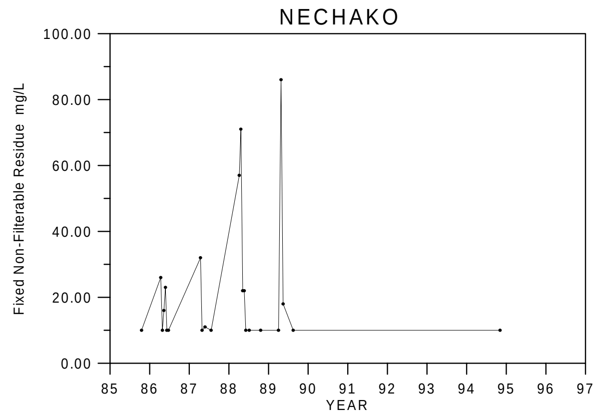


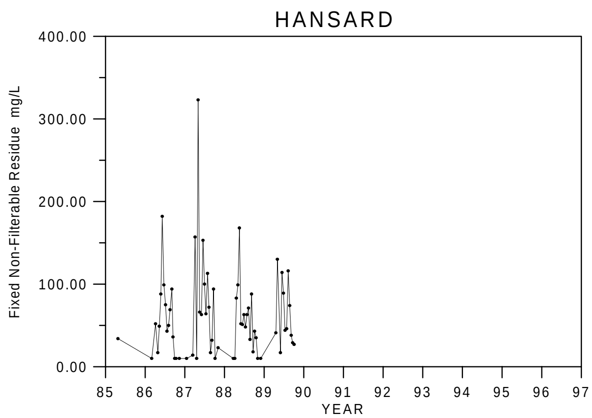




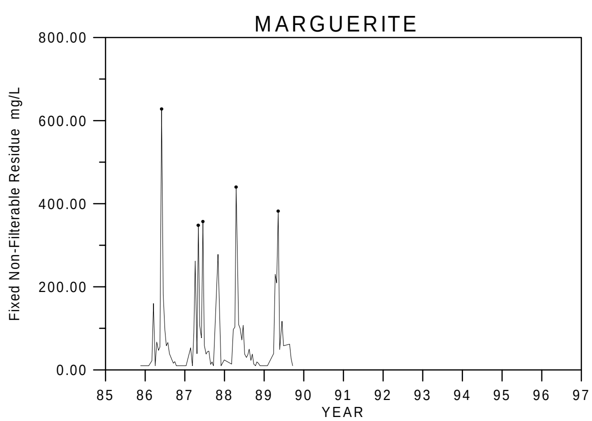


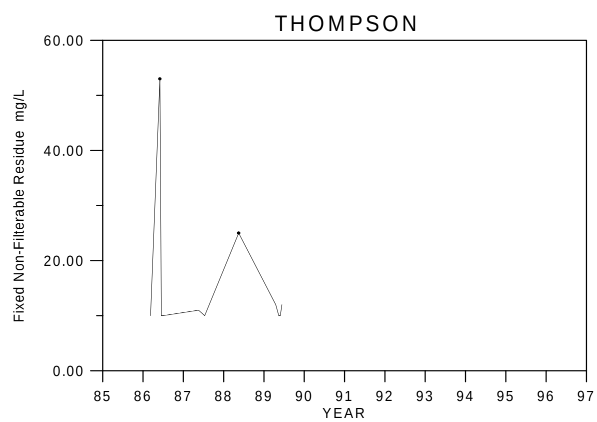


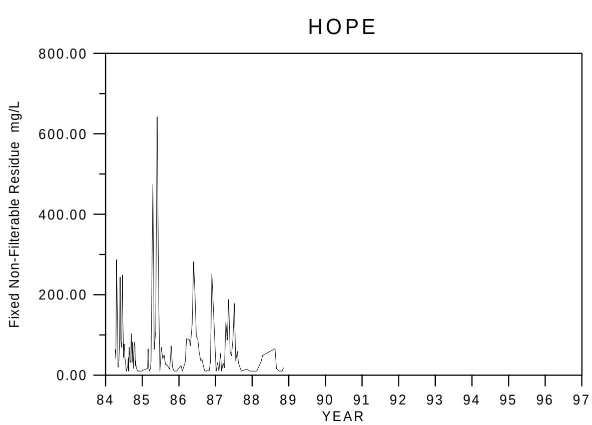


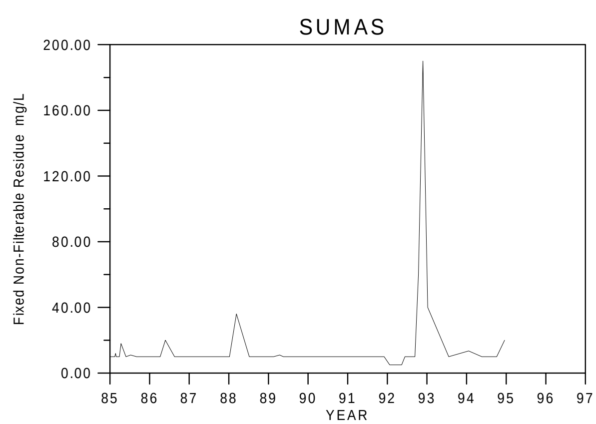


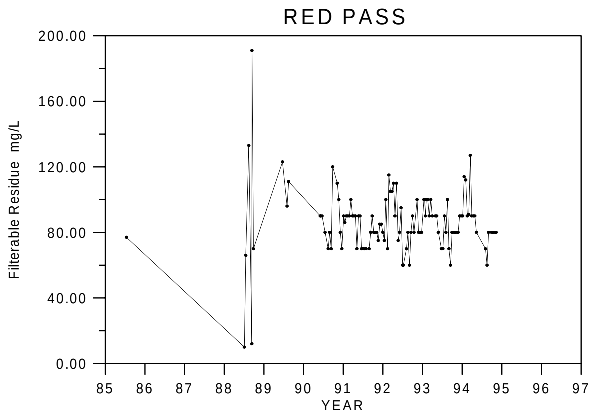
Fixed Non-Filterable Residue was not sampled significantly at the Salmon River monitoring station (one value).

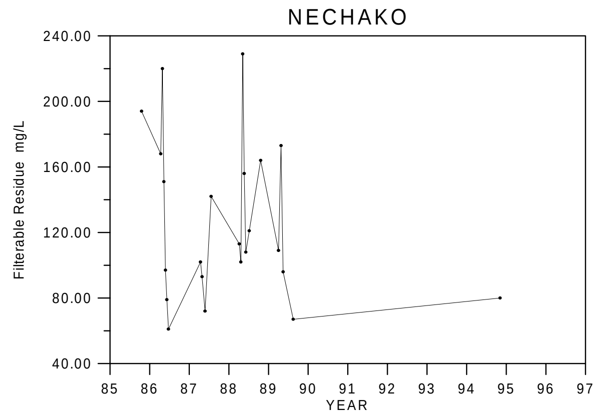


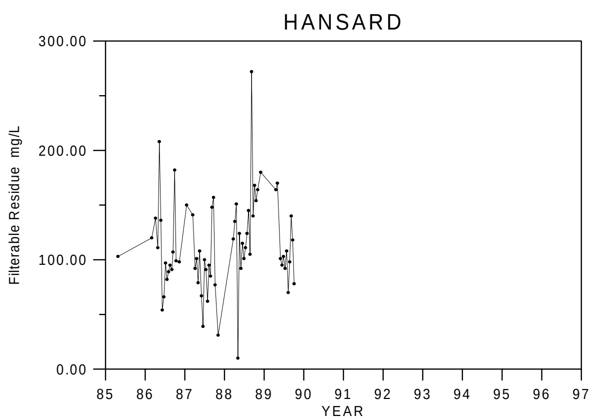




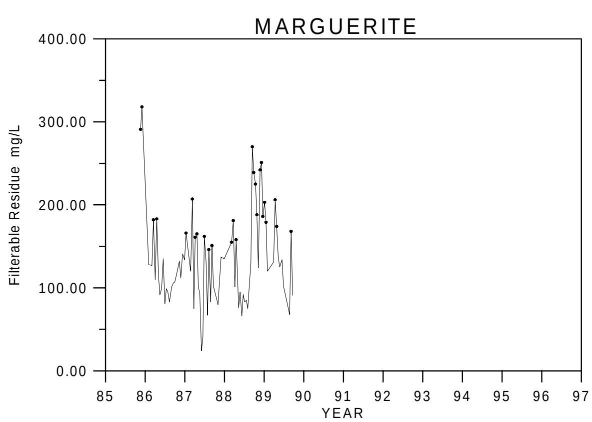


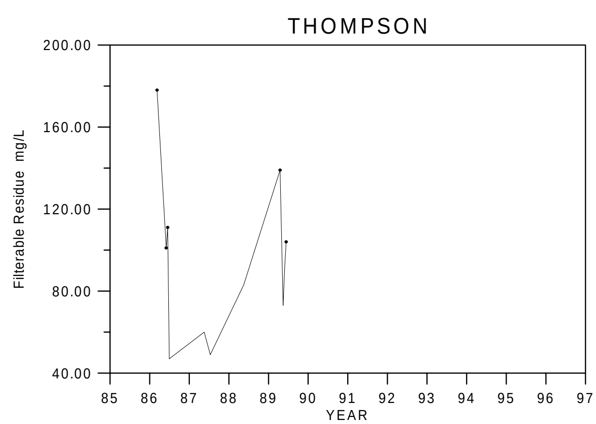


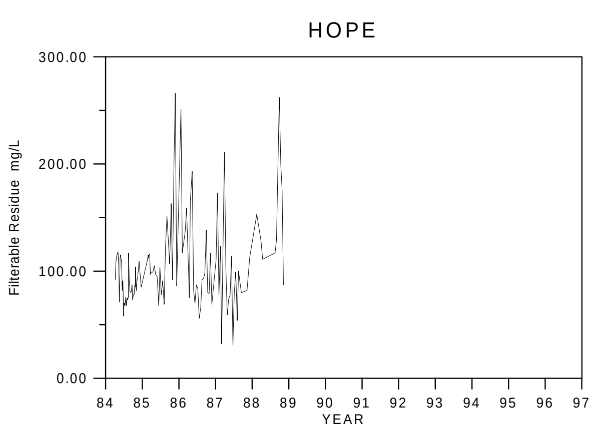


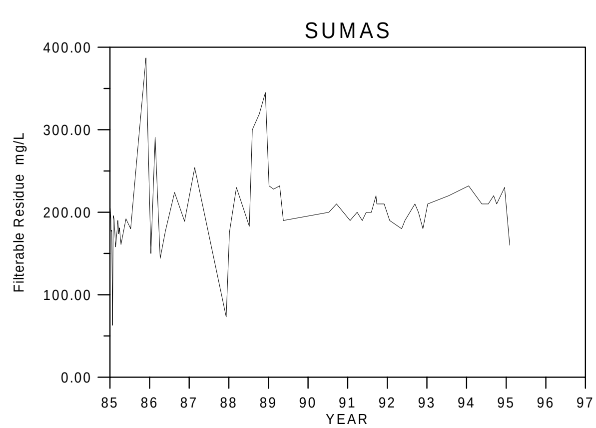


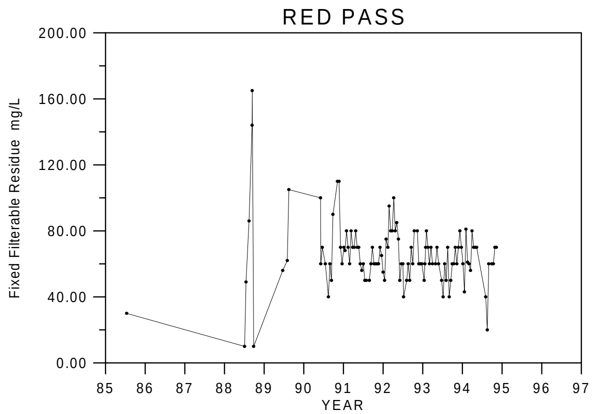
Filterable Residue was not sampled significantly at the Salmon River monitoring station (one value).

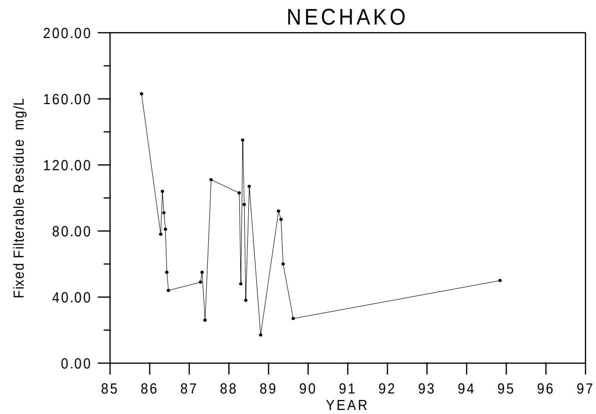


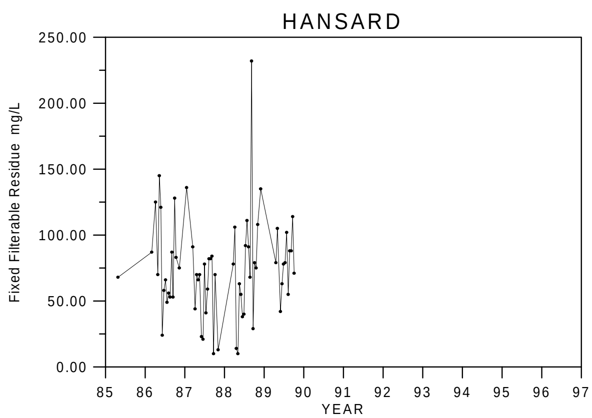




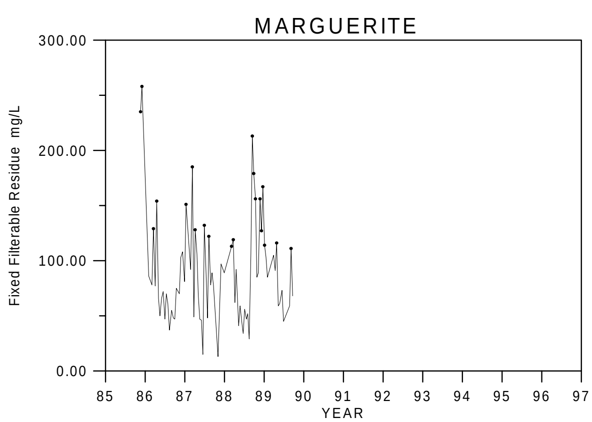


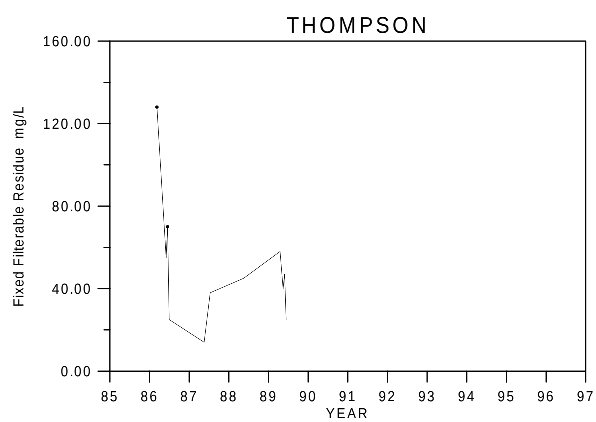


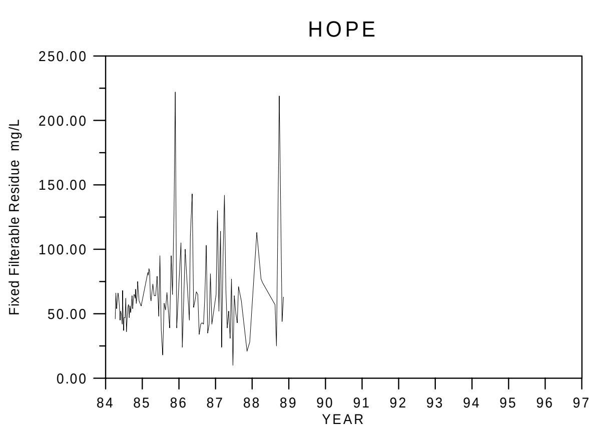


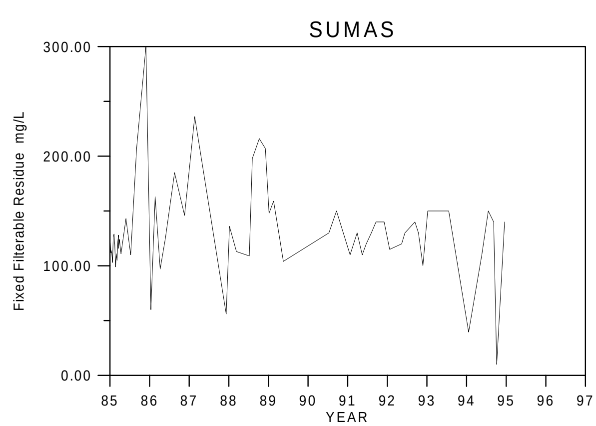


Fixed-Filterable Residue was not sampled significantly at the Salmon River monitoring station (one value).

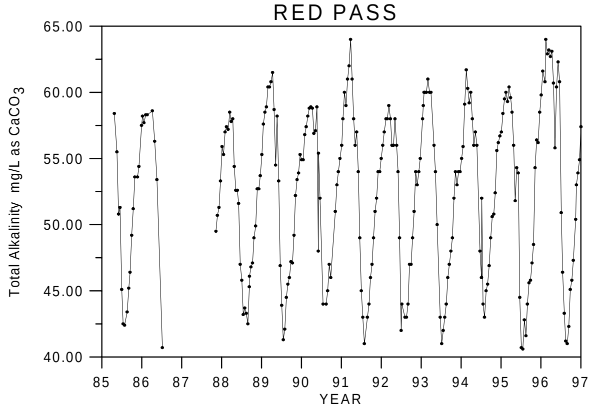




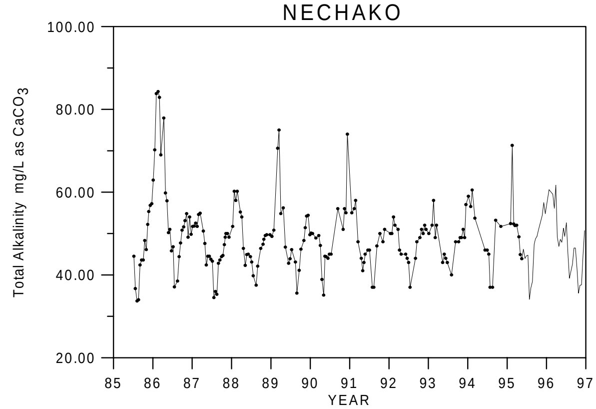




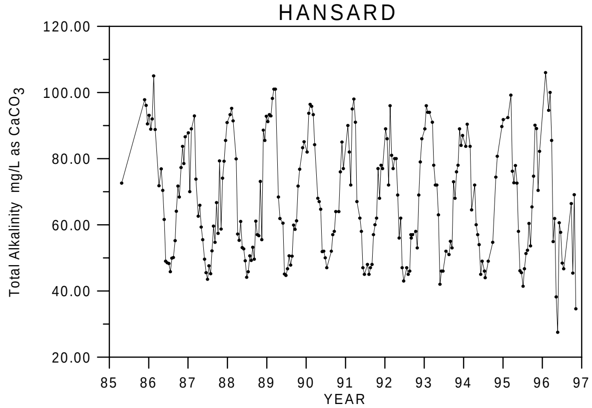
RED PASS



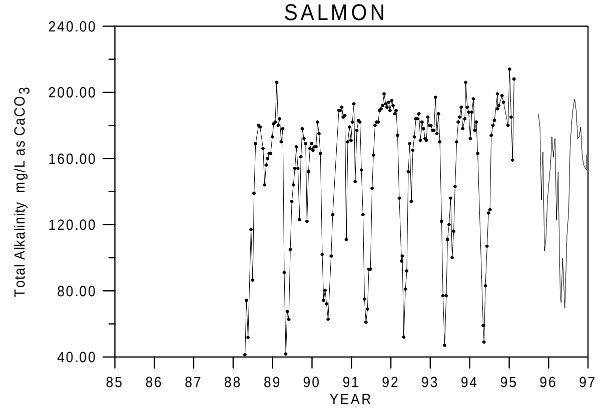
NECHAKO



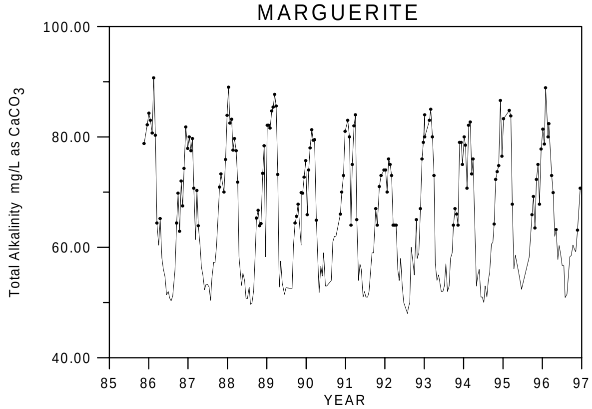
HANSARD



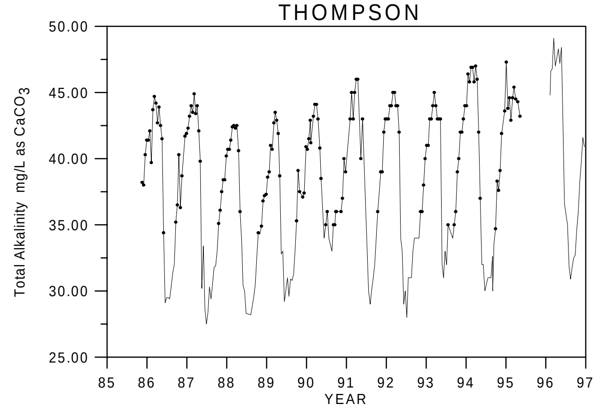
SALMON



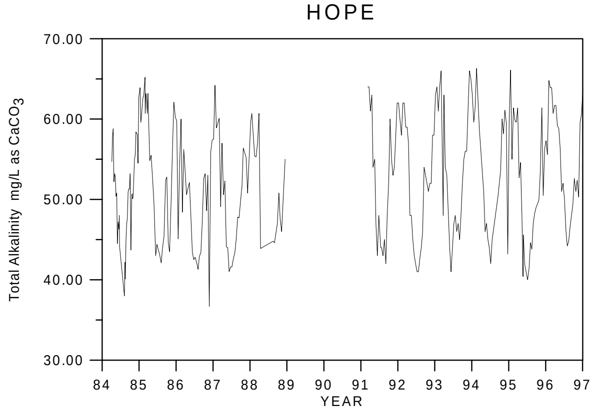
MARGUERITE



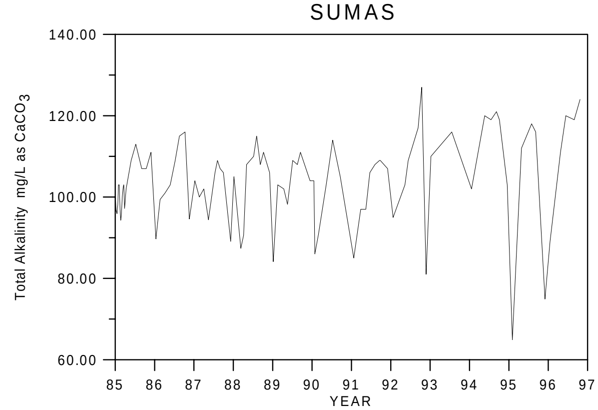
THOMPSON



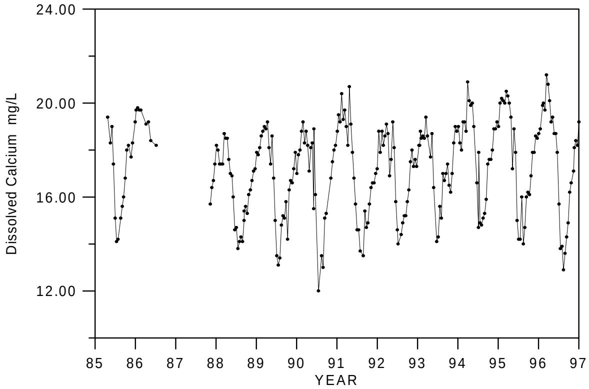
HOPE



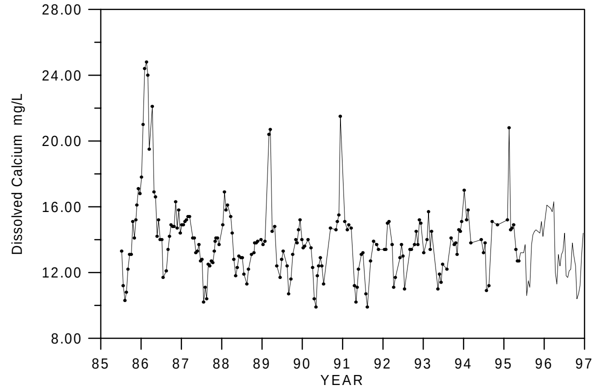
SUMAS



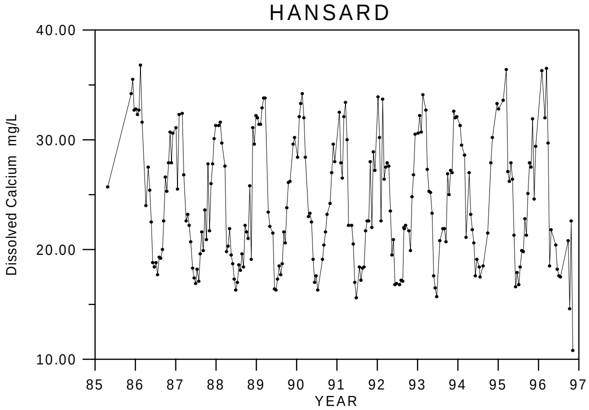
RED PASS



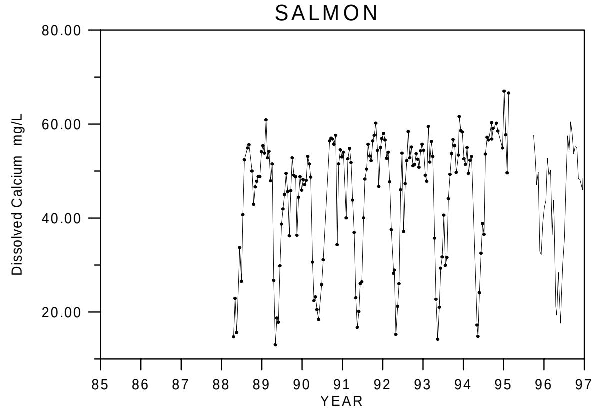
NECHAKO



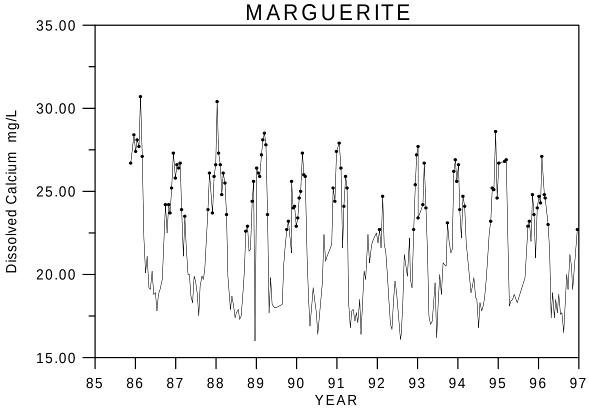
HANSARD



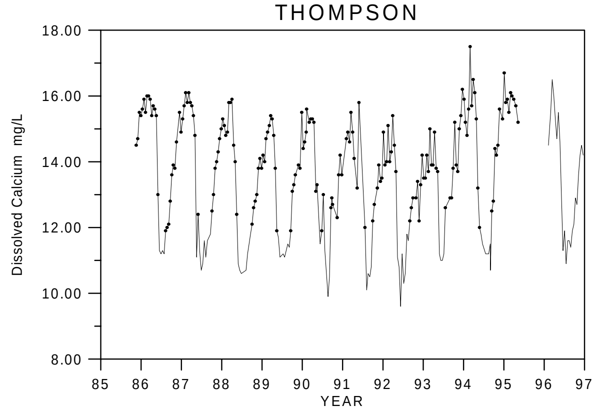
SALMON



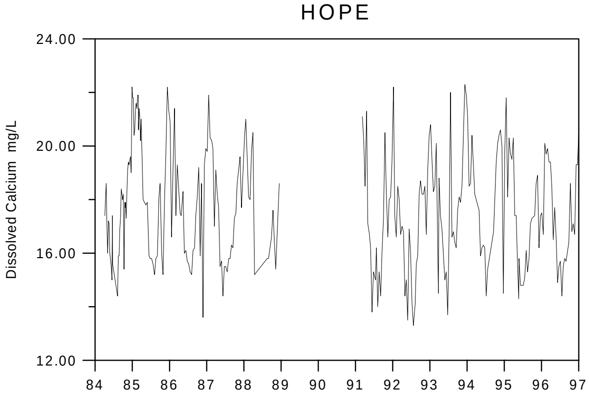
MARGUERITE



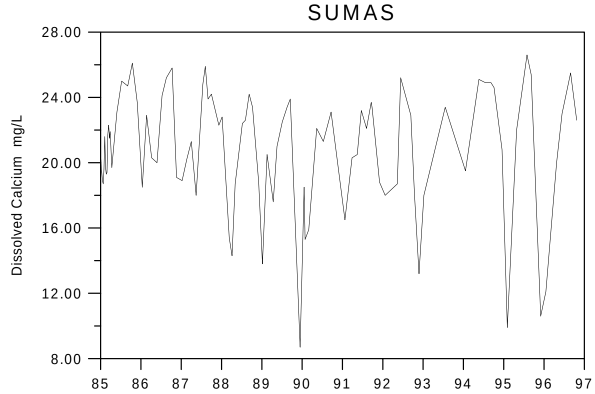
THOMPSON

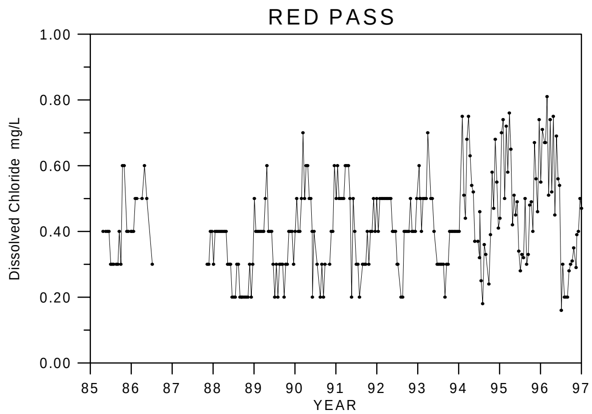


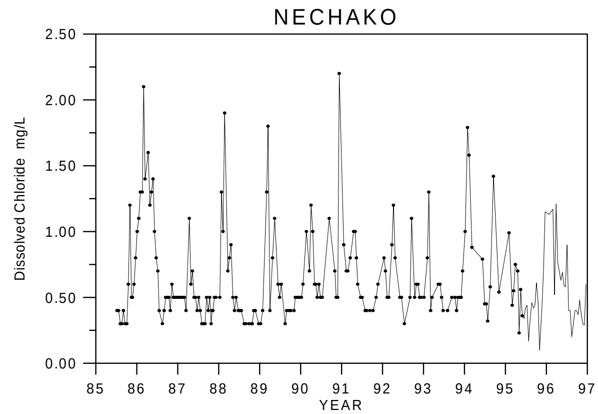
HOPE

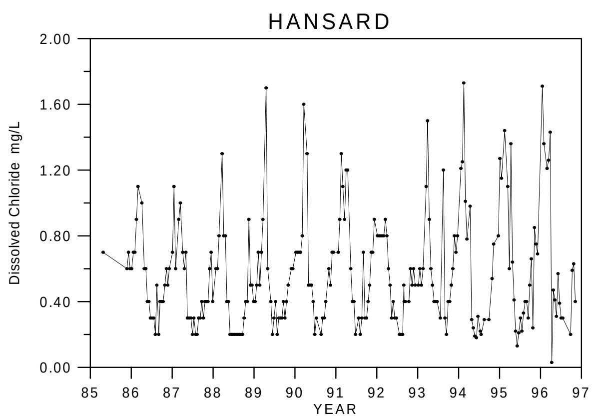


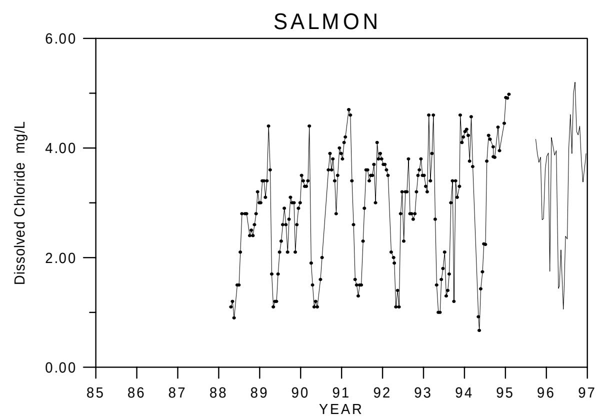
SUMAS

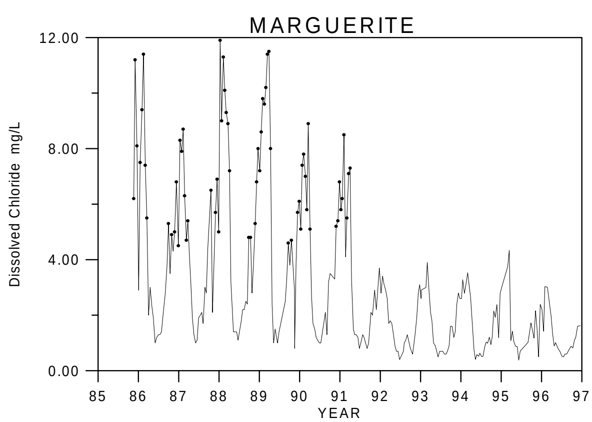


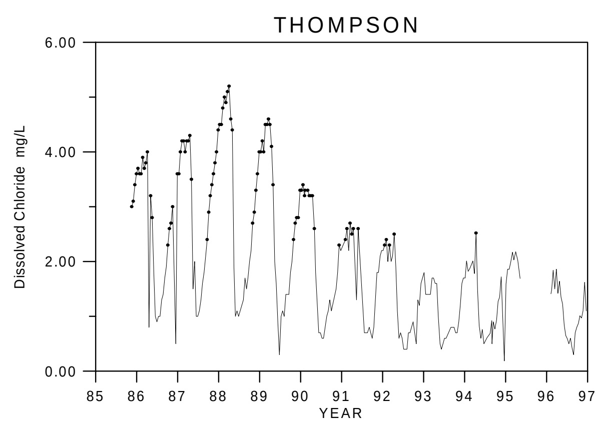

RED PASS
Dissolved Chloride mg/L
YEAR

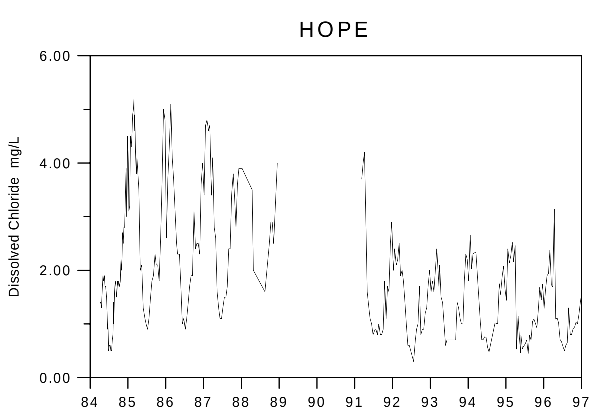

NECHAKO
Dissolved Chloride mg/L
YEAR

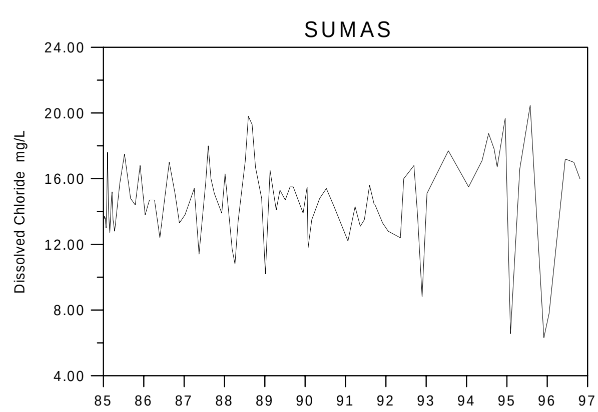

HANSARD
Dissolved Chloride mg/L
YEAR


SALMON
Dissolved Chloride mg/L
YEAR

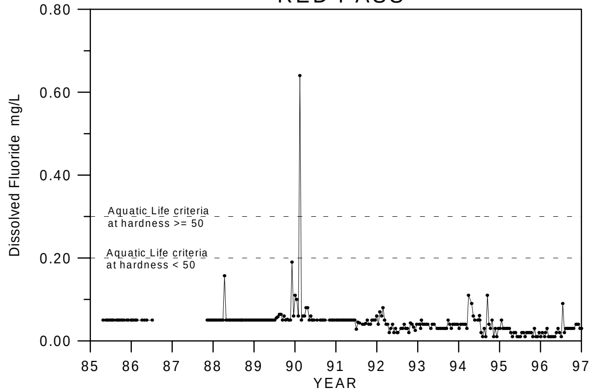

MARGUERITE
Dissolved Chloride mg/L
YEAR


THOMPSON
Dissolved Chloride mg/L
YEAR

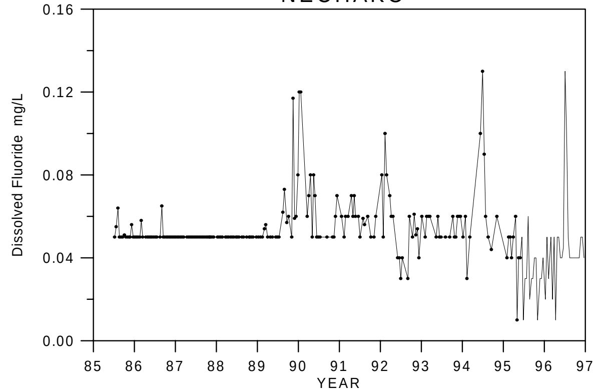

HOPE
Dissolved Chloride mg/L
YEAR


SUMAS
Dissolved Chloride mg/L
YEAR

RED PASS



NECHAKO



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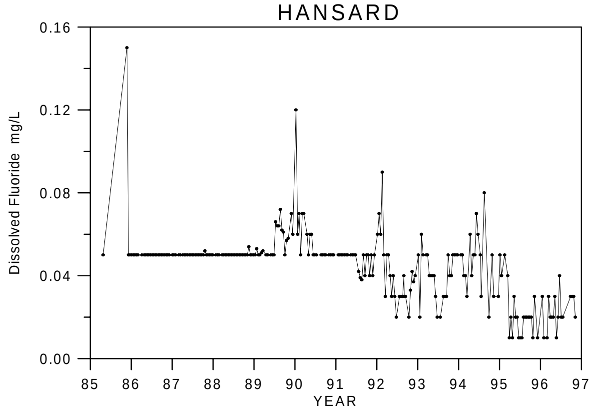
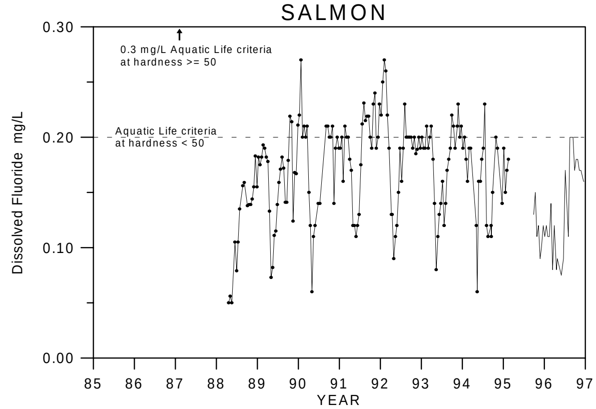
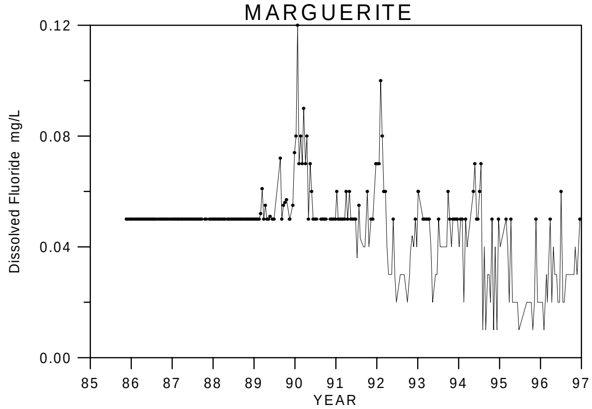


SALMON



MARGUERITE



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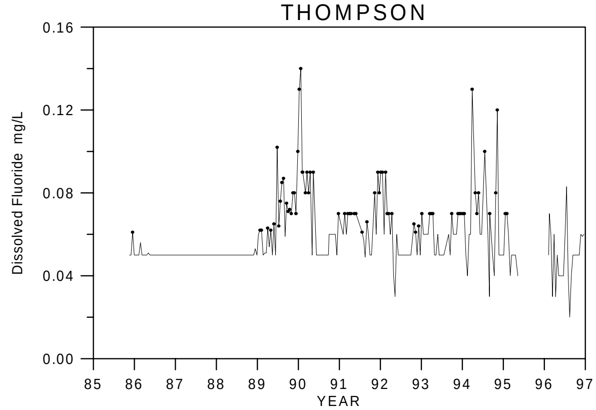
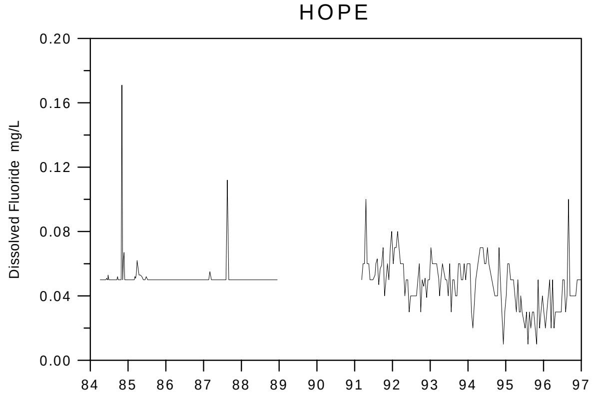
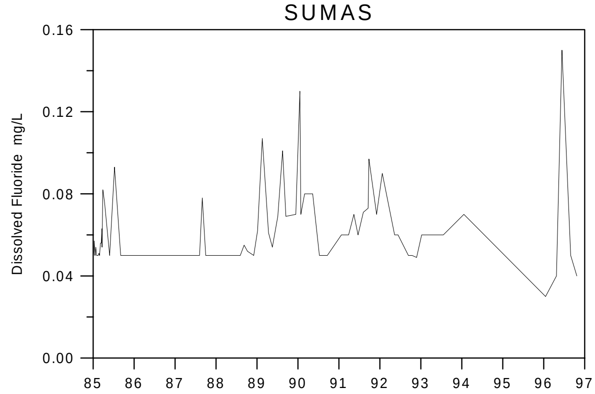
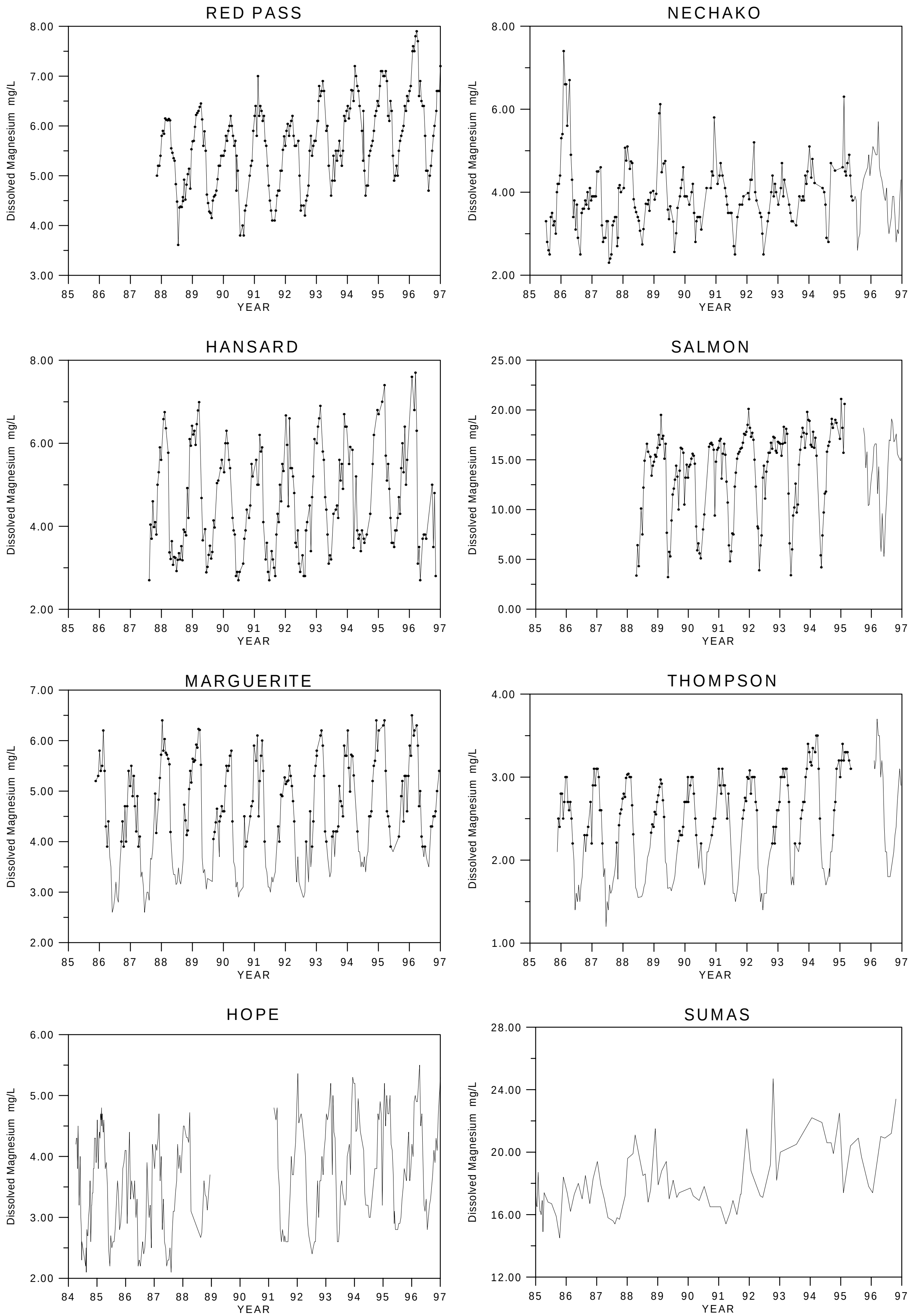


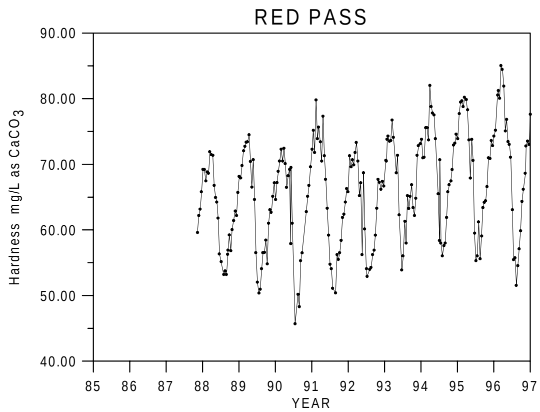
HOPE

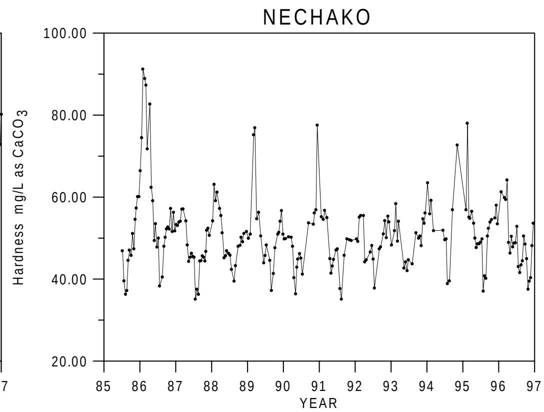


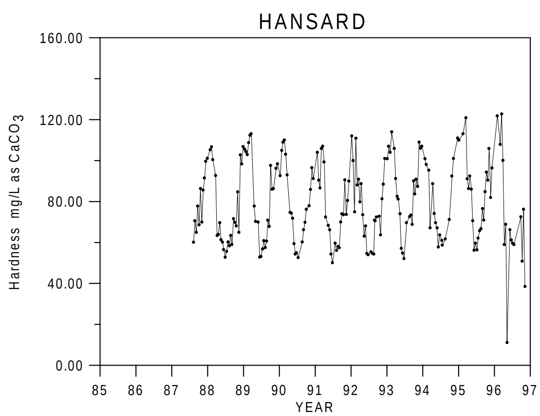
SUMAS

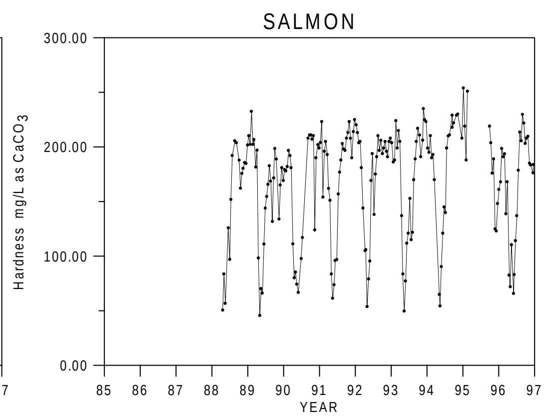


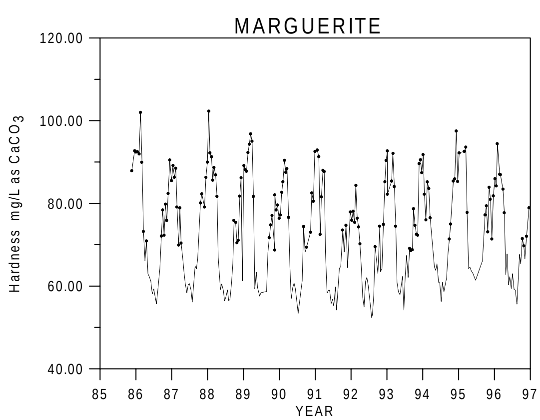

RED PASS
NECHAKO
HANSARD
SALMON
MARGUERITE
THOMPSON
HOPE
SUMAS
Dissolved Magnesium mg/L
YEAR

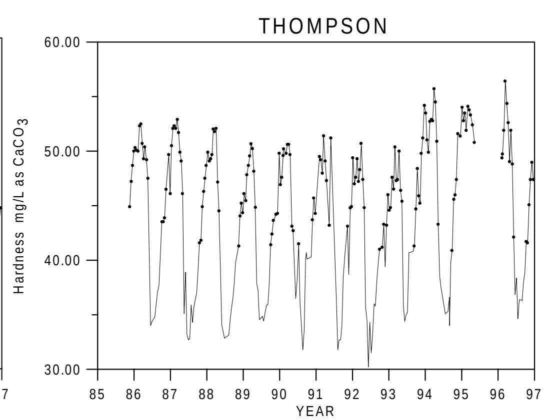

RED PASS
Hardness mg/L as $CaCO_3$
YEAR

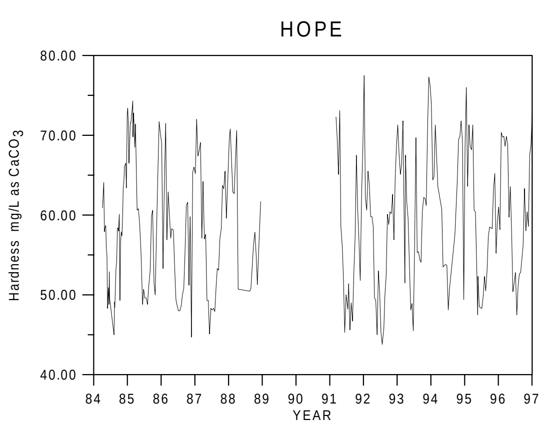

NECHAKO
Hardness mg/L as $CaCO_3$
YEAR

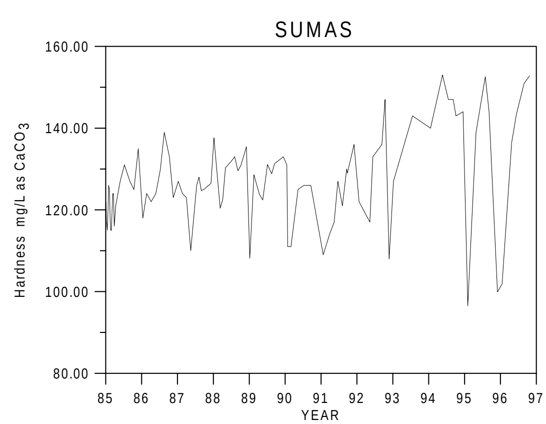

HANSARD
Hardness mg/L as $CaCO_3$
YEAR

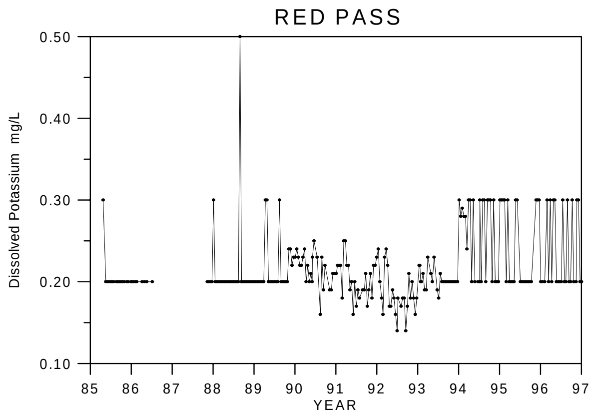

SALMON
Hardness mg/L as $CaCO_3$
YEAR

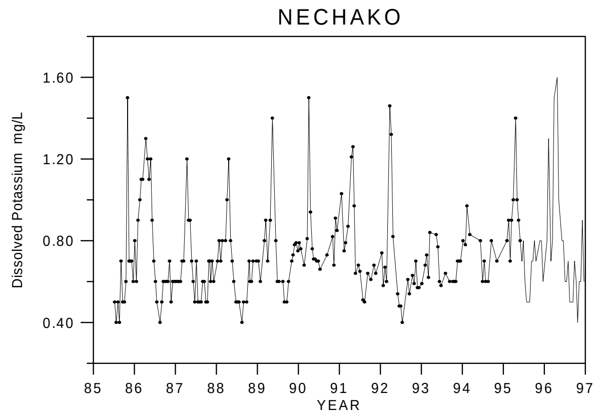

MARGUERITE
Hardness mg/L as $CaCO_3$
YEAR

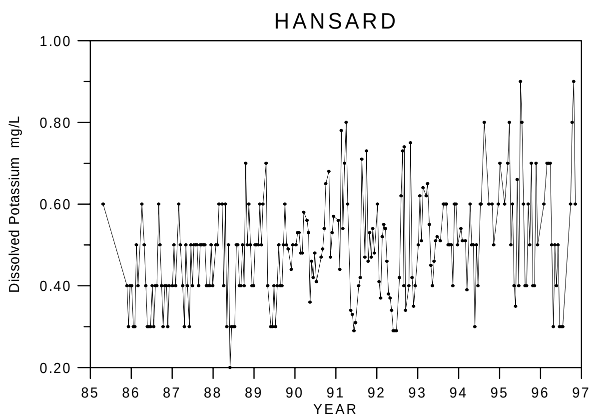

THOMPSON
Hardness mg/L as $CaCO_3$
YEAR

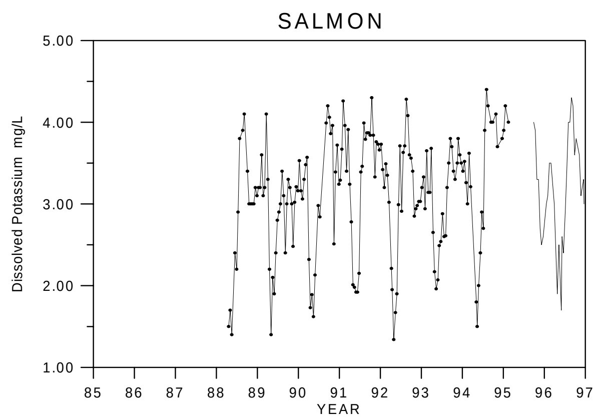

HOPE
Hardness mg/L as $CaCO_3$
YEAR

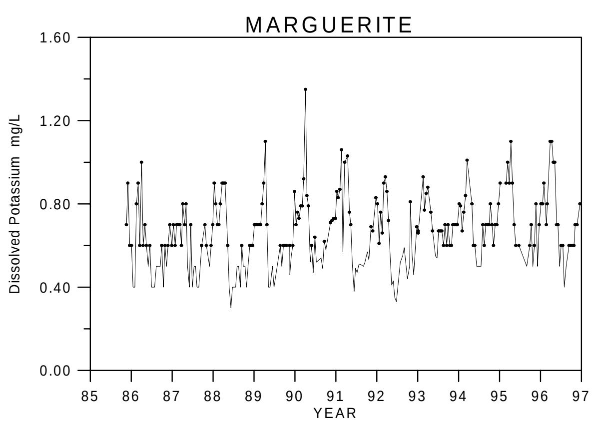

SUMAS
Hardness mg/L as $CaCO_3$
YEAR

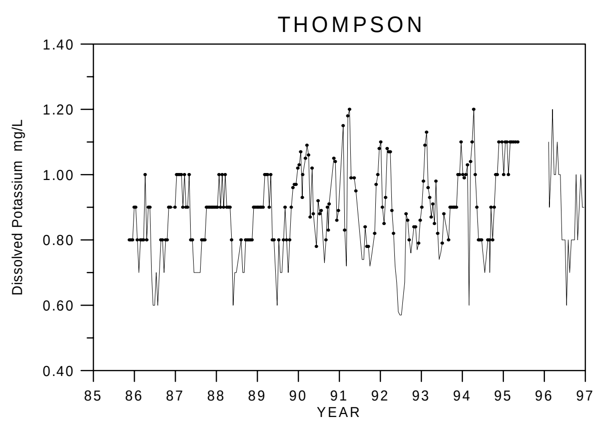

RED PASS
Dissolved Potassium mg/L
0.10
0.20
0.30
0.40
0.50
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

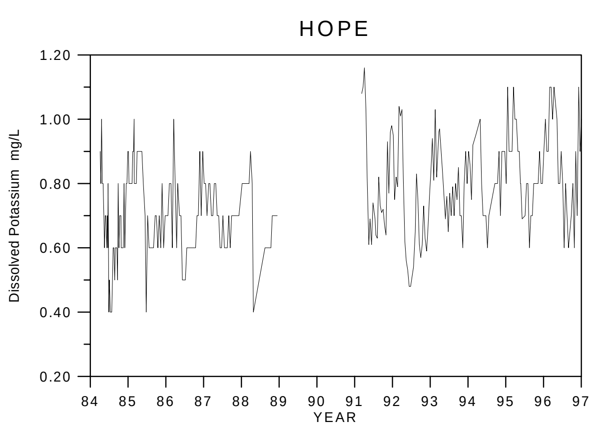

NECHAKO
Dissolved Potassium mg/L
0.40
0.80
1.20
1.60
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

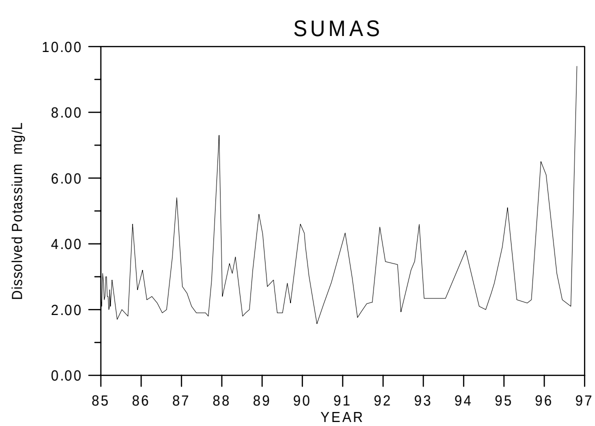

HANSARD
Dissolved Potassium mg/L
0.20
0.40
0.60
0.80
1.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SALMON
Dissolved Potassium mg/L
1.00
2.00
3.00
4.00
5.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

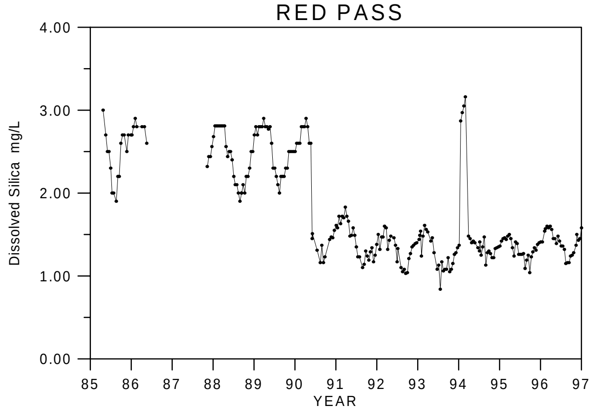

MARGUERITE
Dissolved Potassium mg/L
0.00
0.40
0.80
1.20
1.60
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


THOMPSON
Dissolved Potassium mg/L
0.40
0.60
0.80
1.00
1.20
1.40
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

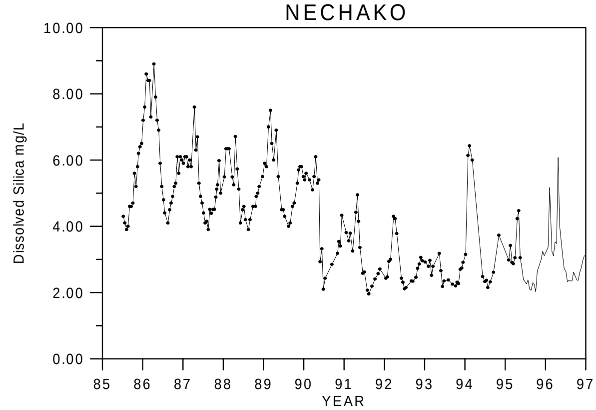

HOPE
Dissolved Potassium mg/L
0.20
0.40
0.60
0.80
1.00
1.20
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SUMAS
Dissolved Potassium mg/L
0.00
2.00
4.00
6.00
8.00
10.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

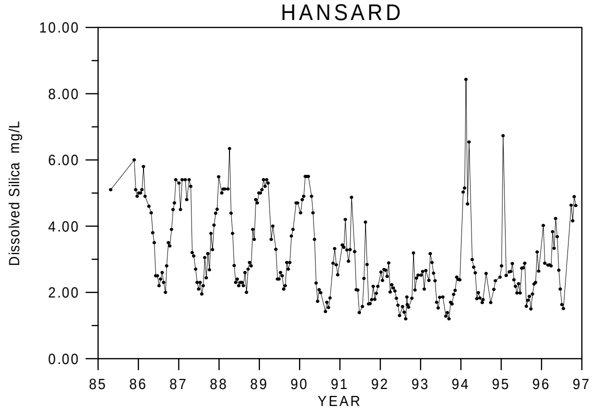
RED PASS



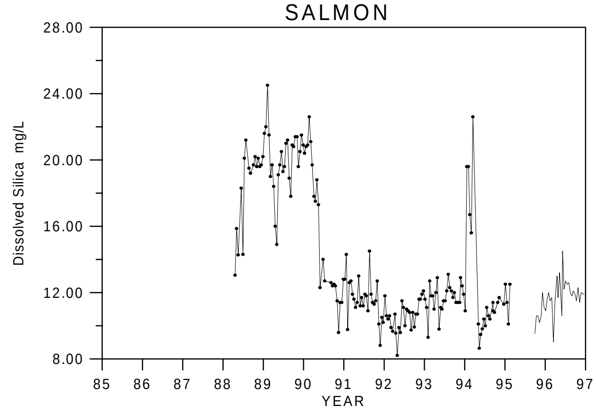
NECHAKO



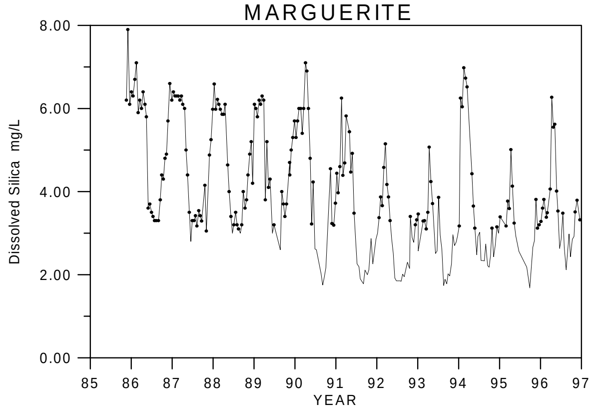
HANSARD



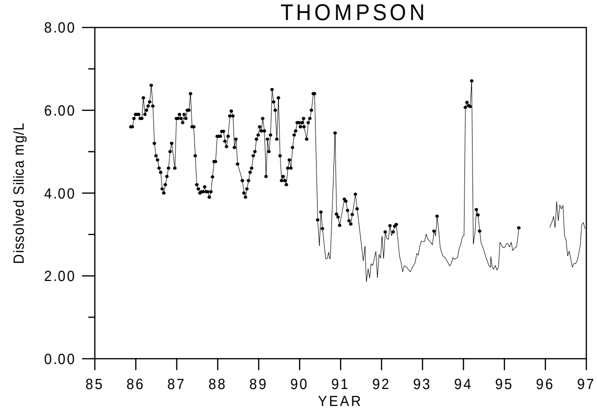
SALMON



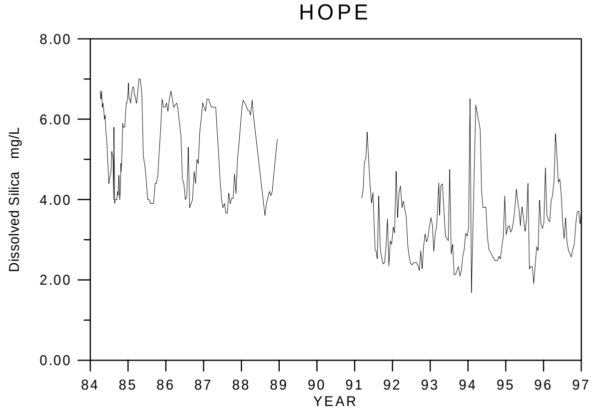
MARGUERITE



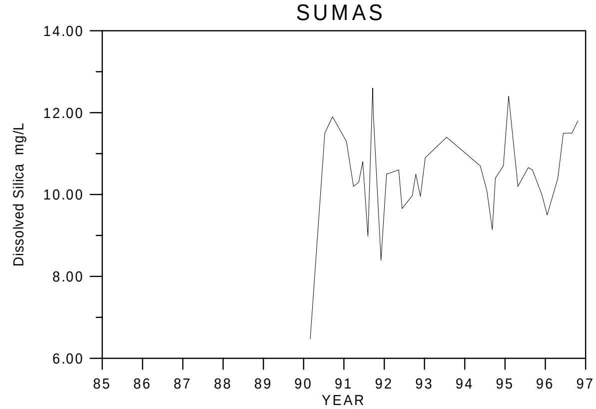
THOMPSON



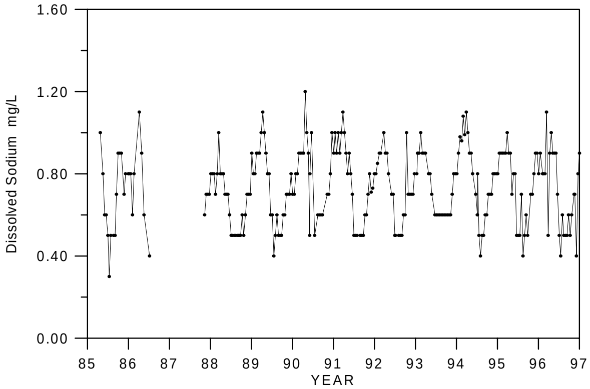
HOPE



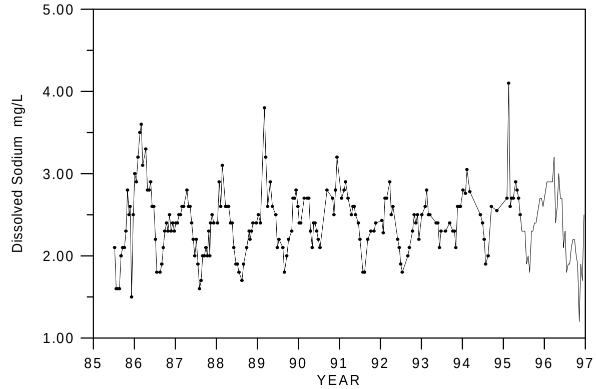
SUMAS



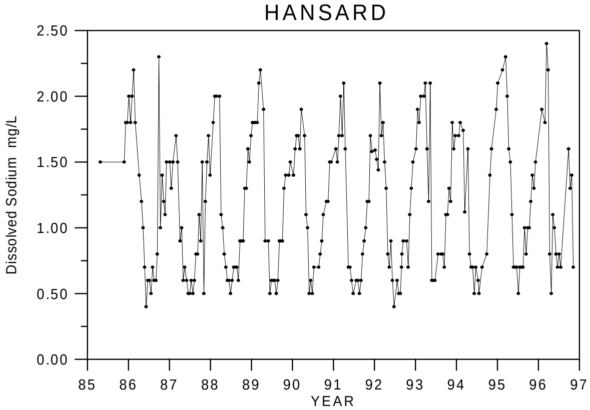
RED PASS



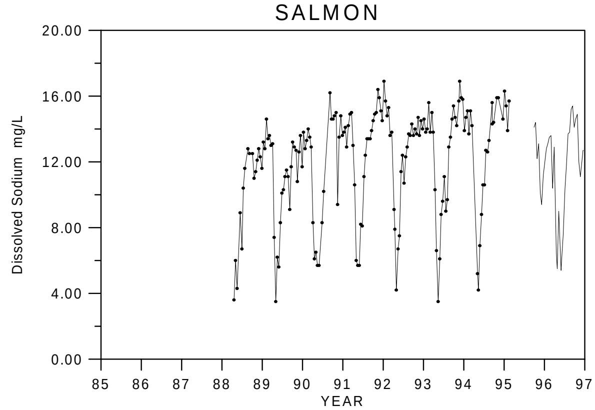
NECHAKO



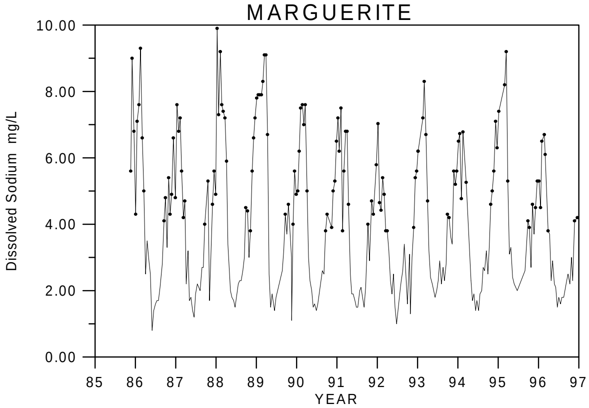
HANSARD



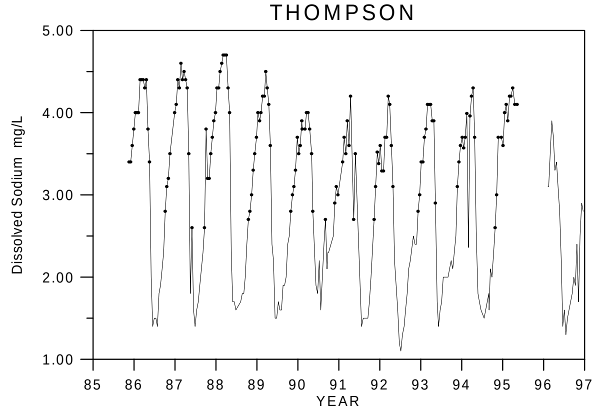
SALMON



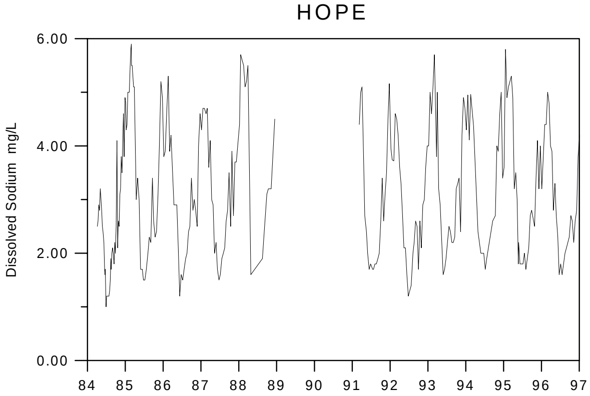
MARGUERITE



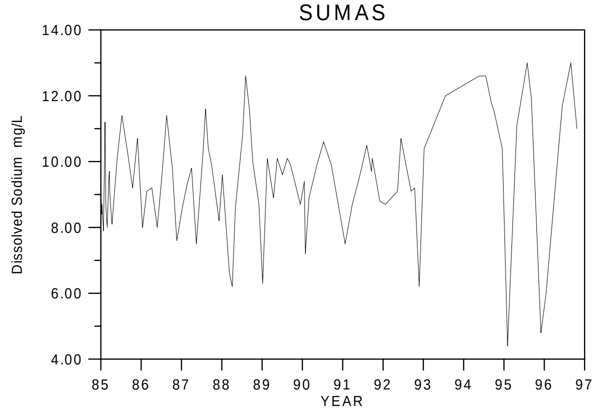
THOMPSON

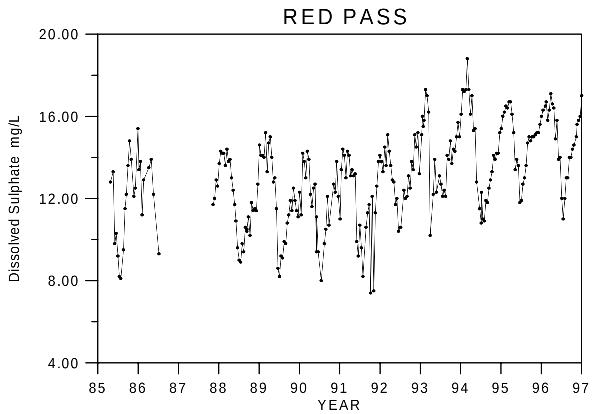


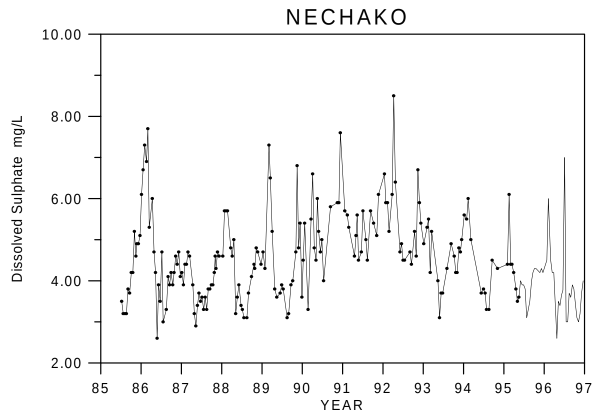
HOPE

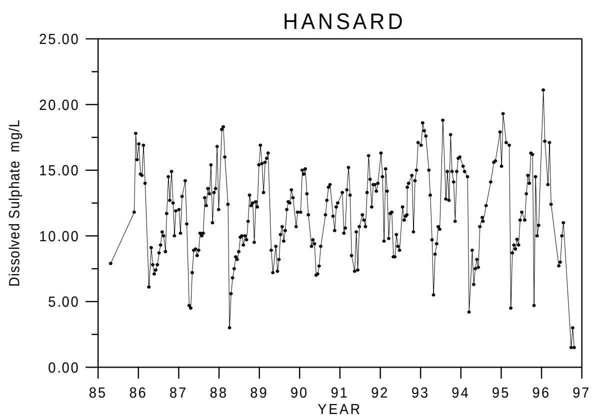


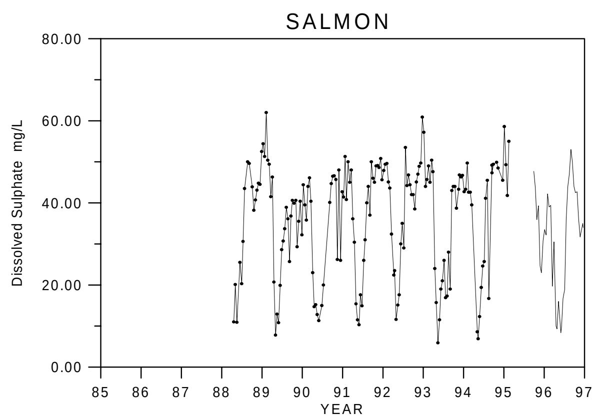
SUMAS

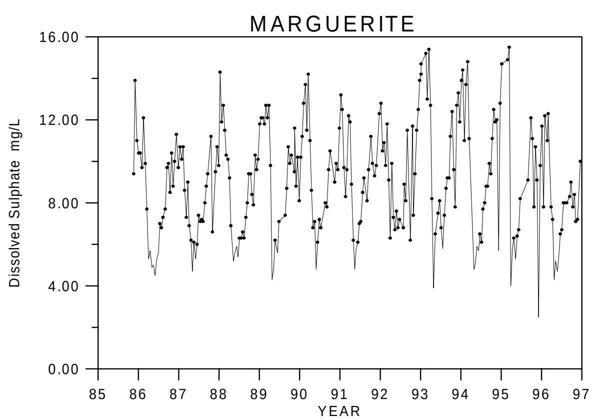


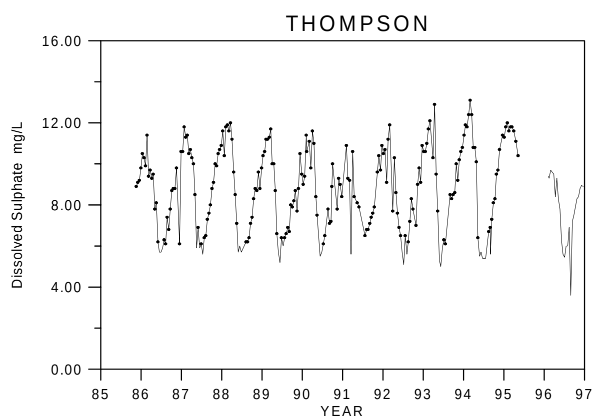

RED PASS
Dissolved Sulphate mg/L
20.00
16.00
12.00
8.00
4.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

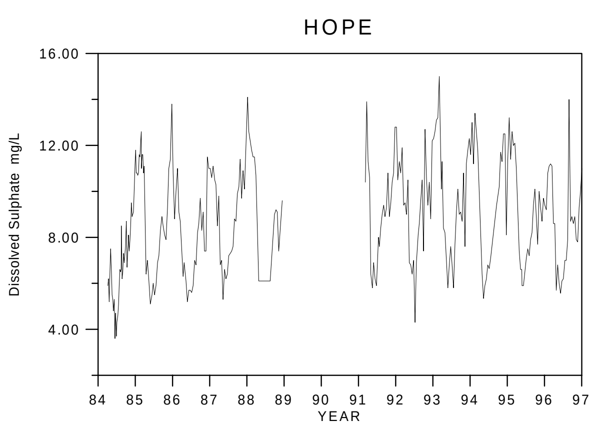

NECHAKO
Dissolved Sulphate mg/L
10.00
8.00
6.00
4.00
2.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

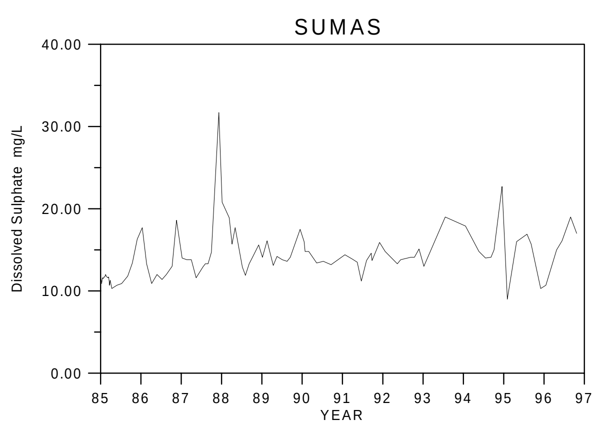

HANSARD
Dissolved Sulphate mg/L
25.00
20.00
15.00
10.00
5.00
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

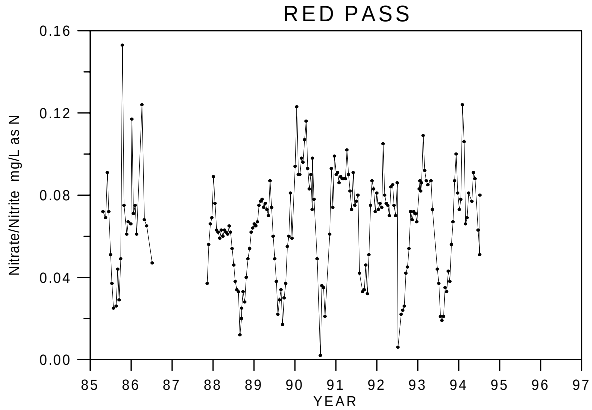

SALMON
Dissolved Sulphate mg/L
80.00
60.00
40.00
20.00
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

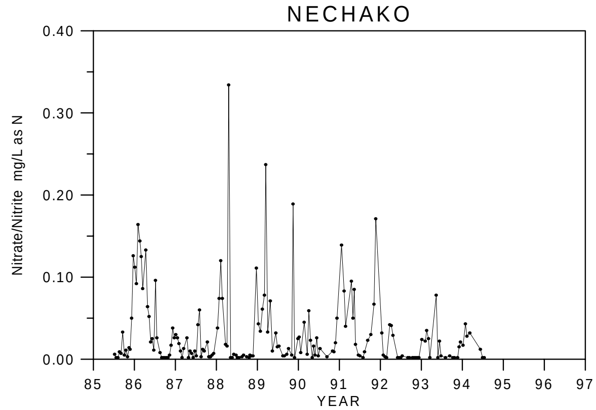

MARGUERITE
Dissolved Sulphate mg/L
16.00
12.00
8.00
4.00
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

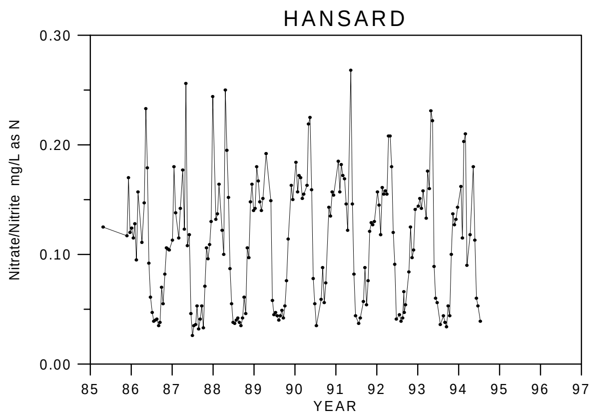

THOMPSON
Dissolved Sulphate mg/L
16.00
12.00
8.00
4.00
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

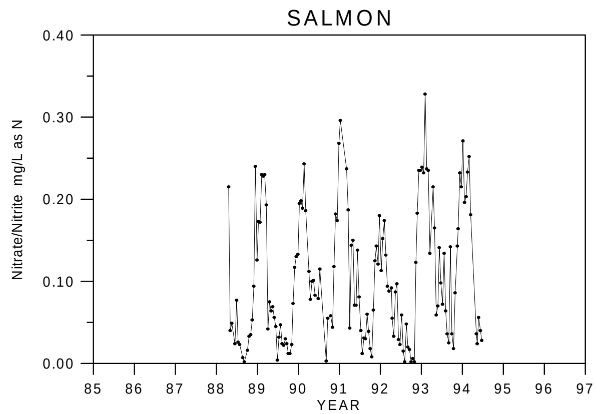

HOPE
Dissolved Sulphate mg/L
16.00
12.00
8.00
4.00
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

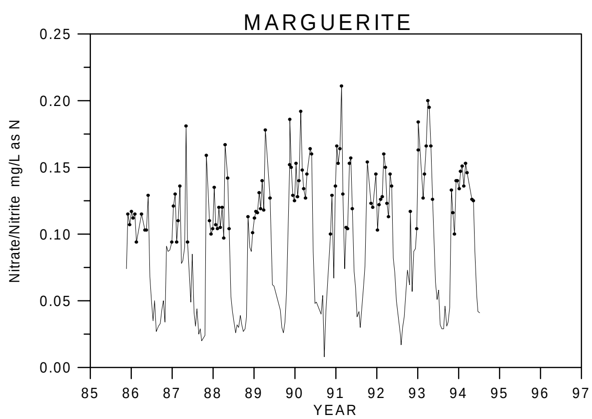

SUMAS
Dissolved Sulphate mg/L
40.00
30.00
20.00
10.00
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

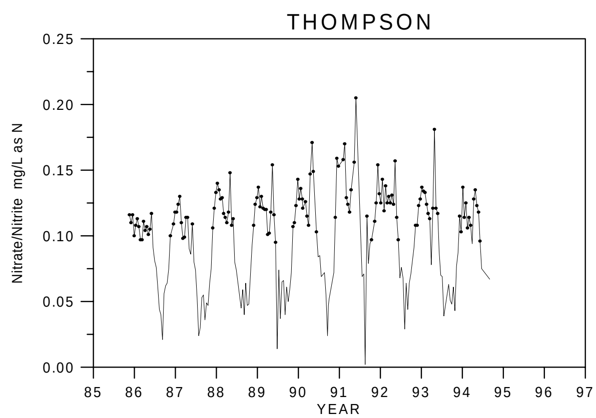

RED PASS
Nitrate/Nitrite mg/L as N
YEAR

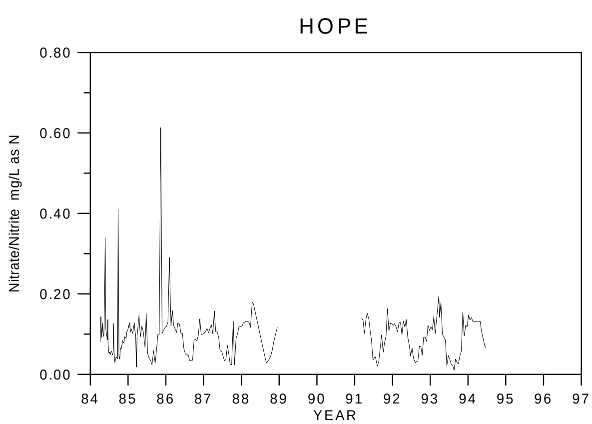

NECHAKO
Nitrate/Nitrite mg/L as N
YEAR

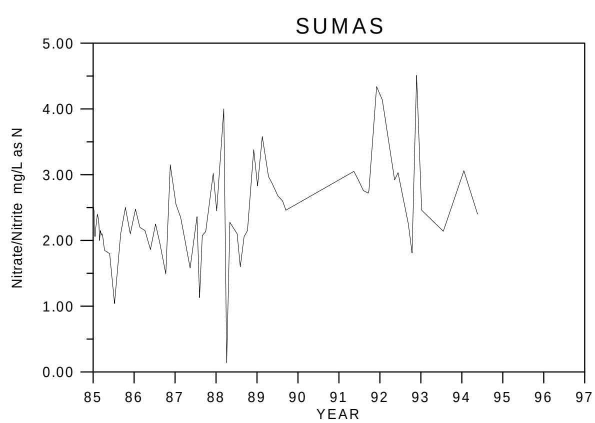

HANSARD
Nitrate/Nitrite mg/L as N
YEAR

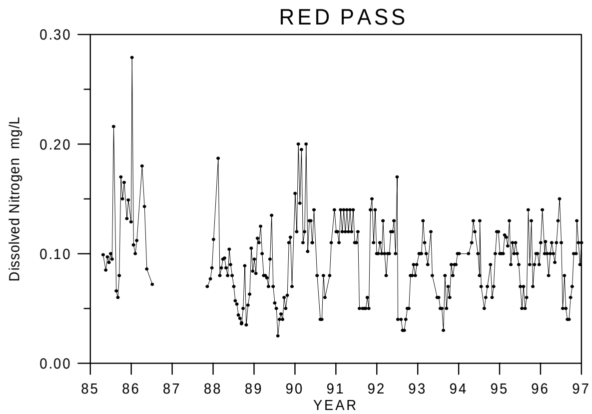

SALMON
Nitrate/Nitrite mg/L as N
YEAR

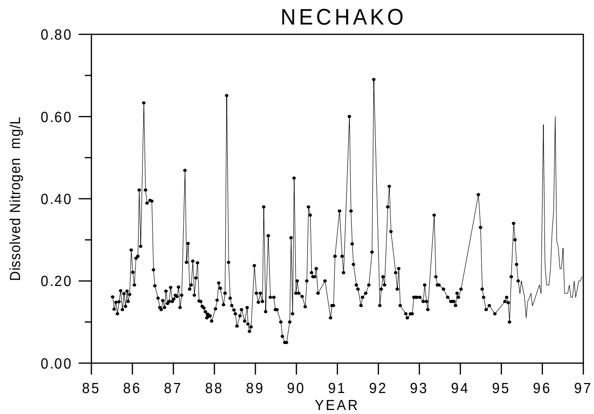

MARGUERITE
Nitrate/Nitrite mg/L as N
YEAR

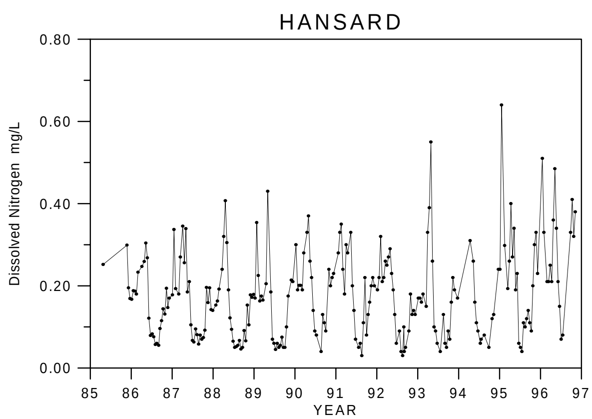

THOMPSON
Nitrate/Nitrite mg/L as N
YEAR

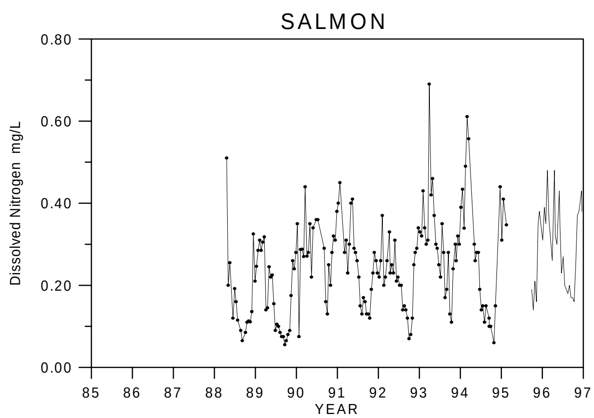

HOPE
Nitrate/Nitrite mg/L as N
YEAR

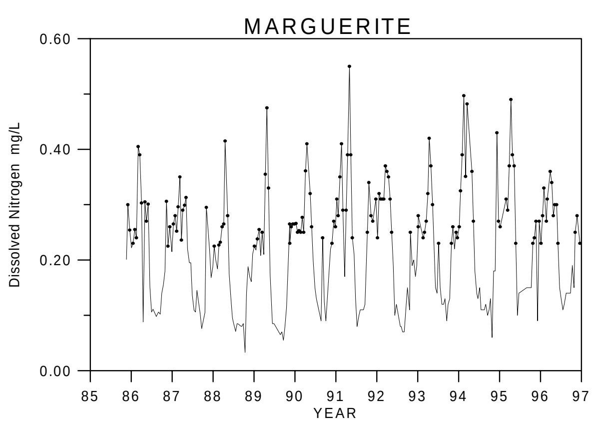

SUMAS
Nitrate/Nitrite mg/L as N
YEAR

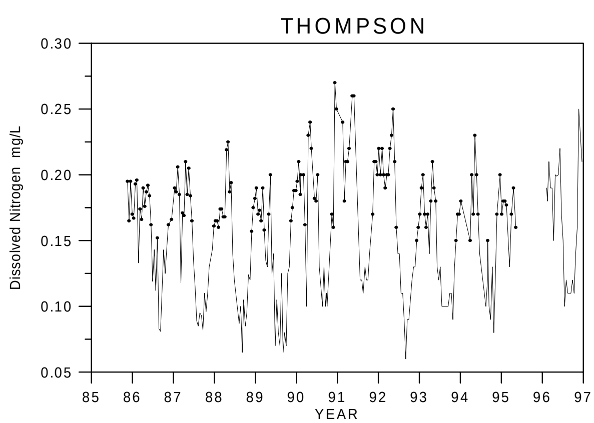

RED PASS
Dissolved Nitrogen mg/L
0.00 0.10 0.20 0.30
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

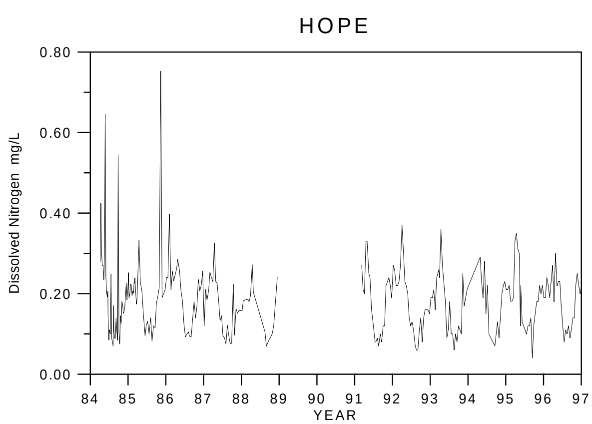

NECHAKO
Dissolved Nitrogen mg/L
0.00 0.20 0.40 0.60 0.80
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

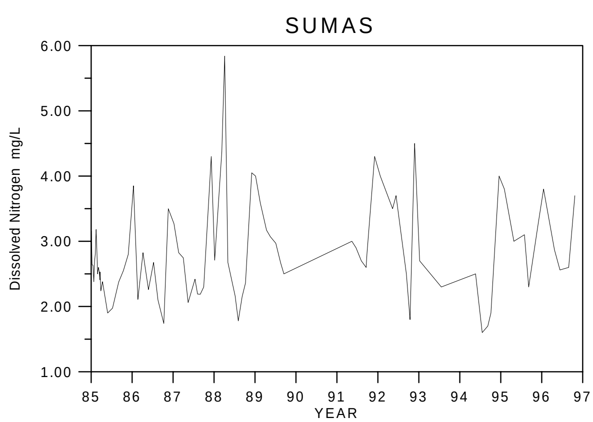

HANSARD
Dissolved Nitrogen mg/L
0.00 0.20 0.40 0.60 0.80
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

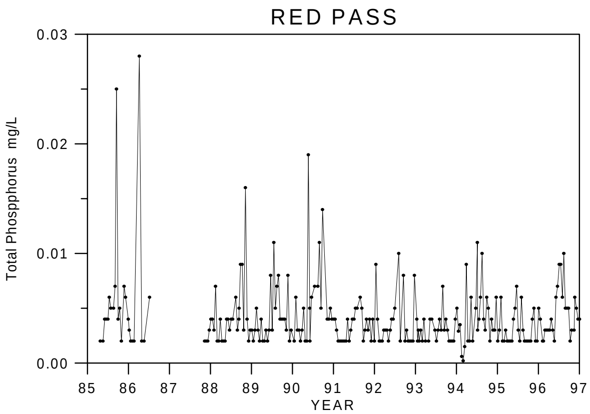

SALMON
Dissolved Nitrogen mg/L
0.00 0.20 0.40 0.60 0.80
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

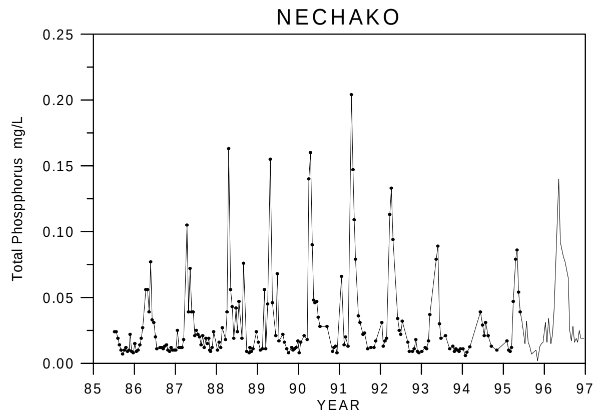

MARGUERITE
Dissolved Nitrogen mg/L
0.00 0.20 0.40 0.60
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

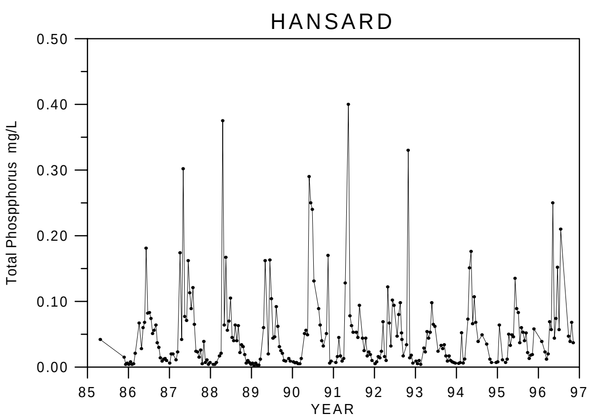

THOMPSON
Dissolved Nitrogen mg/L
0.05 0.10 0.15 0.20 0.25 0.30
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

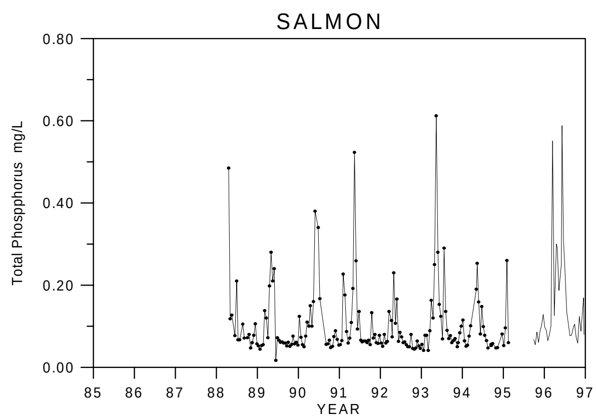

HOPE
Dissolved Nitrogen mg/L
0.00 0.20 0.40 0.60 0.80
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

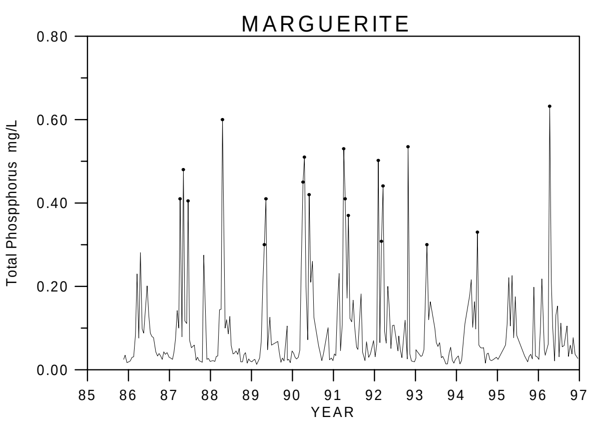

SUMAS
Dissolved Nitrogen mg/L
1.00 2.00 3.00 4.00 5.00 6.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

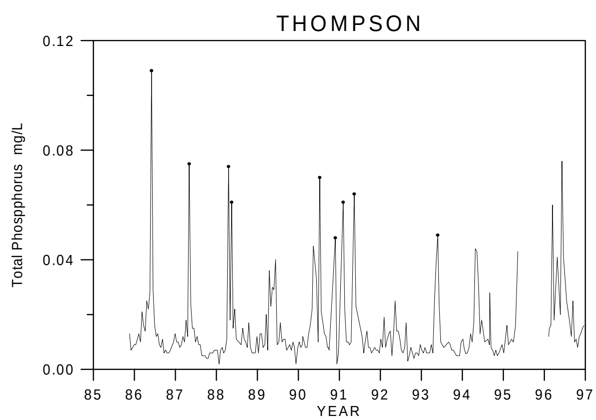

RED PASS
Total Phospphorus mg/L
0.00
0.01
0.02
0.03
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

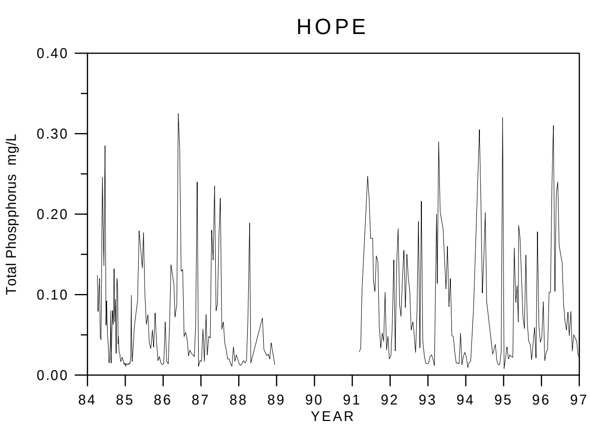

NECHAKO
Total Phospphorus mg/L
0.00
0.05
0.10
0.15
0.20
0.25
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

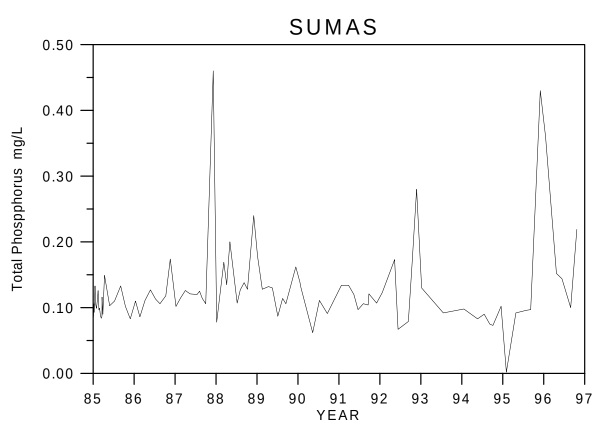

HANSARD
Total Phospphorus mg/L
0.00
0.10
0.20
0.30
0.40
0.50
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

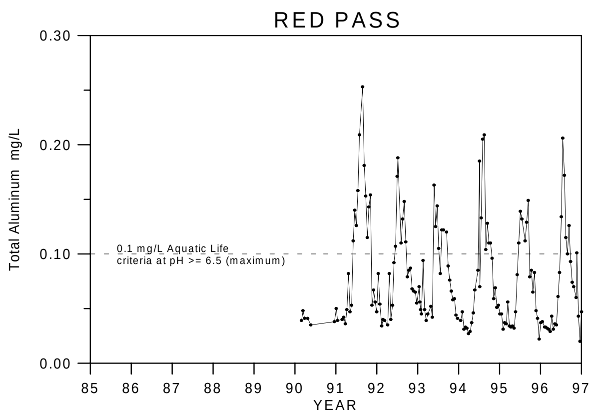

SALMON
Total Phospphorus mg/L
0.00
0.20
0.40
0.60
0.80
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

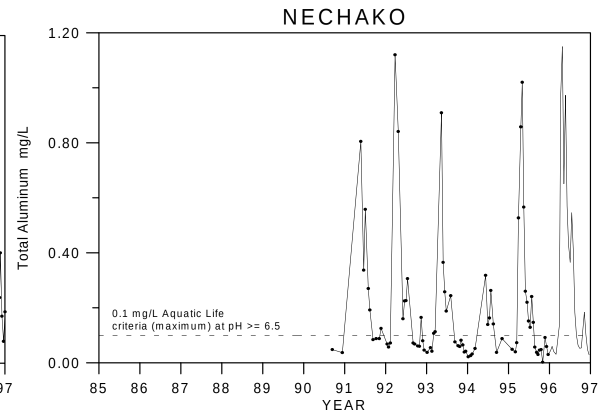

MARGUERITE
Total Phospphorus mg/L
0.00
0.20
0.40
0.60
0.80
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

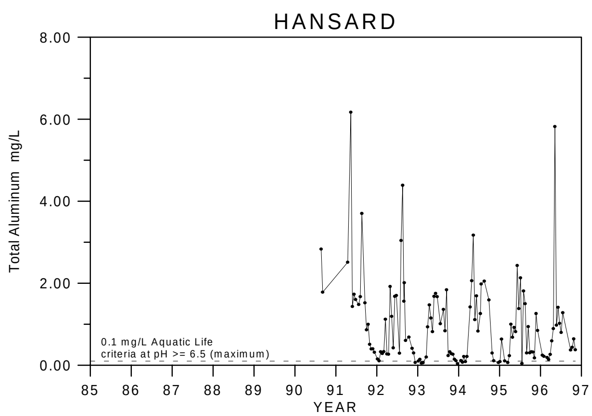

THOMPSON
Total Phospphorus mg/L
0.00
0.04
0.08
0.12
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

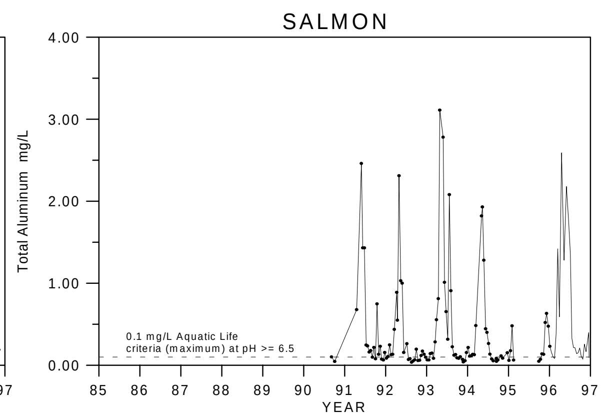

HOPE
Total Phospphorus mg/L
0.00
0.10
0.20
0.30
0.40
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

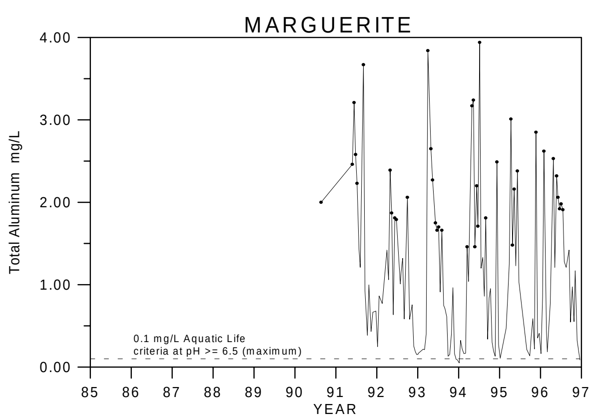

SUMAS
Total Phospphorus mg/L
0.00
0.10
0.20
0.30
0.40
0.50
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

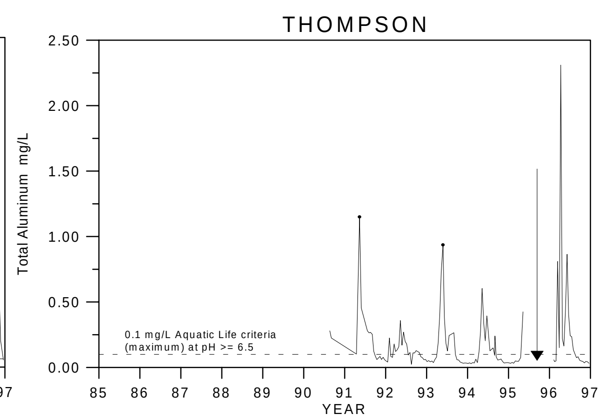

RED PASS
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria at pH >= 6.5 (maximum)
YEAR

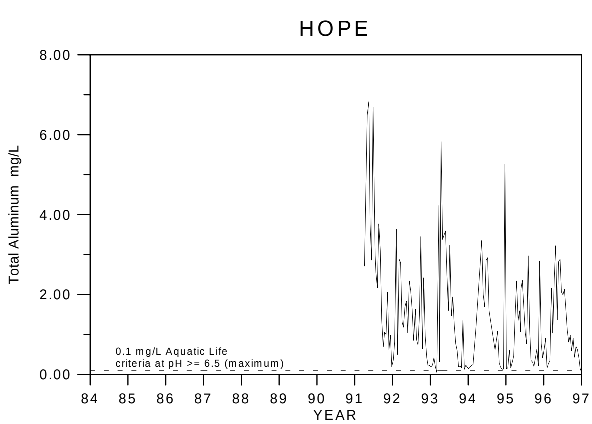

NECHAKO
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria (maximum) at pH >= 6.5
YEAR

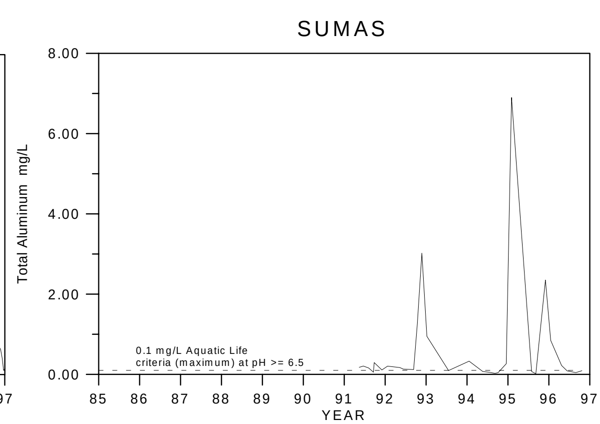

HANSARD
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria at pH >= 6.5 (maximum)
YEAR

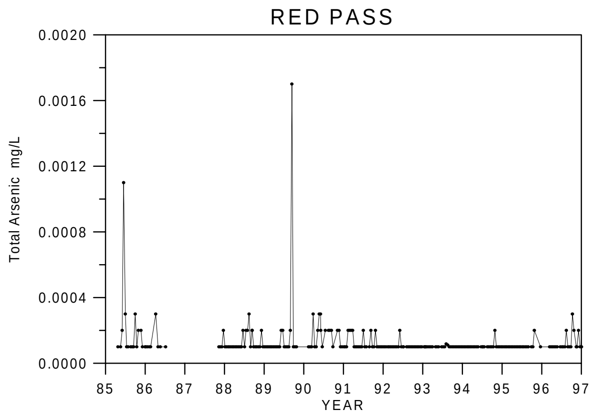

SALMON
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria (maximum) at pH >= 6.5
YEAR

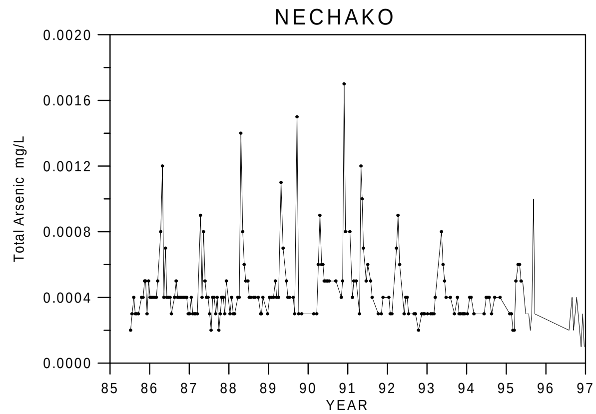

MARGUERITE
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria at pH >= 6.5 (maximum)
YEAR

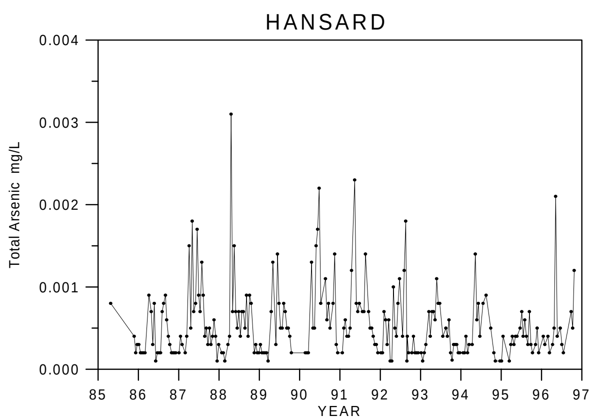

THOMPSON
Total Aluminum mg/L
0.1 mg/L Aquatic Life criteria
(maximum) at pH >= 6.5
YEAR

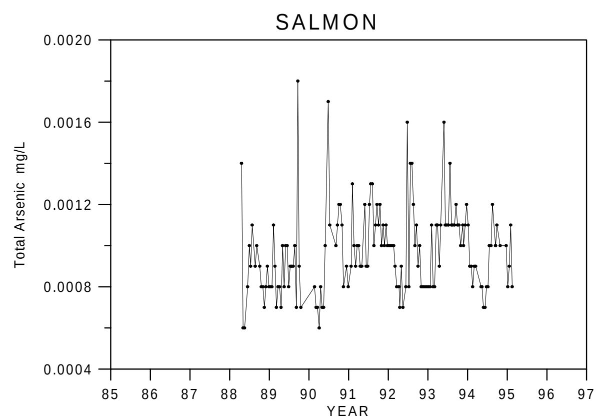

HOPE
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria at pH >= 6.5 (maximum)
YEAR

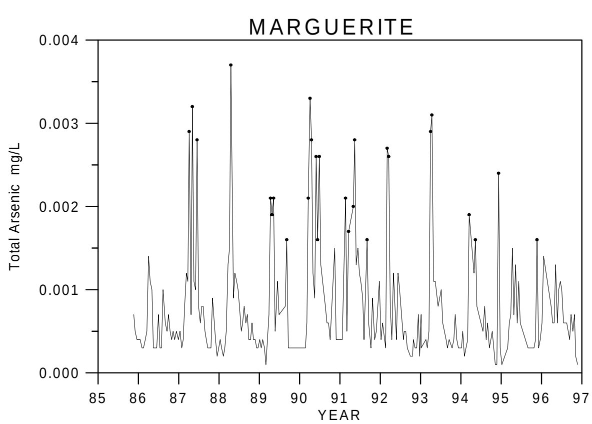

SUMAS
Total Aluminum mg/L
0.1 mg/L Aquatic Life
criteria (maximum) at pH >= 6.5
YEAR

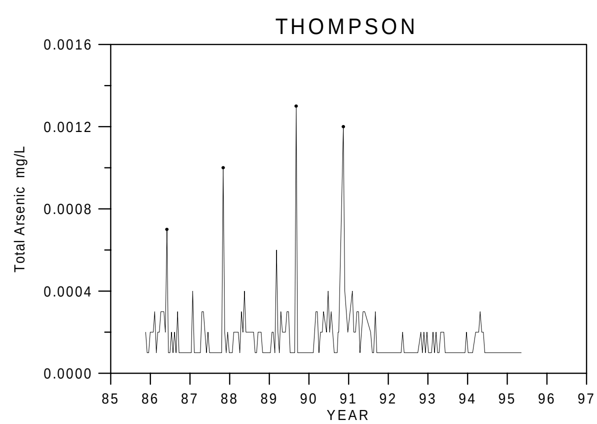

RED PASS
Total Arsenic mg/L
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

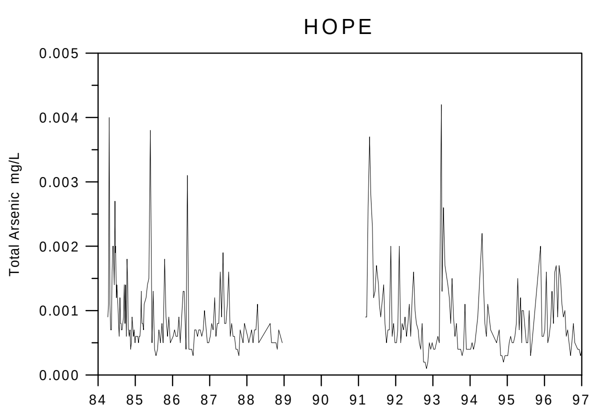

NECHAKO
Total Arsenic mg/L
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

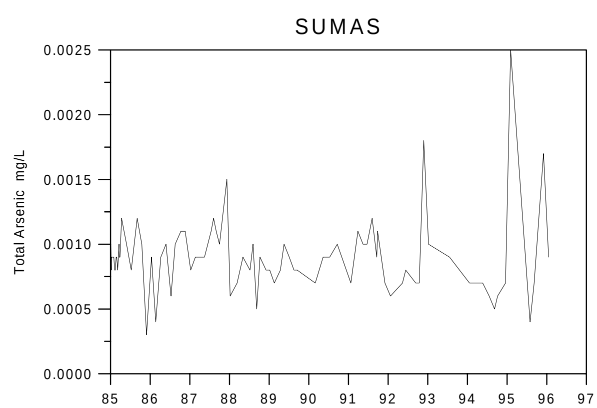

HANSARD
Total Arsenic mg/L
0.004
0.003
0.002
0.001
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

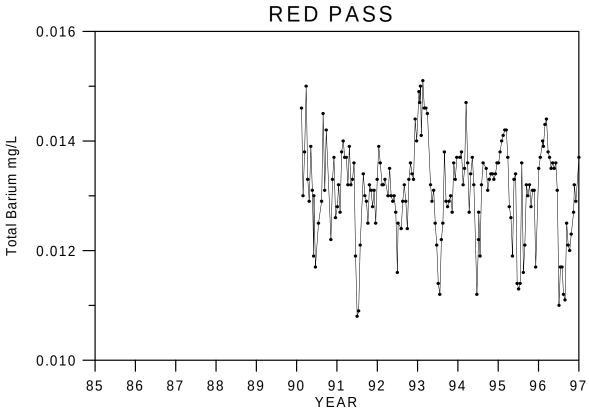

SALMON
Total Arsenic mg/L
0.0020
0.0016
0.0012
0.0008
0.0004
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

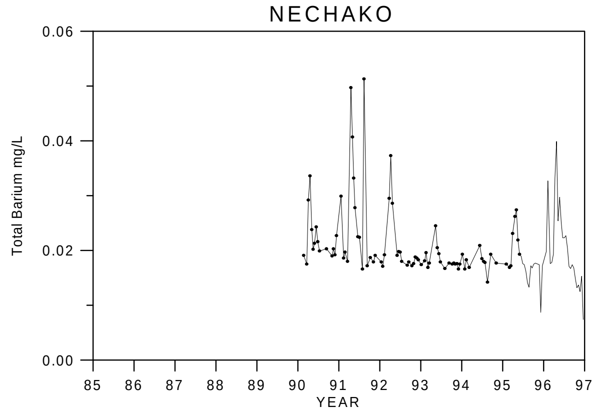

MARGUERITE
Total Arsenic mg/L
0.004
0.003
0.002
0.001
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

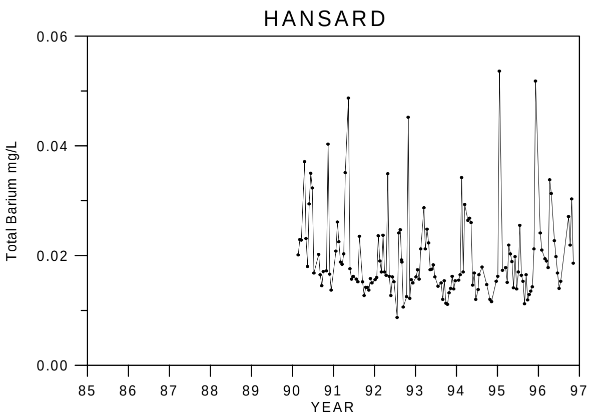

THOMPSON
Total Arsenic mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

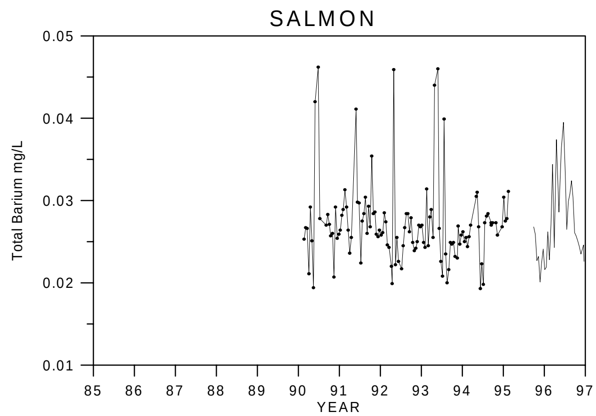

HOPE
Total Arsenic mg/L
0.005
0.004
0.003
0.002
0.001
0.000
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

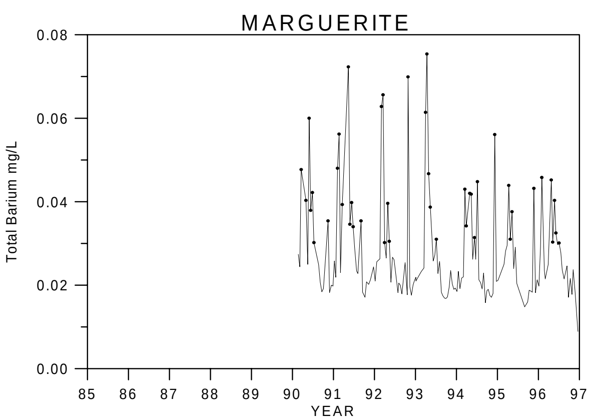

SUMAS
Total Arsenic mg/L
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

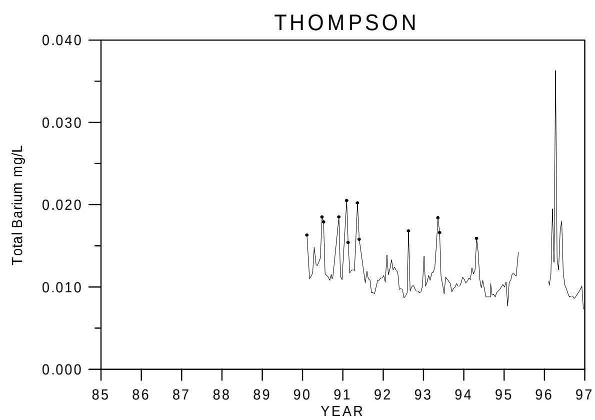

RED PASS
Total Barium mg/L
0.016
0.014
0.012
0.010
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

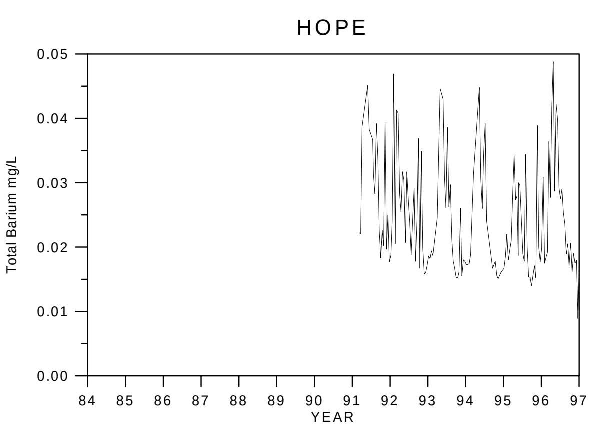

NECHAKO
Total Barium mg/L
0.06
0.04
0.02
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

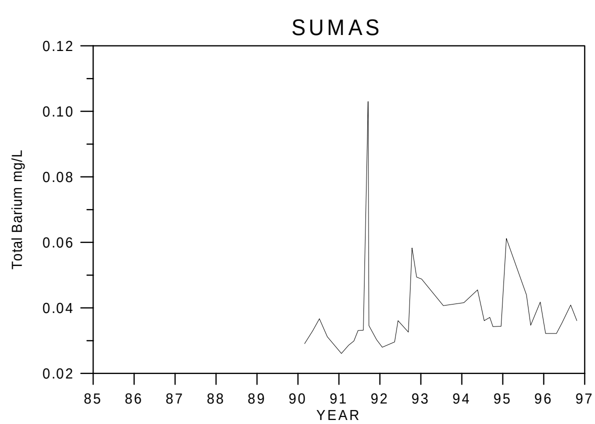

HANSARD
Total Barium mg/L
0.06
0.04
0.02
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

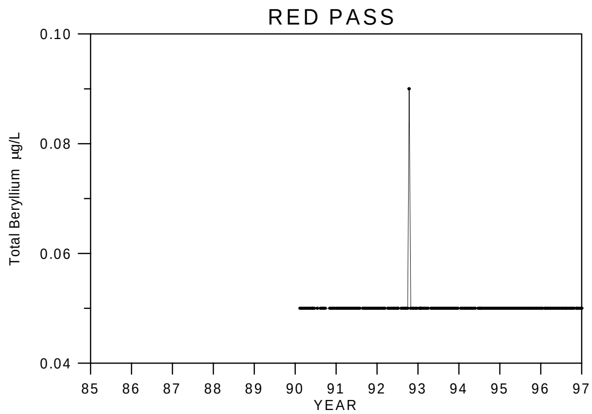

SALMON
Total Barium mg/L
0.05
0.04
0.03
0.02
0.01
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

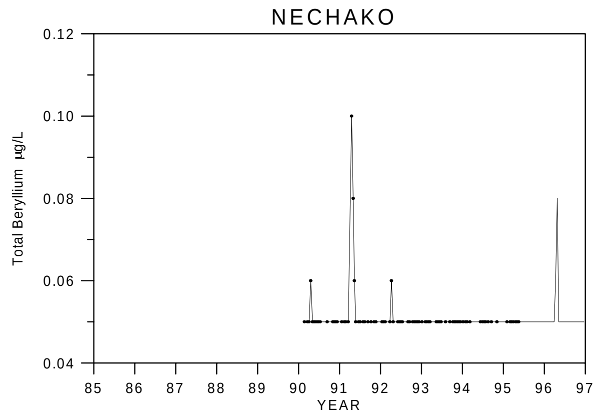

MARGUERITE
Total Barium mg/L
0.08
0.06
0.04
0.02
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

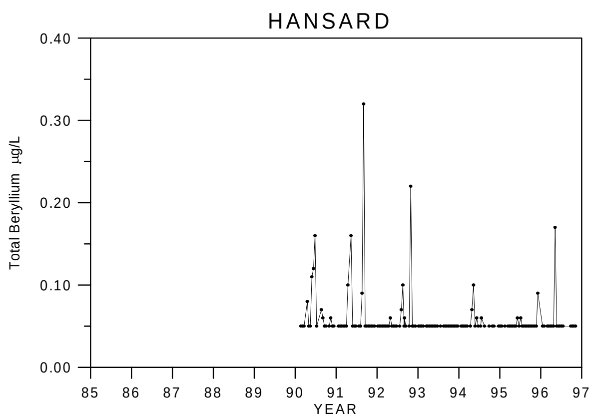

THOMPSON
Total Barium mg/L
0.040
0.030
0.020
0.010
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

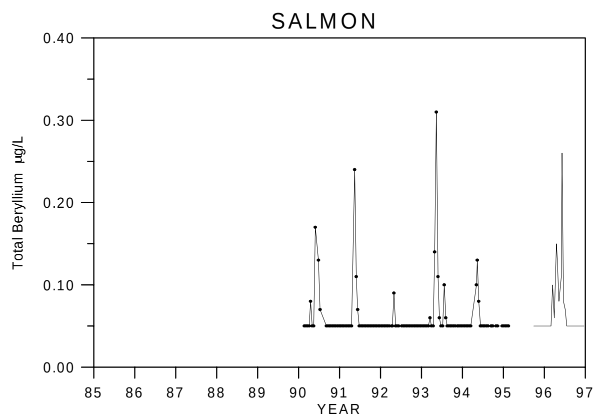

HOPE
Total Barium mg/L
0.05
0.04
0.03
0.02
0.01
0.00
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

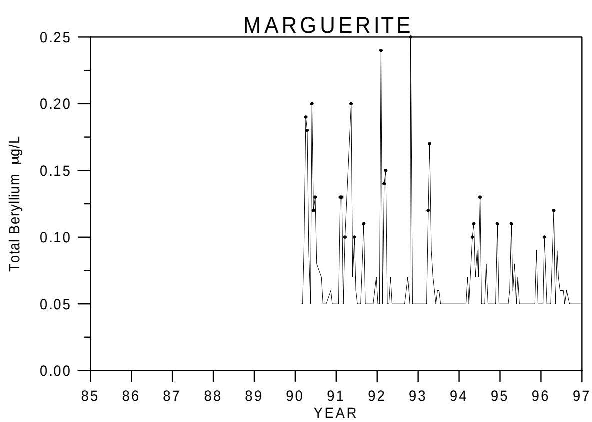

SUMAS
Total Barium mg/L
0.12
0.10
0.08
0.06
0.04
0.02
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

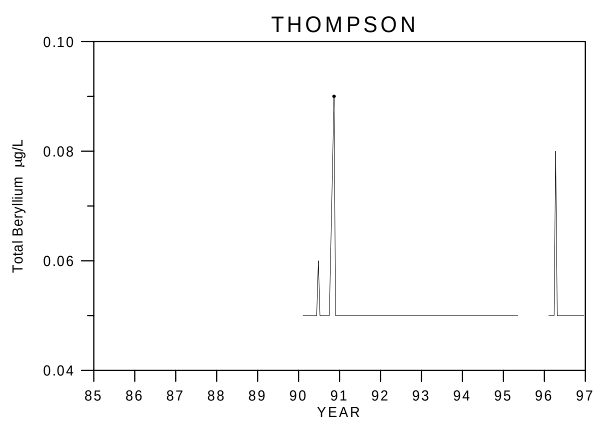

RED PASS
Total Beryllium µg/L
0.04
0.06
0.08
0.10
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

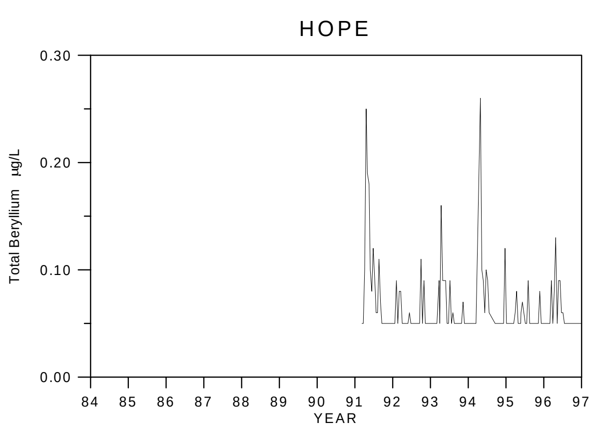

NECHAKO
Total Beryllium µg/L
0.04
0.06
0.08
0.10
0.12
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

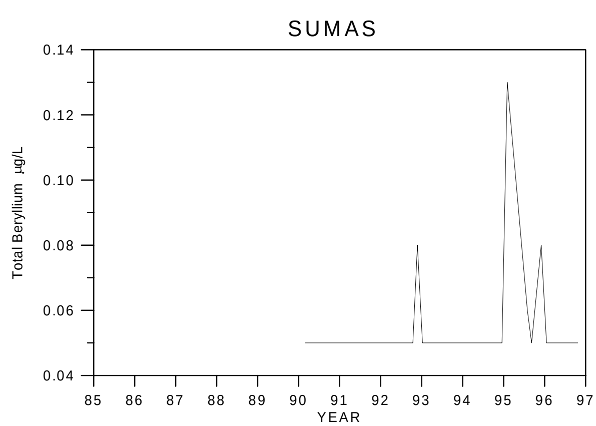

HANSARD
Total Beryllium µg/L
0.00
0.10
0.20
0.30
0.40
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

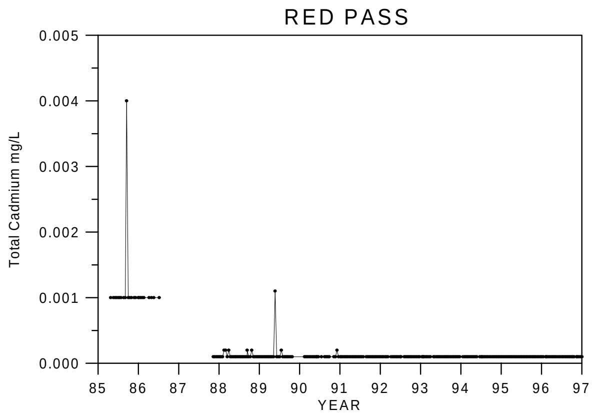

SALMON
Total Beryllium µg/L
0.00
0.10
0.20
0.30
0.40
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

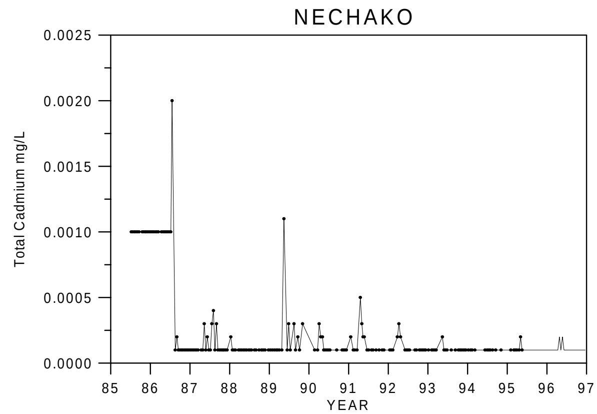

MARGUERITE
Total Beryllium µg/L
0.00
0.05
0.10
0.15
0.20
0.25
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

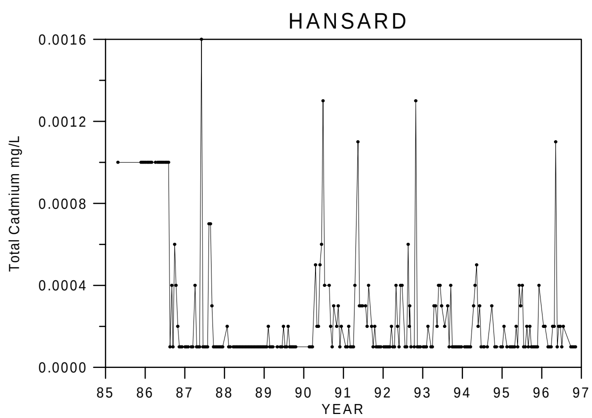

THOMPSON
Total Beryllium µg/L
0.04
0.06
0.08
0.10
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

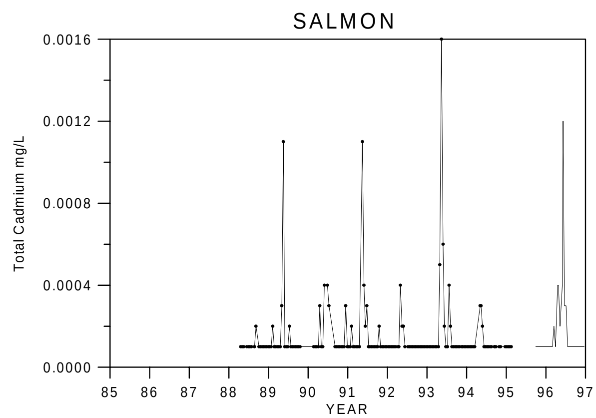

HOPE
Total Beryllium µg/L
0.00
0.10
0.20
0.30
84
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

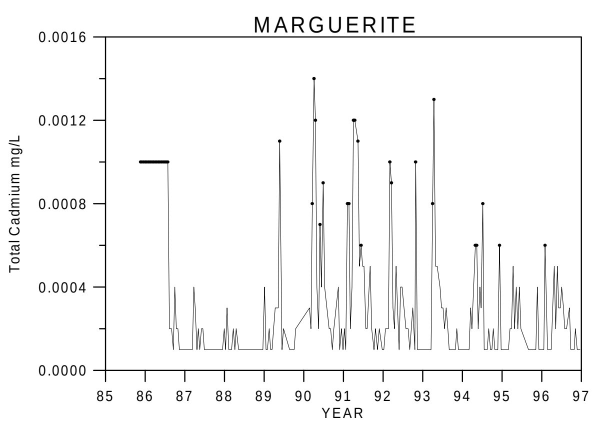

SUMAS
Total Beryllium µg/L
0.04
0.06
0.08
0.10
0.12
0.14
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

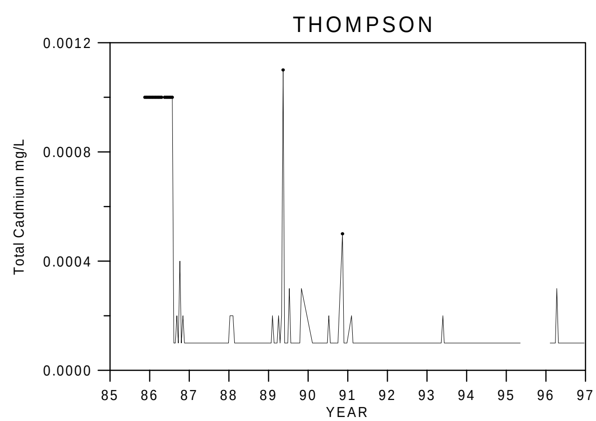

RED PASS
Total Cadmium mg/L
0.005
0.004
0.003
0.002
0.001
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

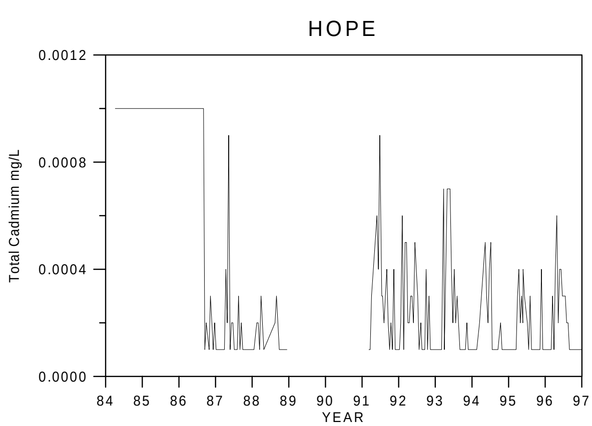

NECHAKO
Total Cadmium mg/L
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

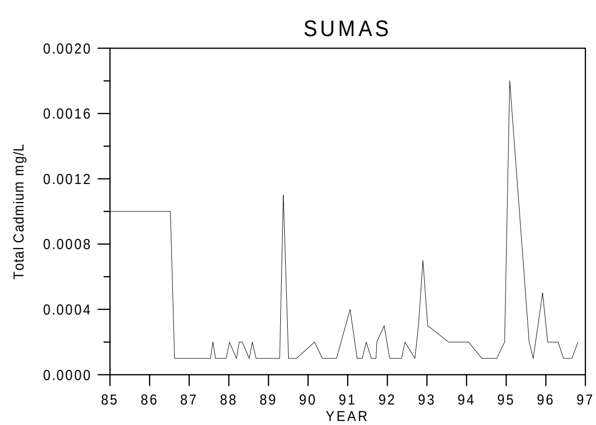

HANSARD
Total Cadmium mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SALMON
Total Cadmium mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

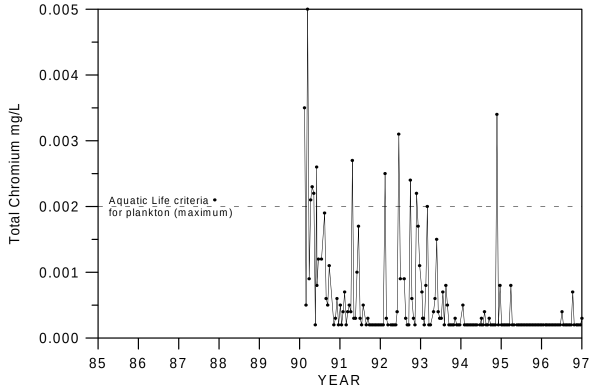

MARGUERITE
Total Cadmium mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


THOMPSON
Total Cadmium mg/L
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

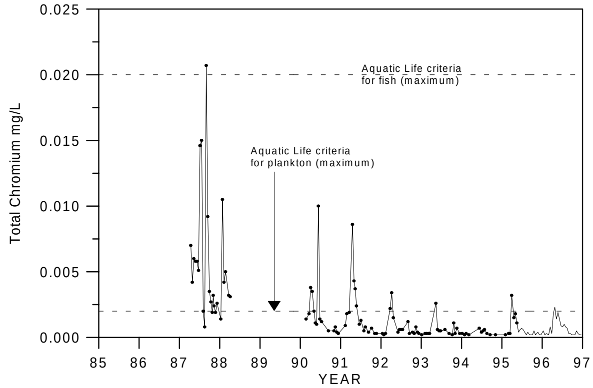

HOPE
Total Cadmium mg/L
0.0012
0.0008
0.0004
0.0000
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SUMAS
Total Cadmium mg/L
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

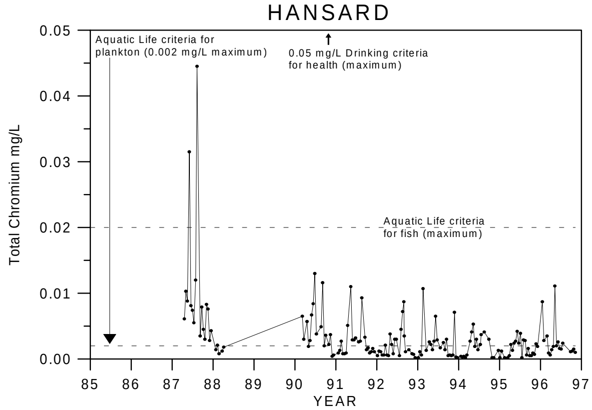
RED PASS



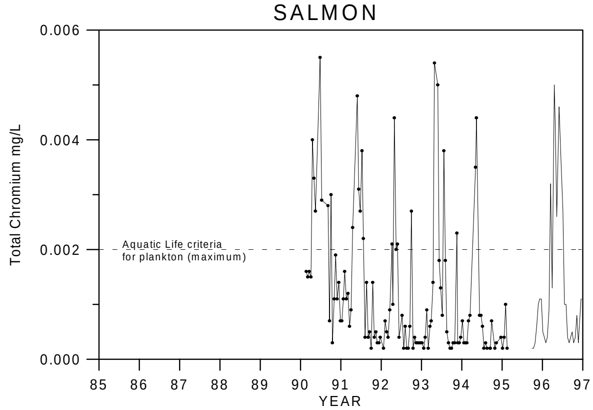
NECHAKO



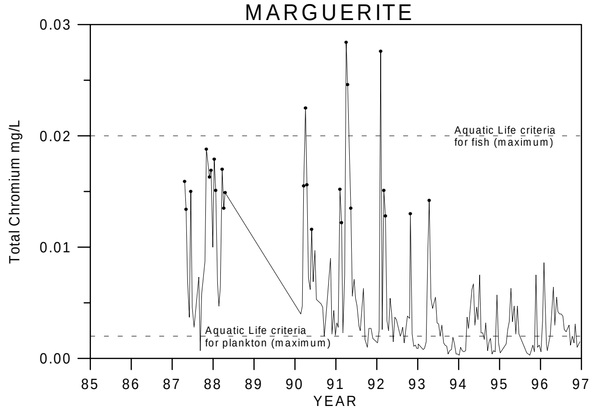
HANSARD



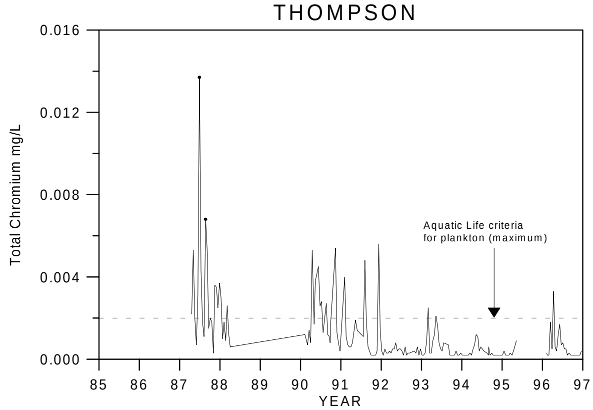
SALMON



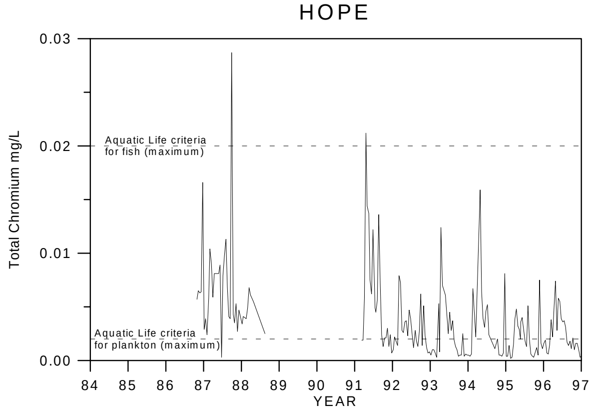
MARGUERITE



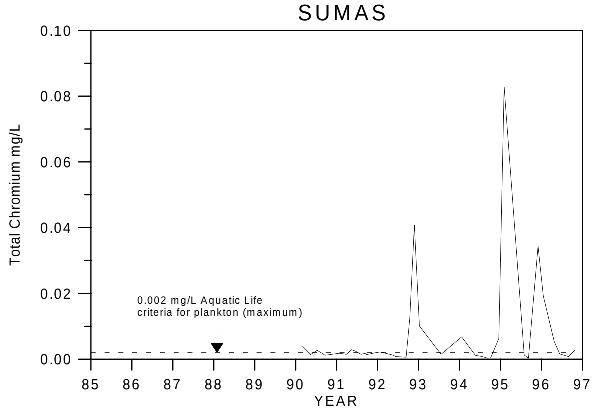
THOMPSON

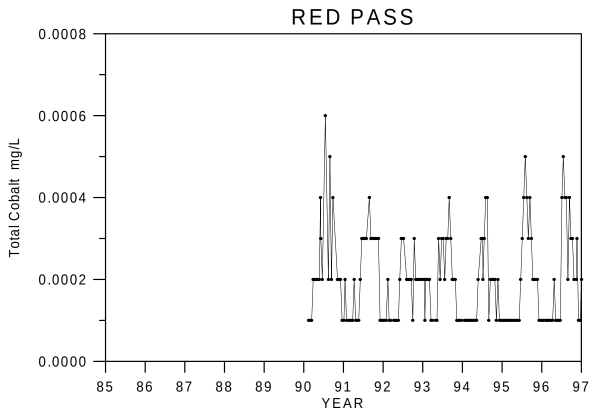


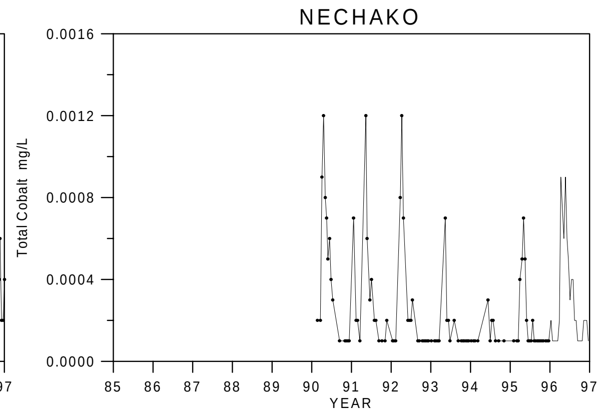
HOPE

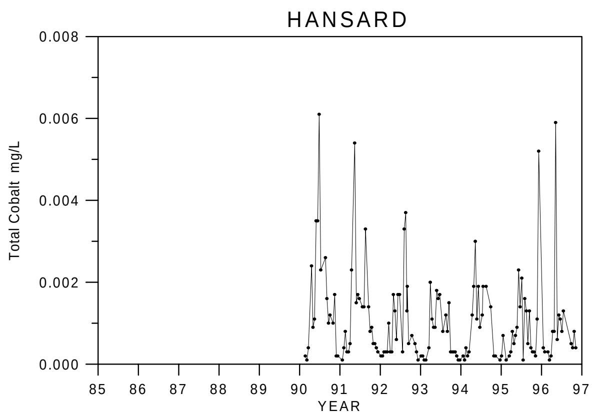


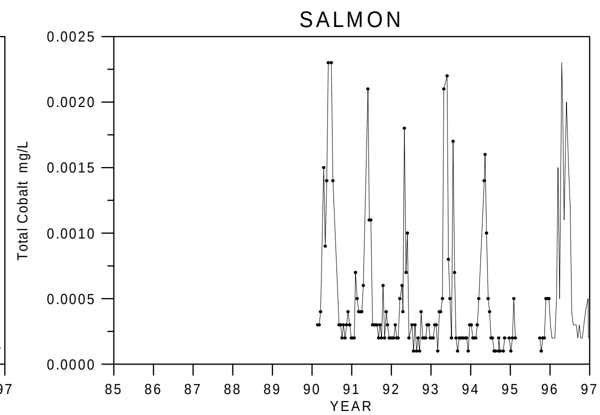
SUMAS

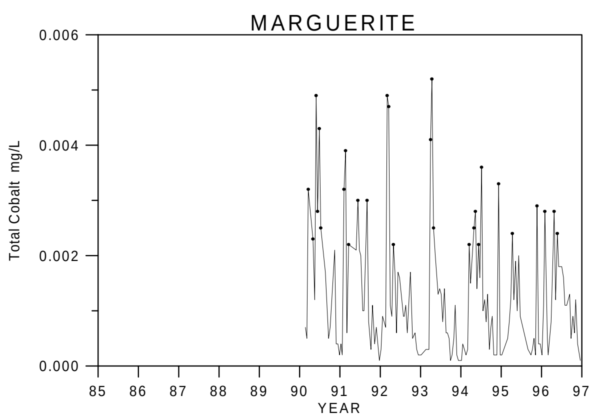


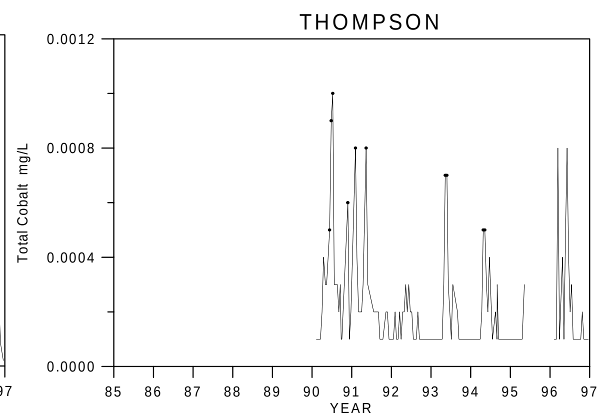

RED PASS
Total Cobalt mg/L
0.0000
0.0002
0.0004
0.0006
0.0008
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

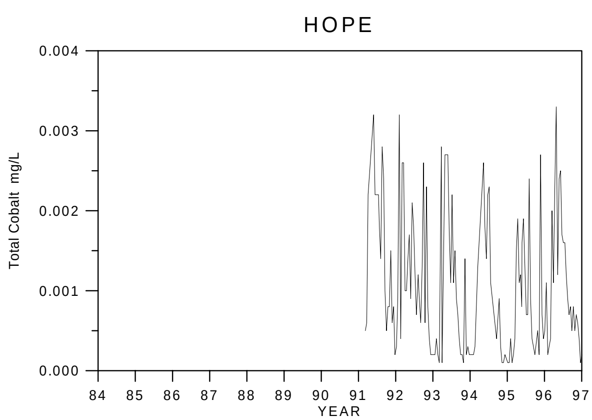

NECHAKO
Total Cobalt mg/L
0.0000
0.0004
0.0008
0.0012
0.0016
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

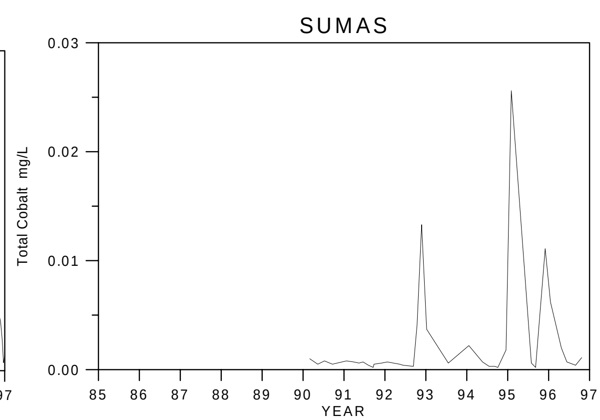

HANSARD
Total Cobalt mg/L
0.000
0.002
0.004
0.006
0.008
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

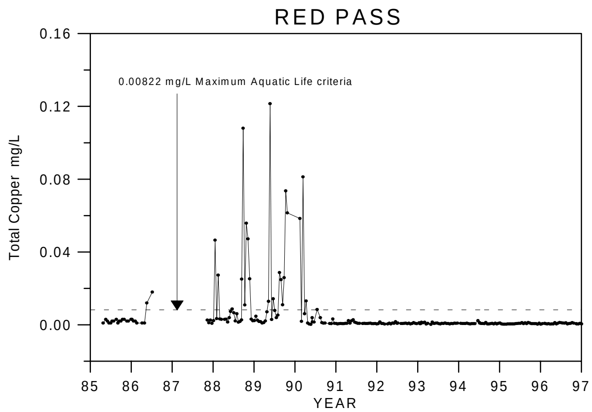

SALMON
Total Cobalt mg/L
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

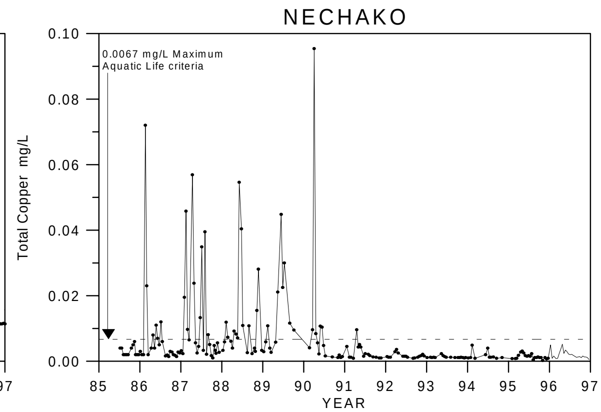

MARGUERITE
Total Cobalt mg/L
0.000
0.002
0.004
0.006
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

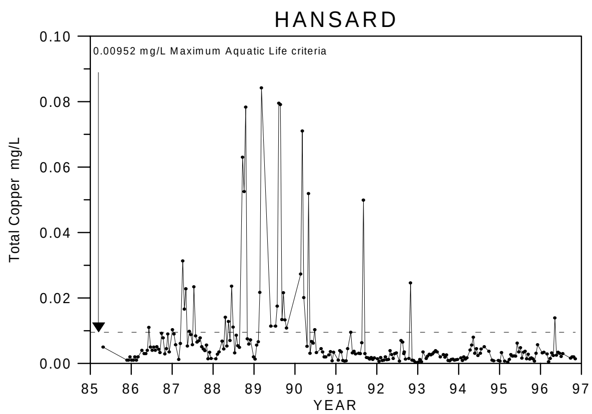

THOMPSON
Total Cobalt mg/L
0.0000
0.0004
0.0008
0.0012
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

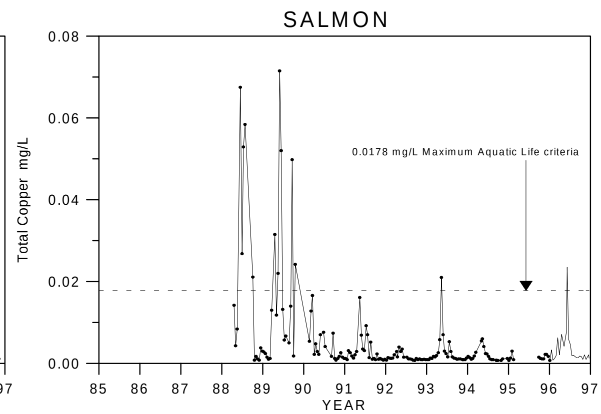

HOPE
Total Cobalt mg/L
0.000
0.001
0.002
0.003
0.004
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

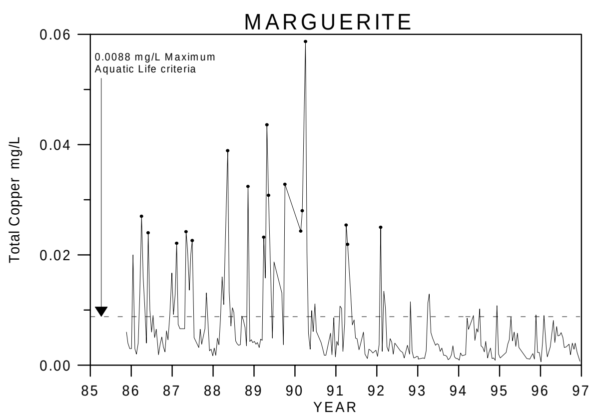

SUMAS
Total Cobalt mg/L
0.00
0.01
0.02
0.03
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

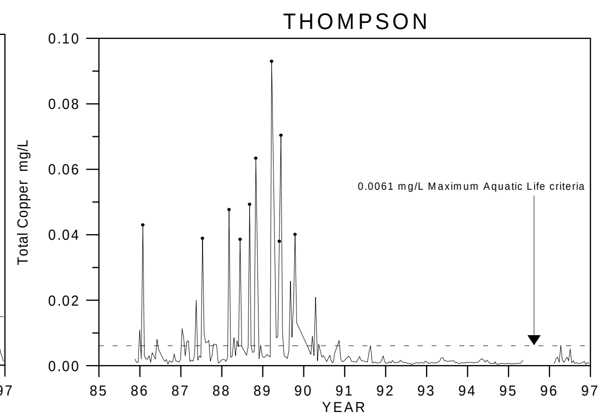

RED PASS
0.00822 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

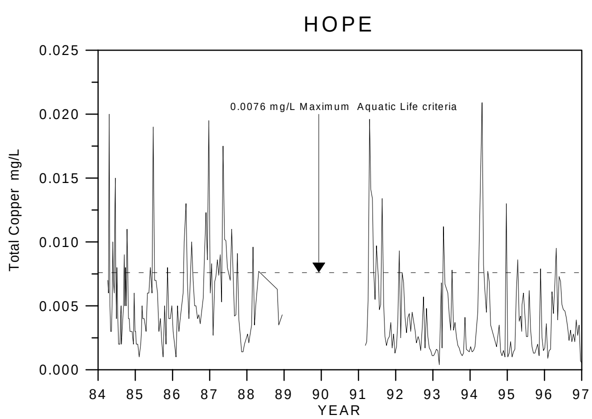

NECHAKO
0.0067 mg/L Maximum
Aquatic Life criteria
Total Copper mg/L
YEAR

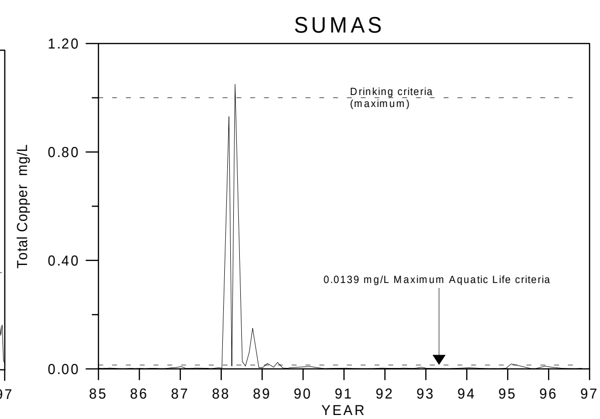

HANSARD
0.00952 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

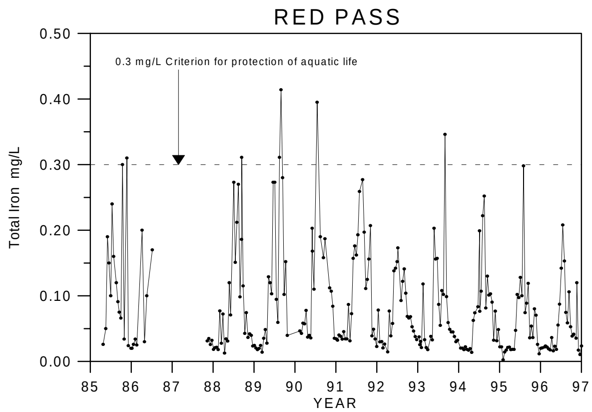

SALMON
0.0178 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

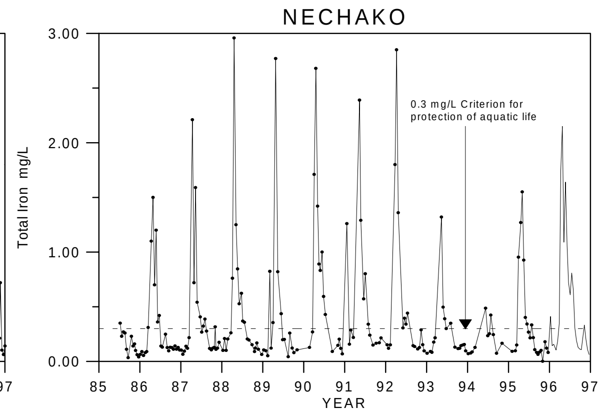

MARGUERITE
0.0088 mg/L Maximum
Aquatic Life criteria
Total Copper mg/L
YEAR

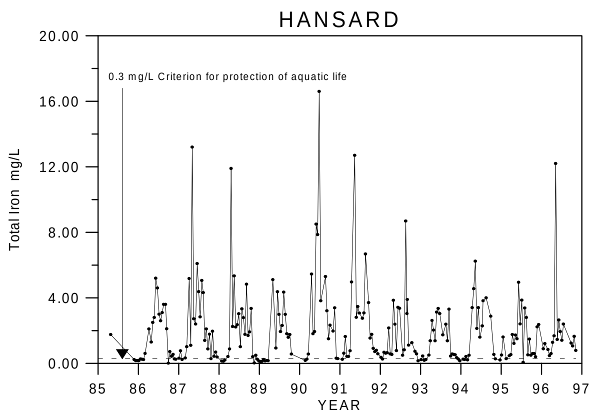

THOMPSON
0.0061 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

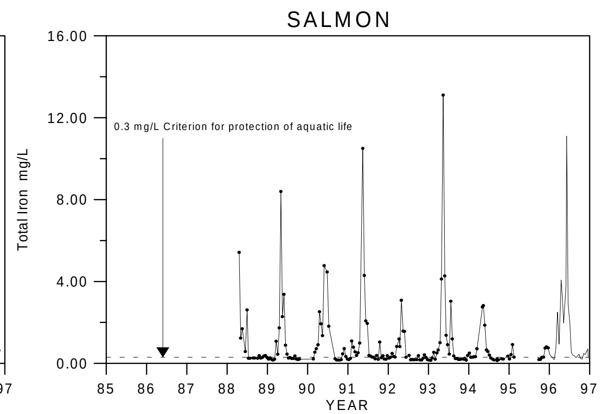

HOPE
0.0076 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

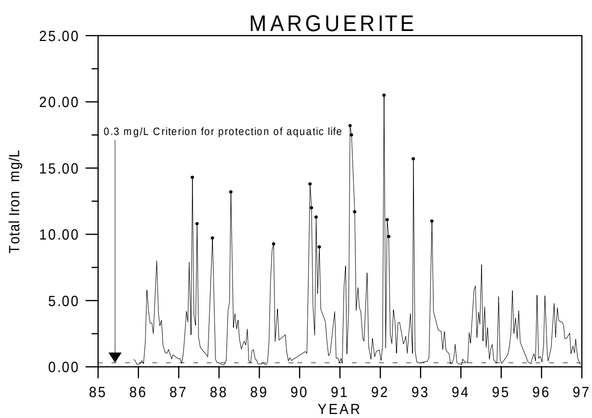

SUMAS
Drinking criteria
(maximum)
0.0139 mg/L Maximum Aquatic Life criteria
Total Copper mg/L
YEAR

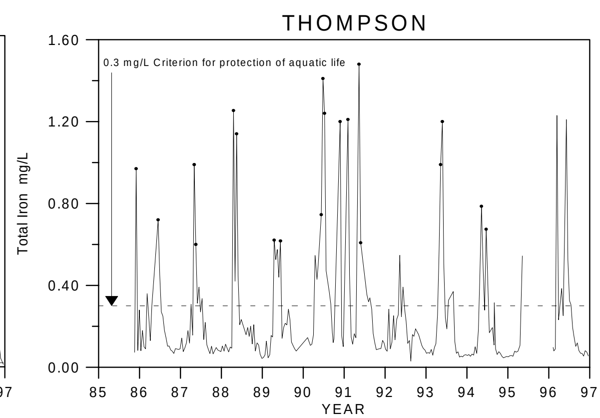

RED PASS
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR

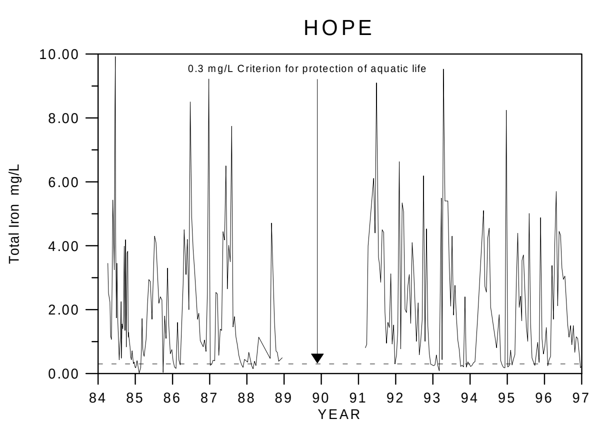

NECHAKO
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR

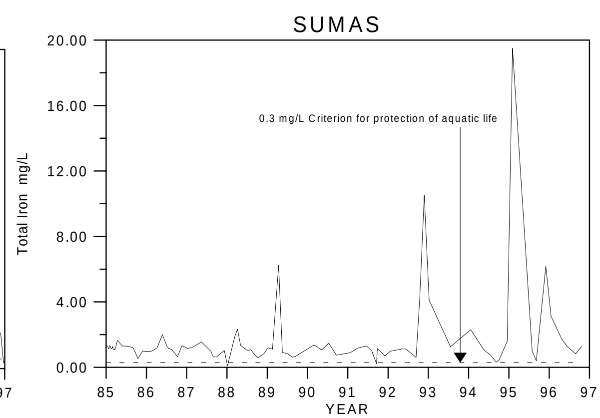

HANSARD
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR


SALMON
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR

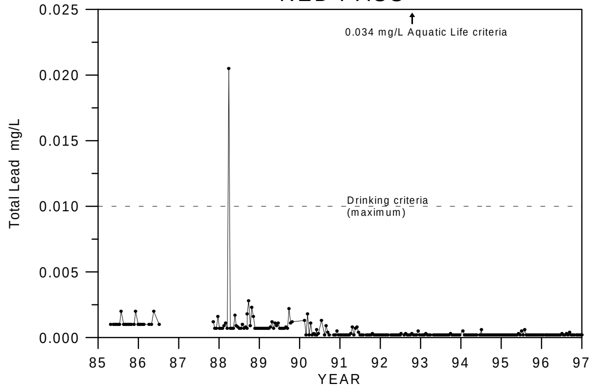

MARGUERITE
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR


THOMPSON
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR

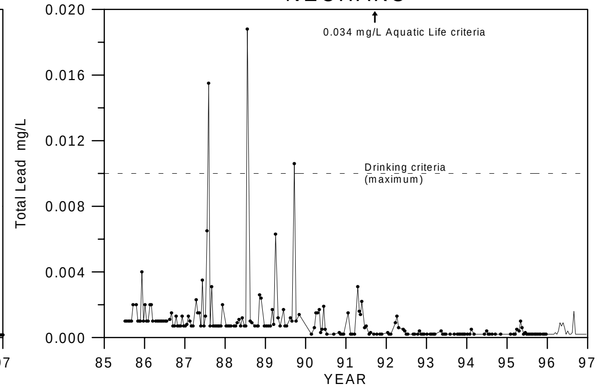

HOPE
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR


SUMAS
0.3 mg/L Criterion for protection of aquatic life
Total Iron mg/L
YEAR

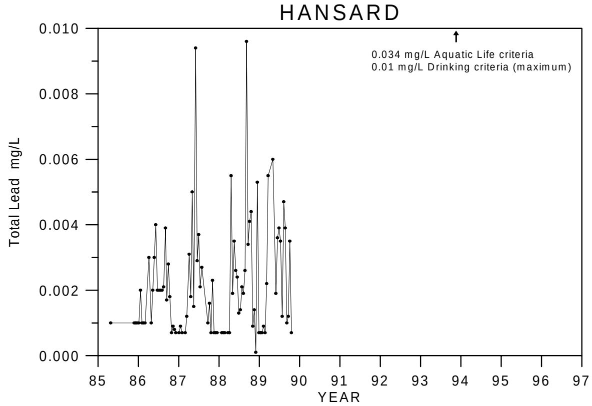
RED PASS



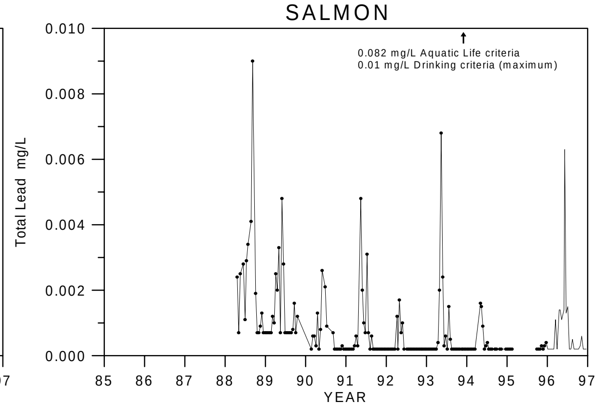
NECHAKO



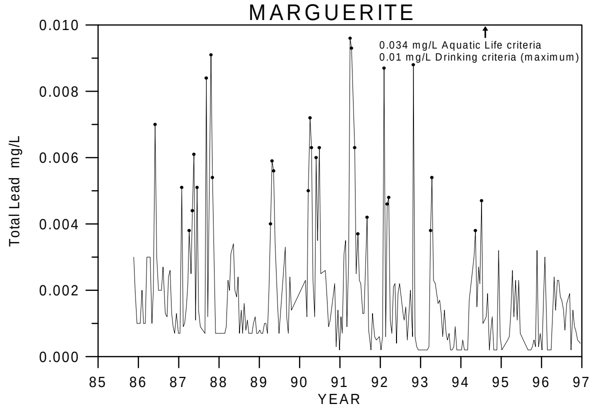
HANSARD



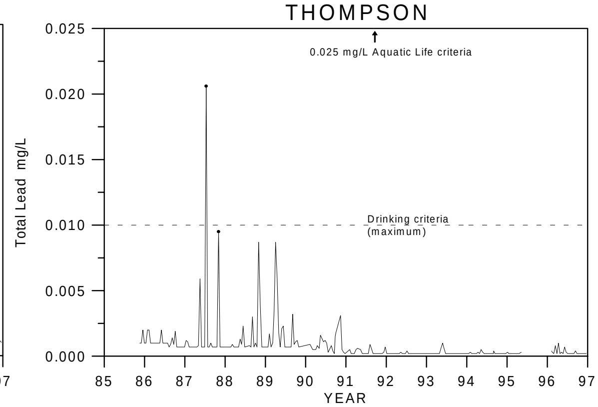
SALMON



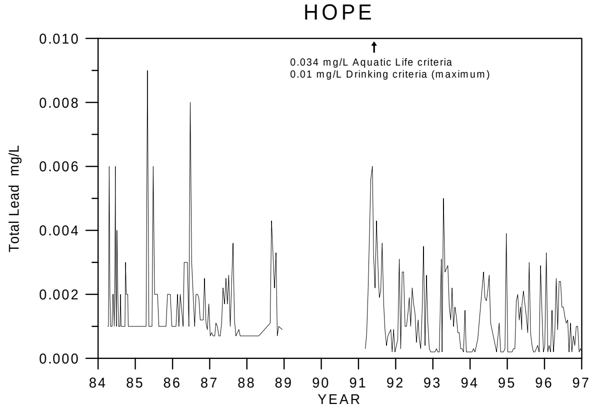
MARGUERITE



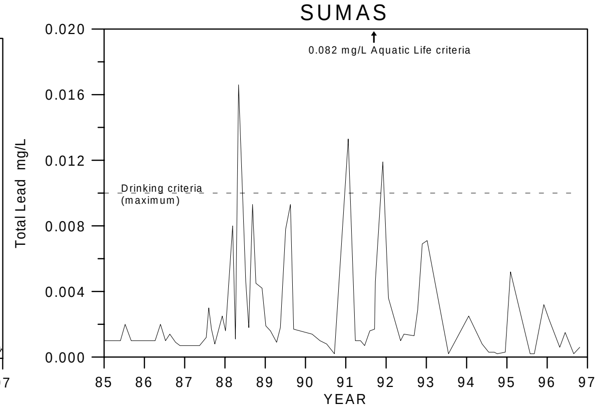
THOMPSON

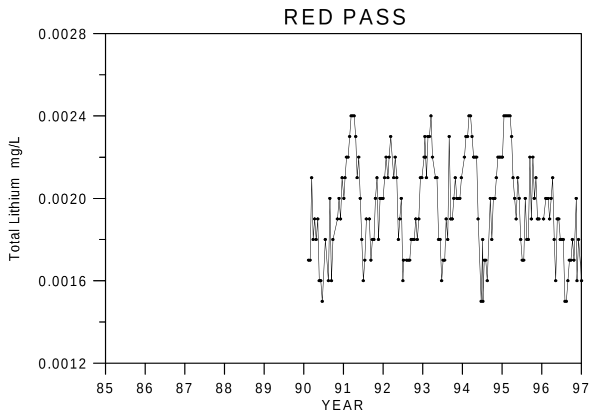


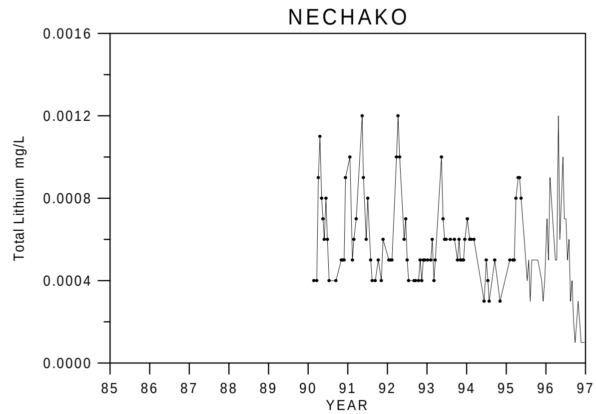
HOPE

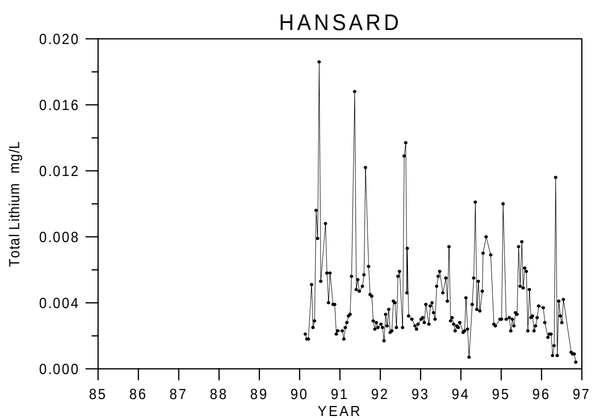


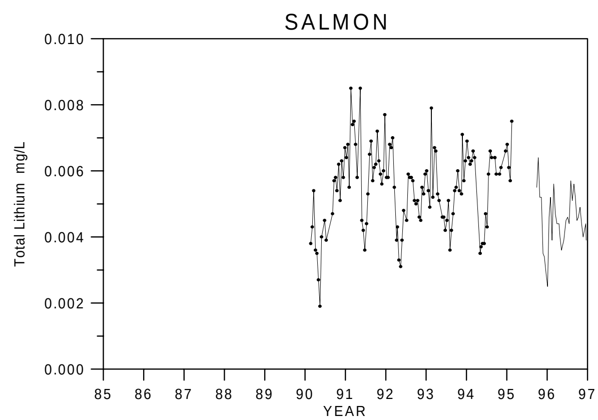
SUMAS

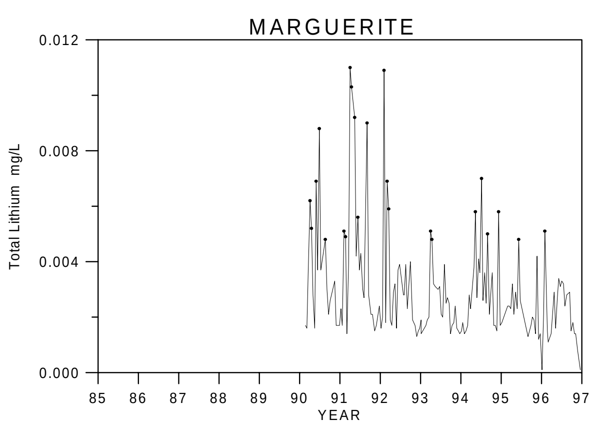


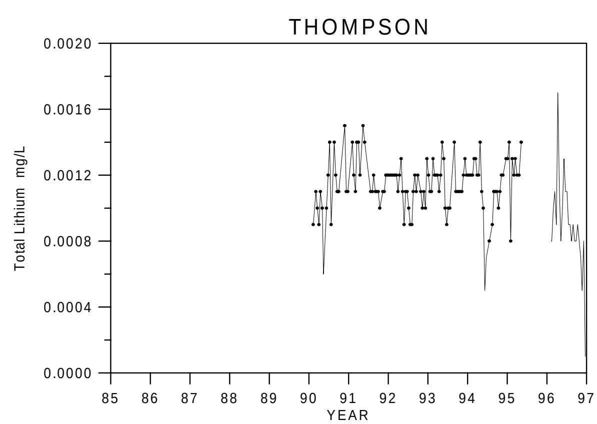

RED PASS
Total Lithium mg/L
0.0028
0.0024
0.0020
0.0016
0.0012
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

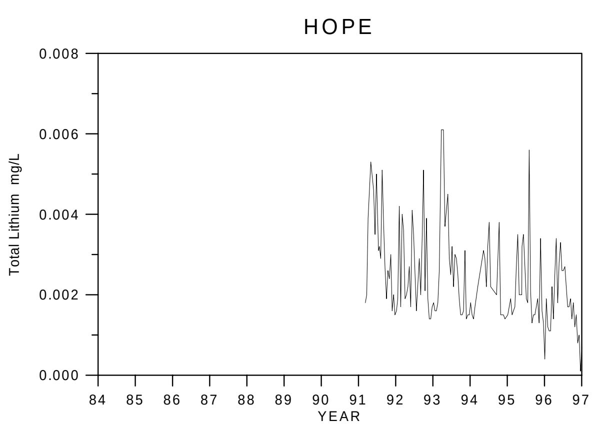

NECHAKO
Total Lithium mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

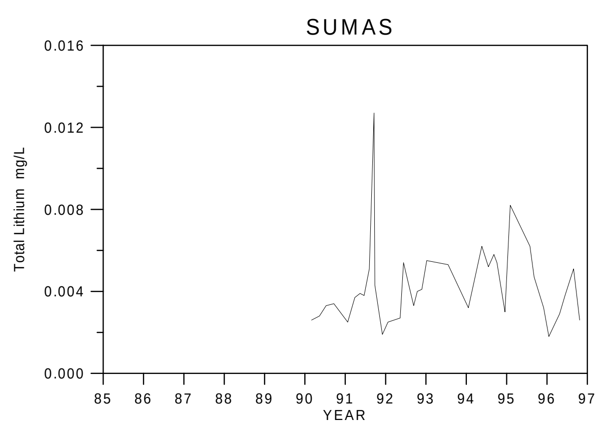

HANSARD
Total Lithium mg/L
0.020
0.016
0.012
0.008
0.004
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

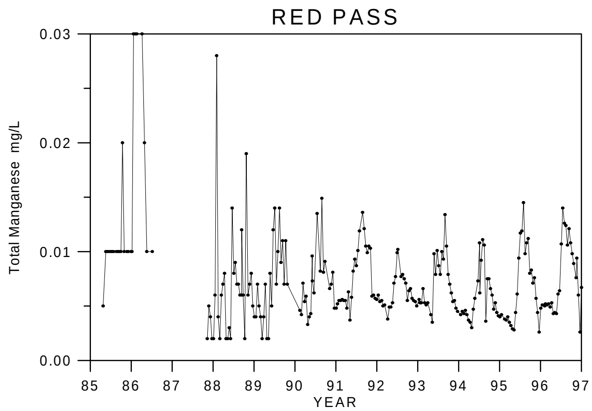

SALMON
Total Lithium mg/L
0.010
0.008
0.006
0.004
0.002
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

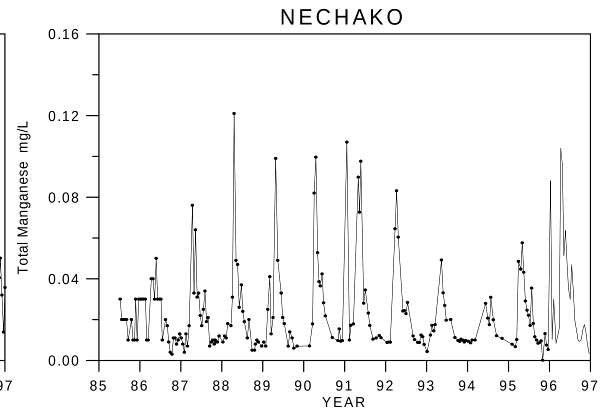

MARGUERITE
Total Lithium mg/L
0.012
0.008
0.004
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

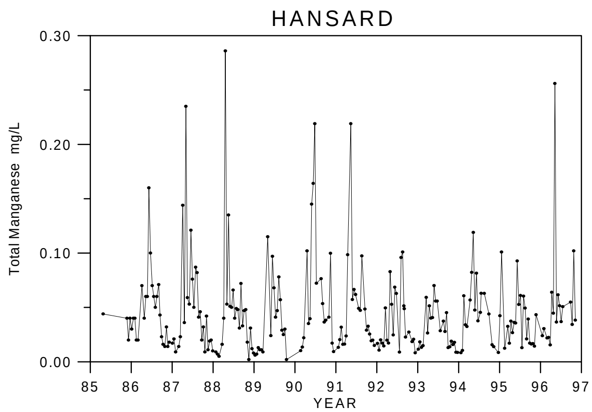

THOMPSON
Total Lithium mg/L
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

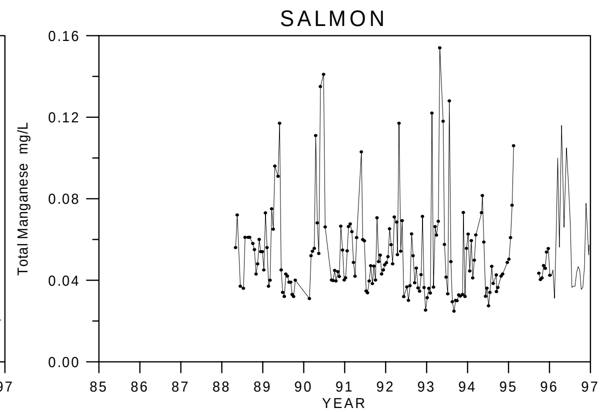

HOPE
Total Lithium mg/L
0.008
0.006
0.004
0.002
0.000
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

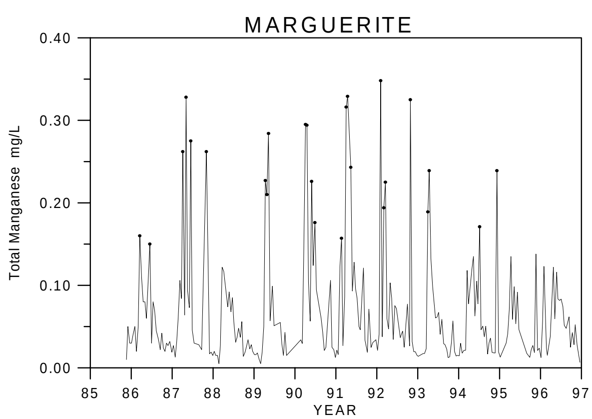

SUMAS
Total Lithium mg/L
0.016
0.012
0.008
0.004
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

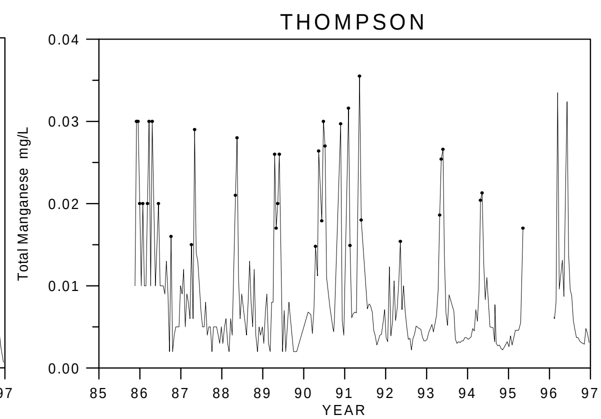

RED PASS
Total Manganese mg/L
0.00
0.01
0.02
0.03
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

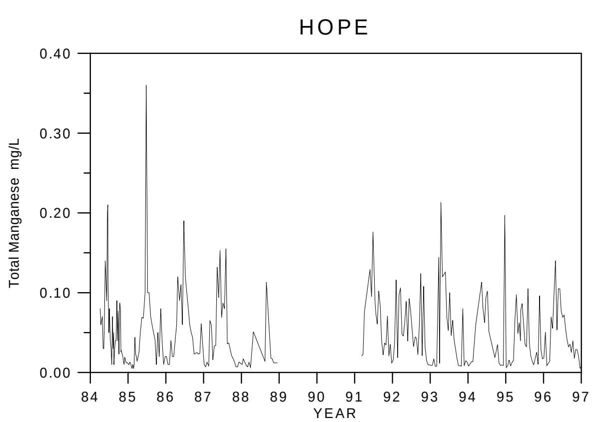

NECHAKO
Total Manganese mg/L
0.00
0.04
0.08
0.12
0.16
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

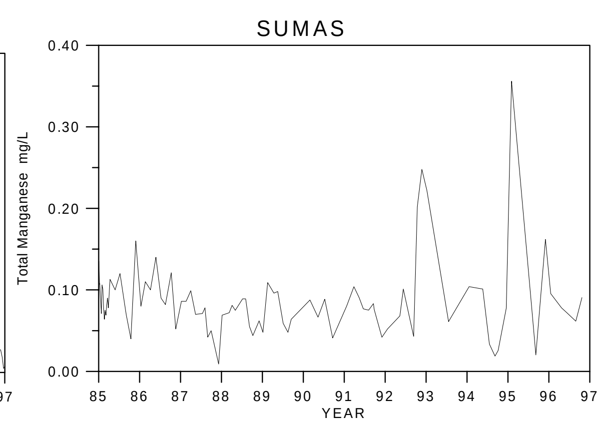

HANSARD
Total Manganese mg/L
0.00
0.10
0.20
0.30
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

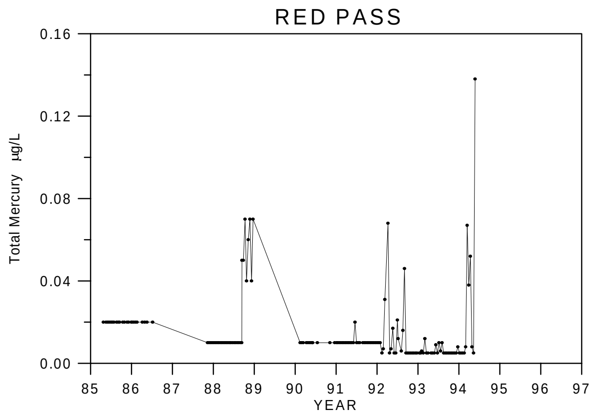

SALMON
Total Manganese mg/L
0.00
0.04
0.08
0.12
0.16
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

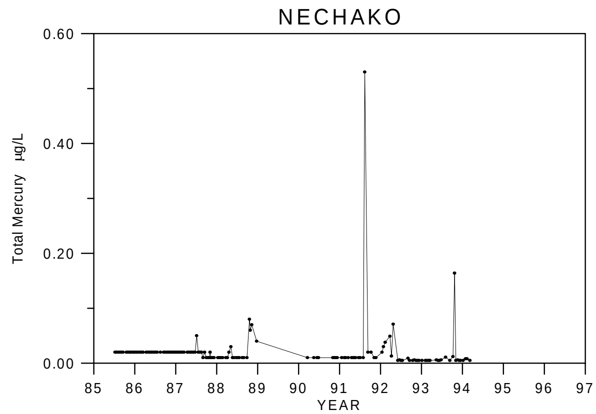

MARGUERITE
Total Manganese mg/L
0.00
0.10
0.20
0.30
0.40
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

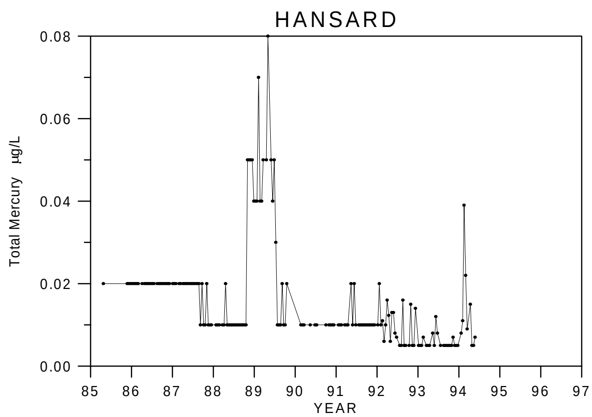

THOMPSON
Total Manganese mg/L
0.00
0.01
0.02
0.03
0.04
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

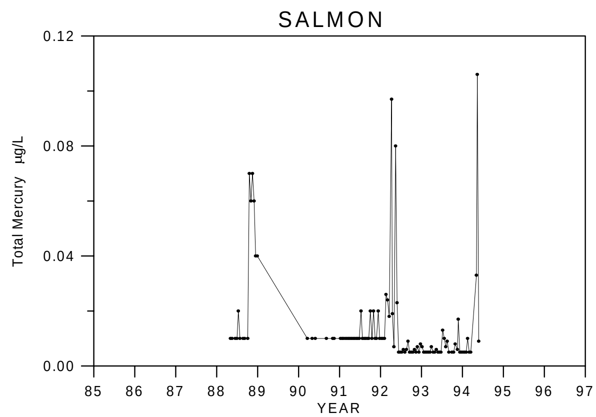

HOPE
Total Manganese mg/L
0.00
0.10
0.20
0.30
0.40
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

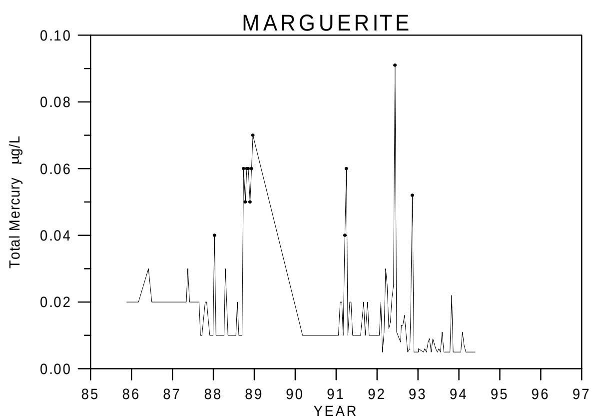

SUMAS
Total Manganese mg/L
0.00
0.10
0.20
0.30
0.40
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

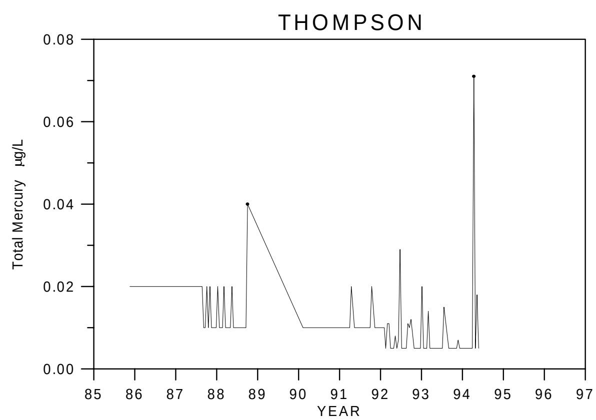

RED PASS
Total Mercury µg/L
0.00
0.04
0.08
0.12
0.16
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

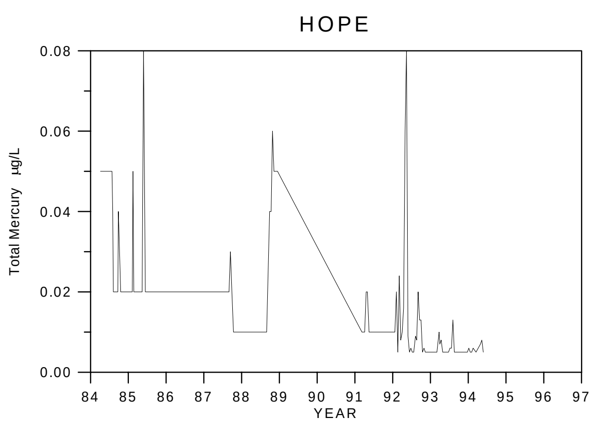

NECHAKO
Total Mercury µg/L
0.00
0.20
0.40
0.60
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

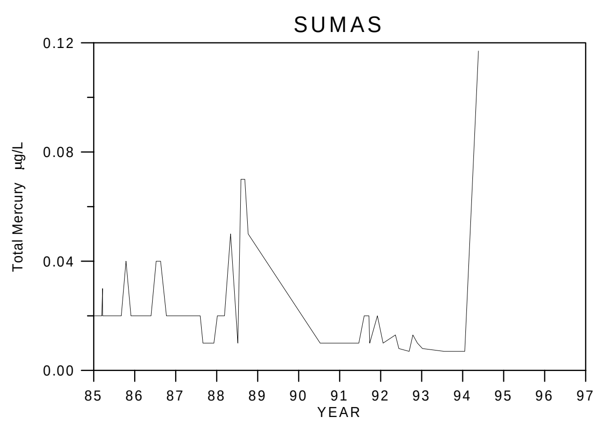

HANSARD
Total Mercury µg/L
0.00
0.02
0.04
0.06
0.08
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

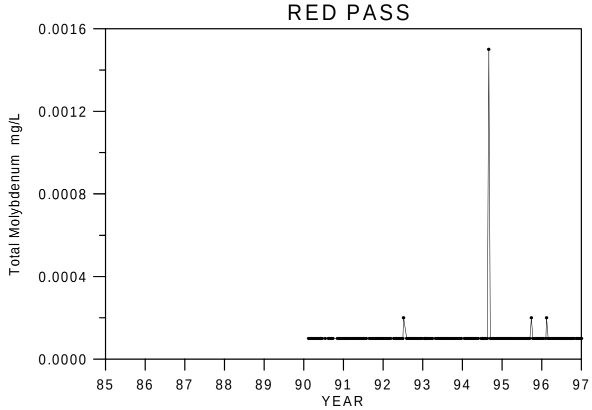

SALMON
Total Mercury µg/L
0.00
0.04
0.08
0.12
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

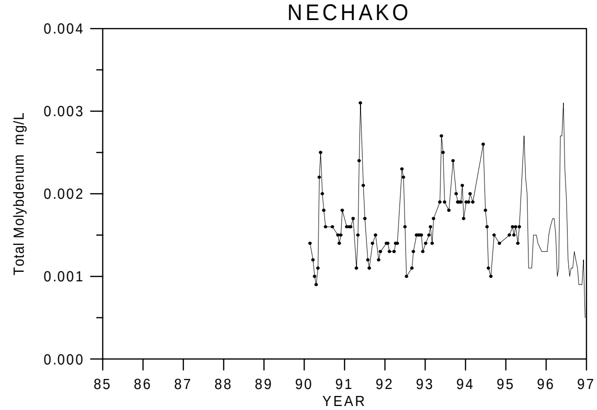

MARGUERITE
Total Mercury µg/L
0.00
0.02
0.04
0.06
0.08
0.10
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

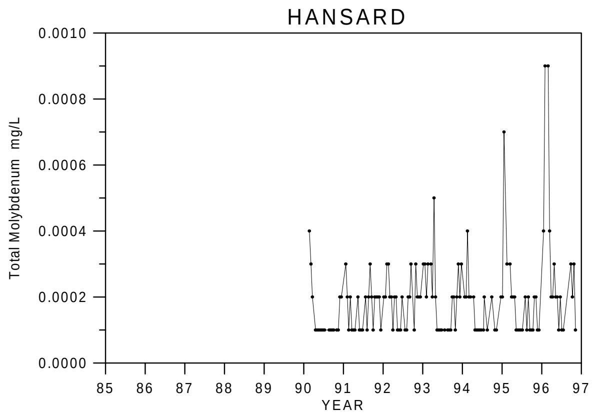

THOMPSON
Total Mercury µg/L
0.00
0.02
0.04
0.06
0.08
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

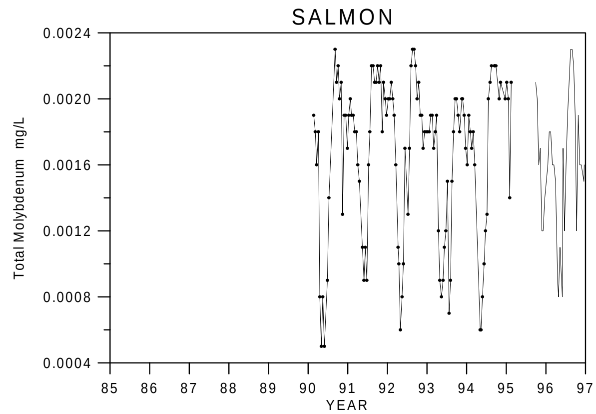

HOPE
Total Mercury µg/L
0.00
0.02
0.04
0.06
0.08
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

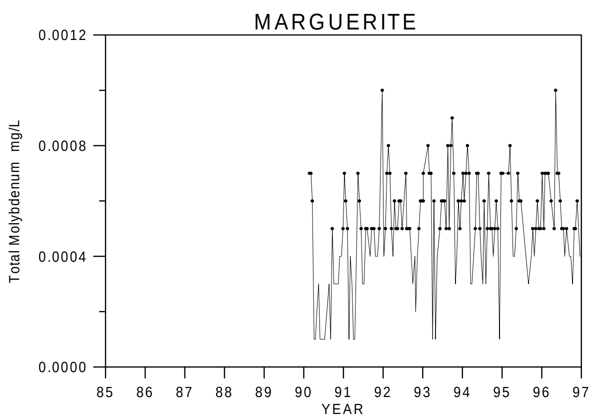

SUMAS
Total Mercury µg/L
0.00
0.04
0.08
0.12
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

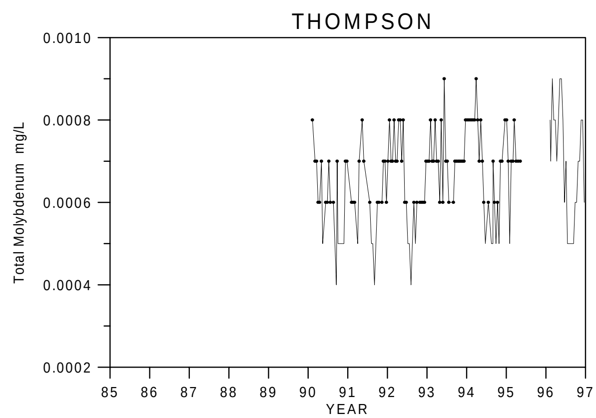

RED PASS
Total Molybdenum mg/L
0.0016
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

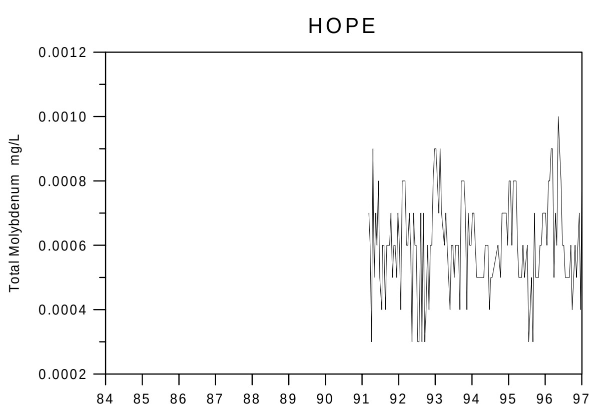

NECHAKO
Total Molybdenum mg/L
0.004
0.003
0.002
0.001
0.000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

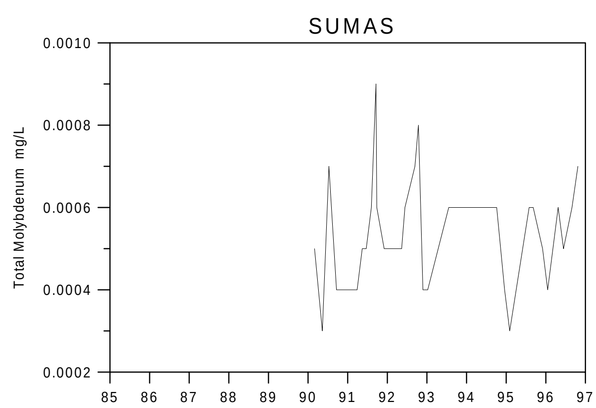

HANSARD
Total Molybdenum mg/L
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

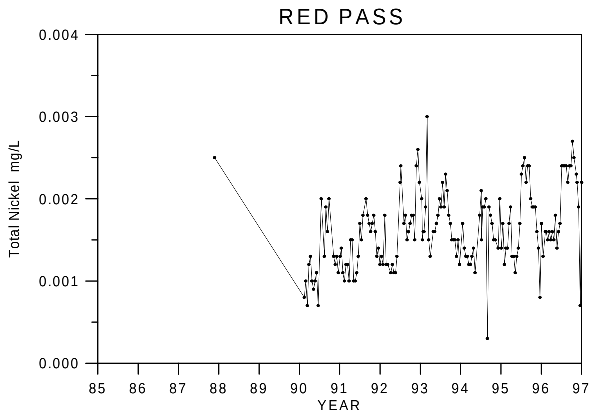

SALMON
Total Molybdenum mg/L
0.0024
0.0020
0.0016
0.0012
0.0008
0.0004
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

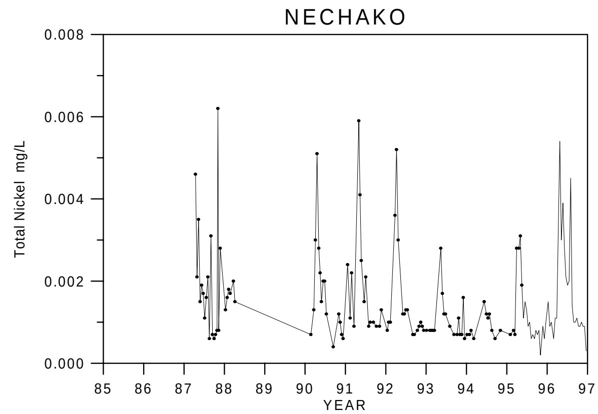

MARGUERITE
Total Molybdenum mg/L
0.0012
0.0008
0.0004
0.0000
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

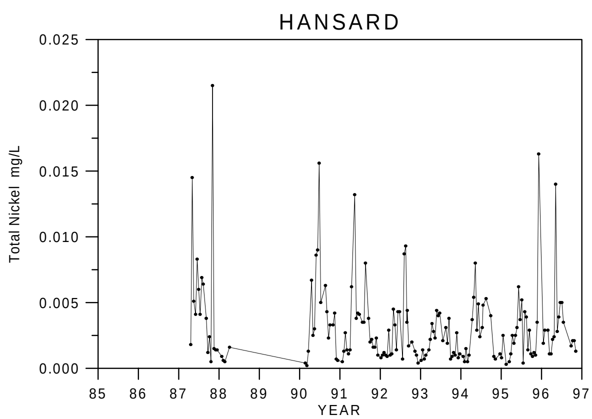

THOMPSON
Total Molybdenum mg/L
0.0010
0.0008
0.0006
0.0004
0.0002
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

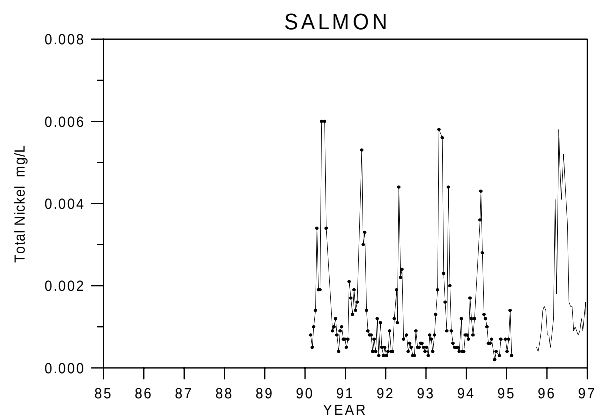

HOPE
Total Molybdenum mg/L
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

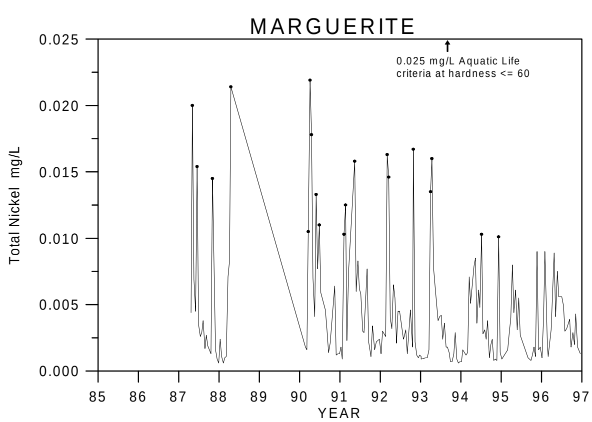

SUMAS
Total Molybdenum mg/L
0.0010
0.0008
0.0006
0.0004
0.0002
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

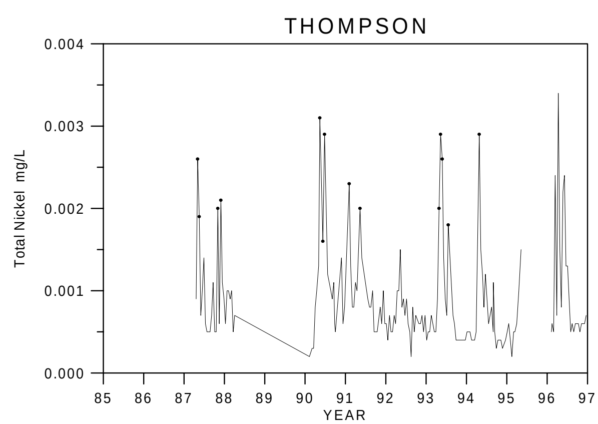

RED PASS
Total Nickel mg/L
0.000
0.001
0.002
0.003
0.004
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

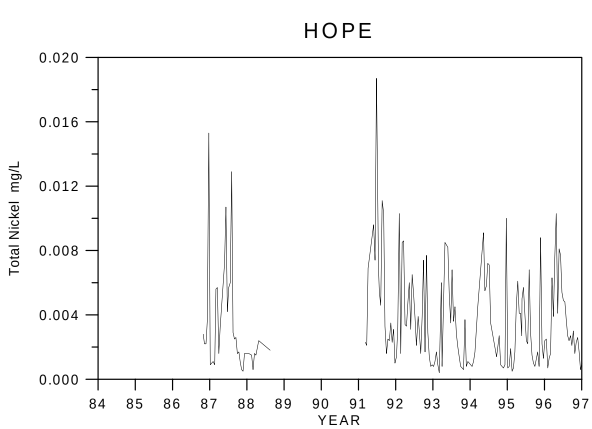

NECHAKO
Total Nickel mg/L
0.000
0.002
0.004
0.006
0.008
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

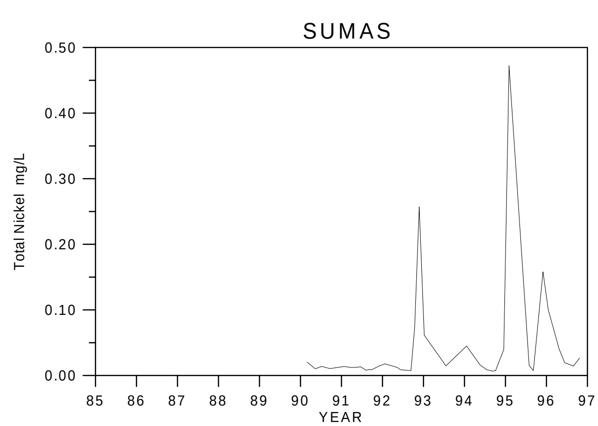

HANSARD
Total Nickel mg/L
0.000
0.005
0.010
0.015
0.020
0.025
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SALMON
Total Nickel mg/L
0.000
0.002
0.004
0.006
0.008
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

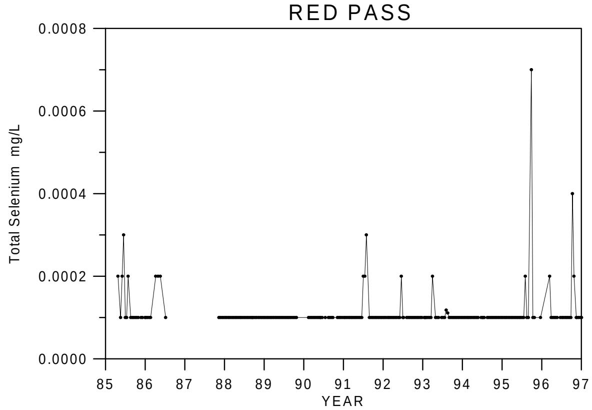

MARGUERITE
0.025 mg/L Aquatic Life
criteria at hardness <= 60
Total Nickel mg/L
0.000
0.005
0.010
0.015
0.020
0.025
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


THOMPSON
Total Nickel mg/L
0.000
0.001
0.002
0.003
0.004
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

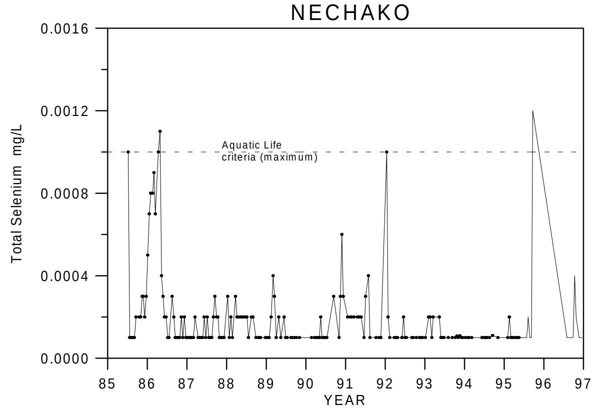

HOPE
Total Nickel mg/L
0.000
0.004
0.008
0.012
0.016
0.020
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SUMAS
Total Nickel mg/L
0.00
0.10
0.20
0.30
0.40
0.50
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

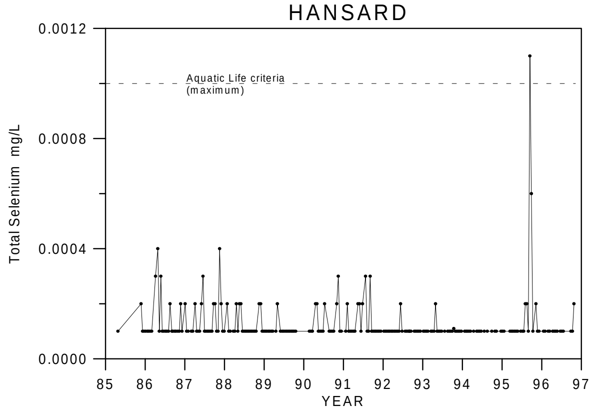
RED PASS



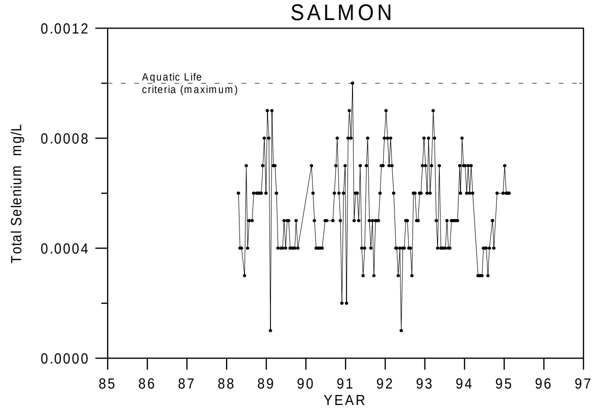
NECHAKO



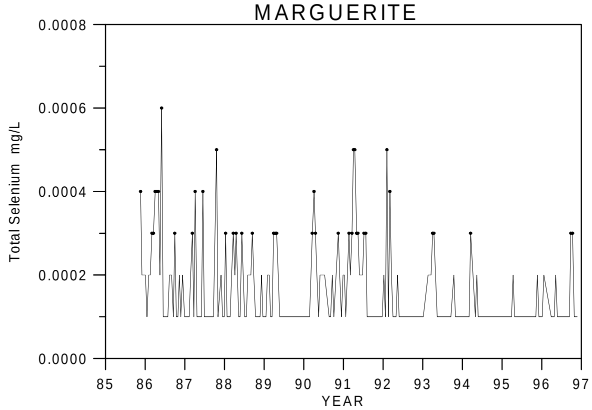
HANSARD



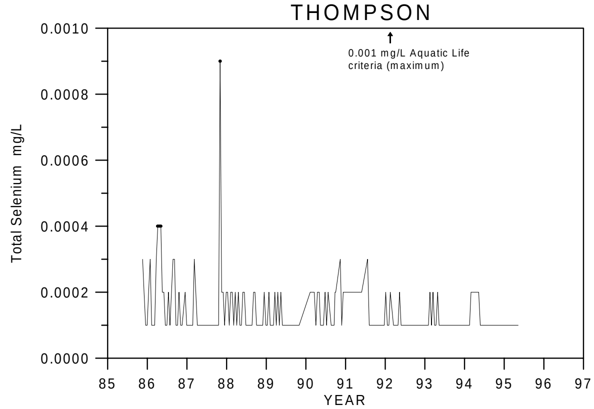
SALMON



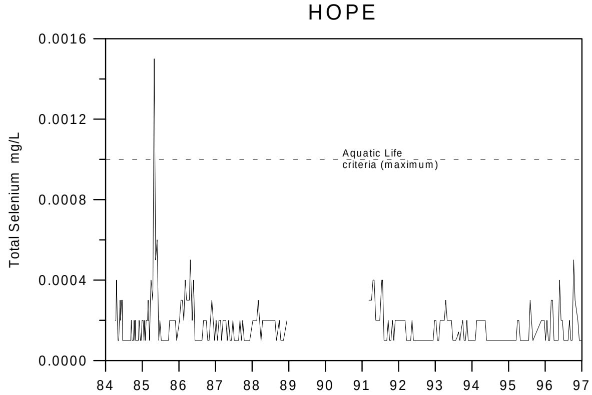
MARGUERITE



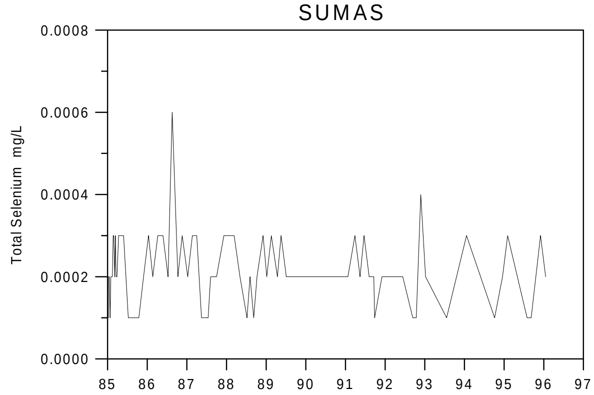
THOMPSON



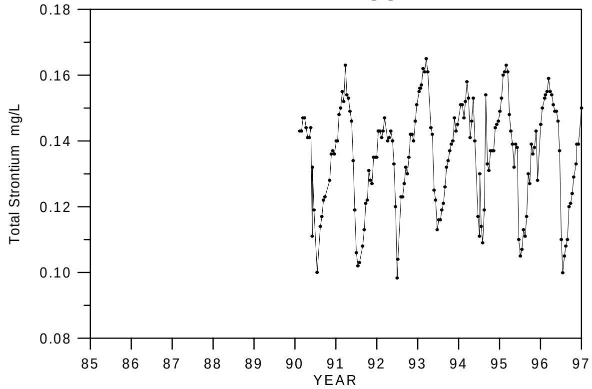
HOPE



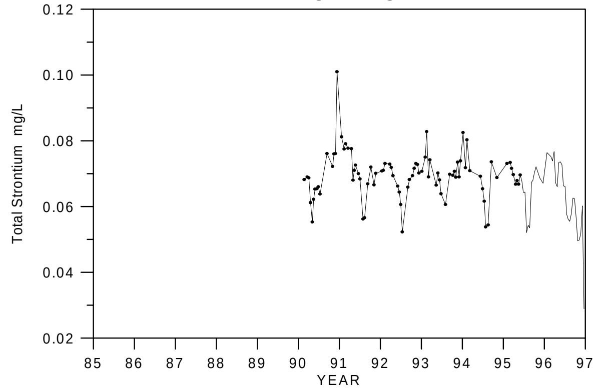
SUMAS



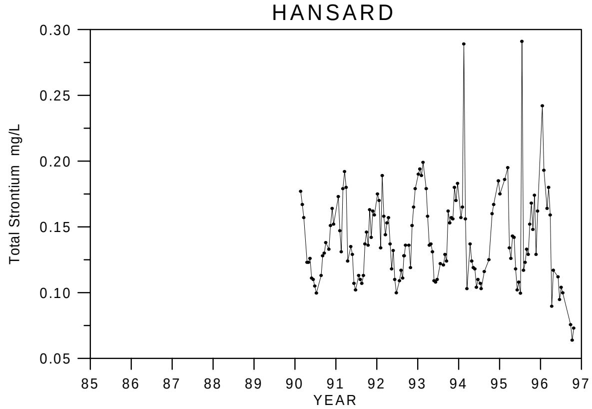
RED PASS



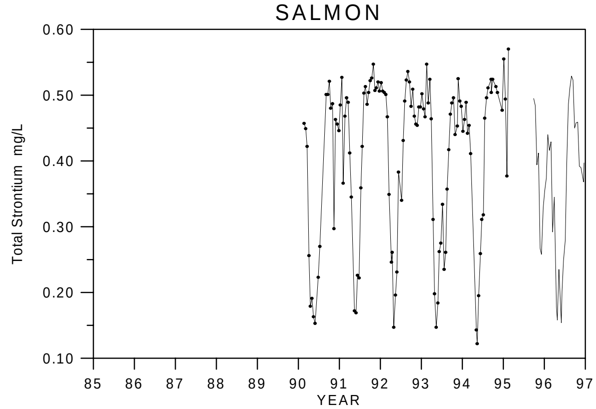
NECHAKO



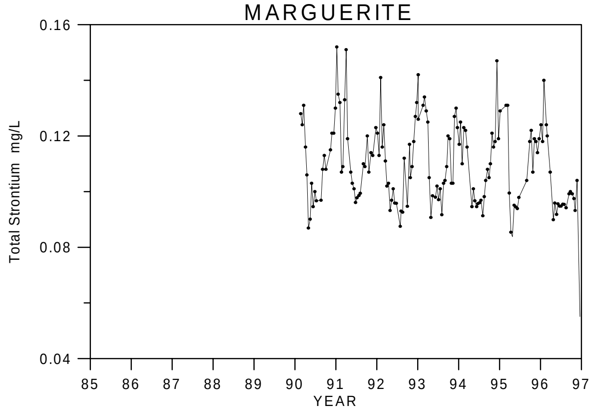
HANSARD



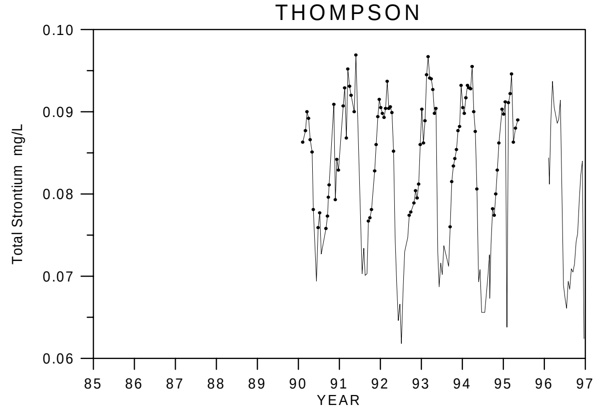
SALMON



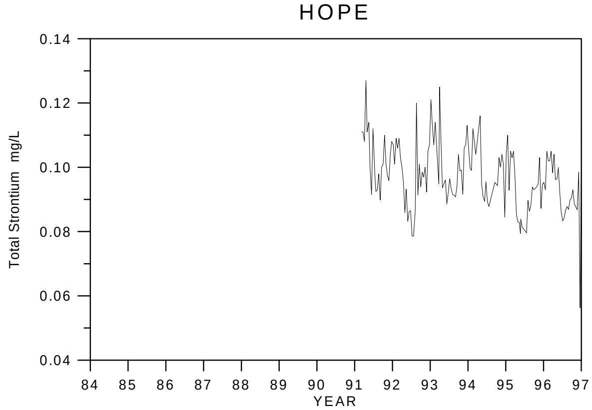
MARGUERITE



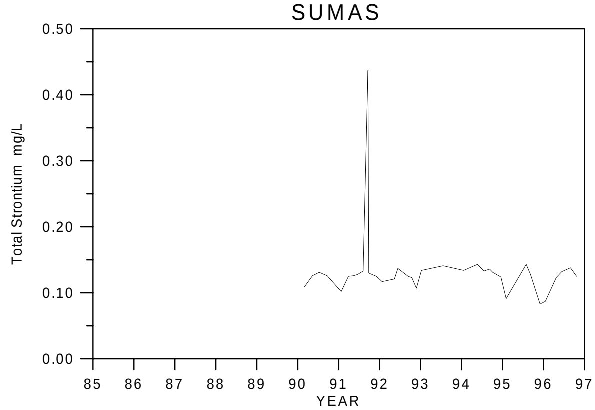
THOMPSON

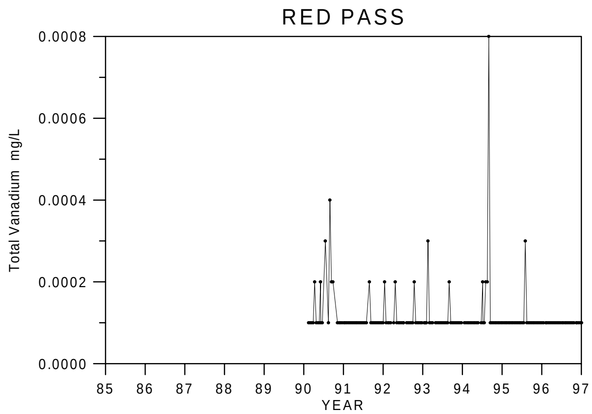


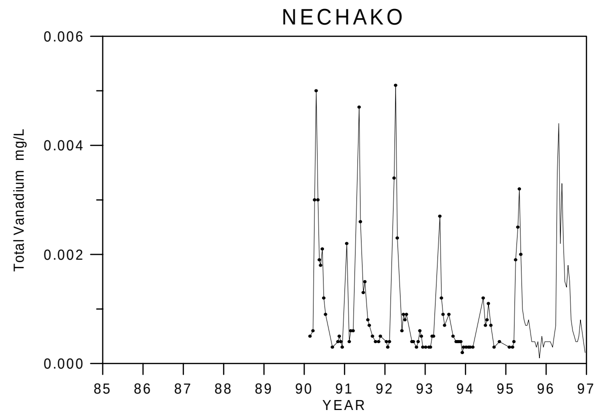
HOPE

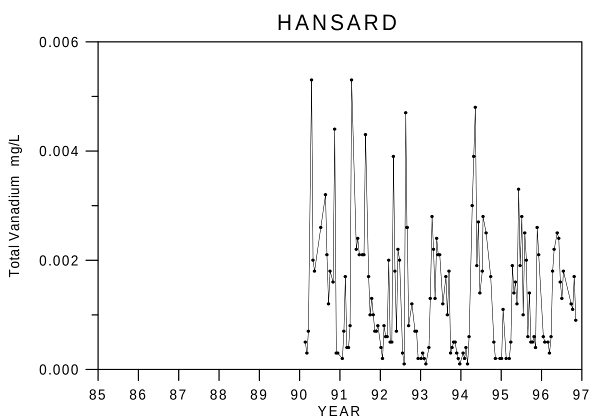


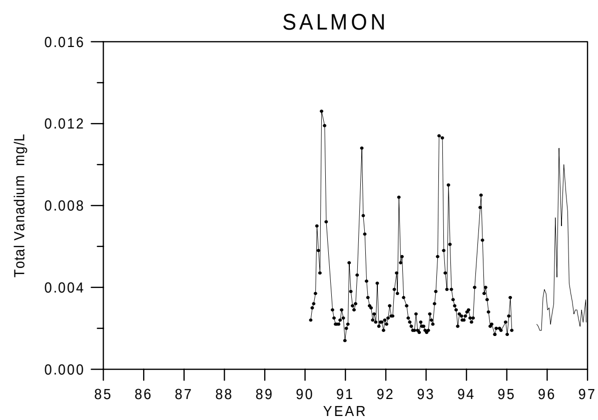
SUMAS

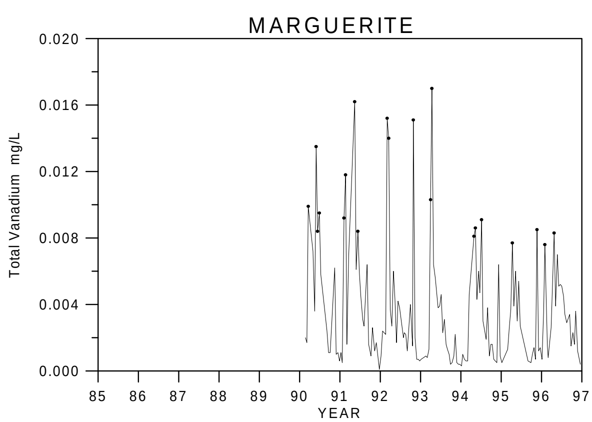


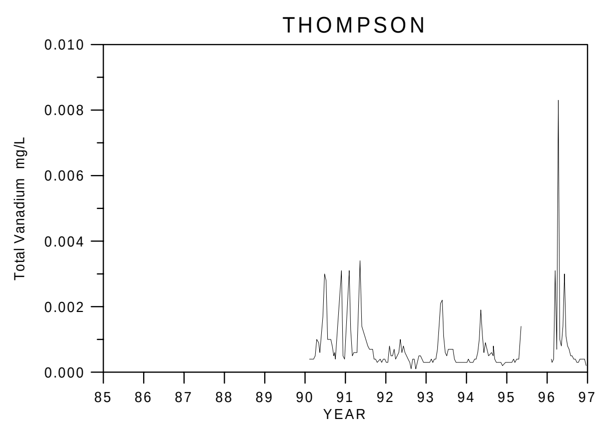

RED PASS
Total Vanadium mg/L
0.0000
0.0002
0.0004
0.0006
0.0008
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

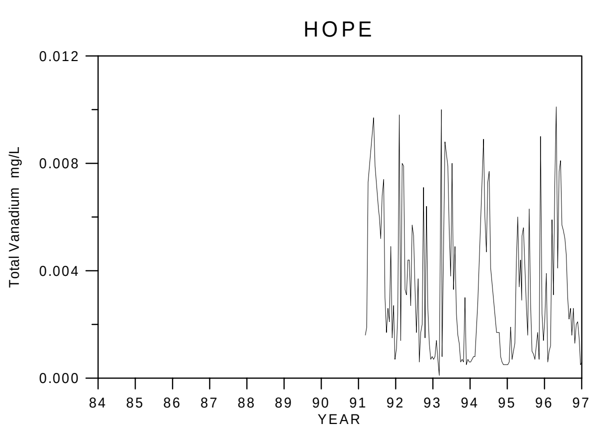

NECHAKO
Total Vanadium mg/L
0.000
0.002
0.004
0.006
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

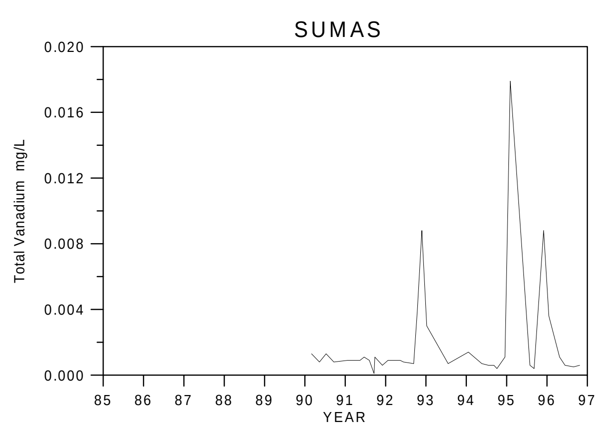

HANSARD
Total Vanadium mg/L
0.000
0.002
0.004
0.006
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SALMON
Total Vanadium mg/L
0.000
0.004
0.008
0.012
0.016
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

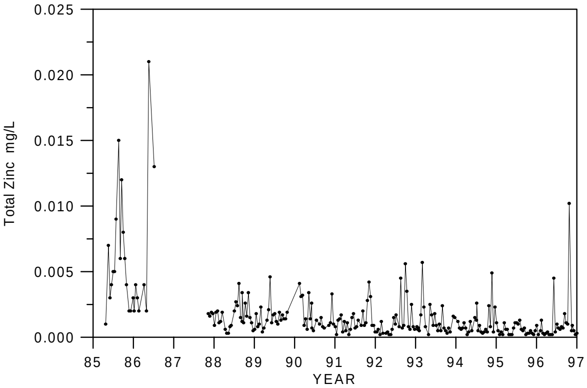

MARGUERITE
Total Vanadium mg/L
0.000
0.004
0.008
0.012
0.016
0.020
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


THOMPSON
Total Vanadium mg/L
0.000
0.002
0.004
0.006
0.008
0.010
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

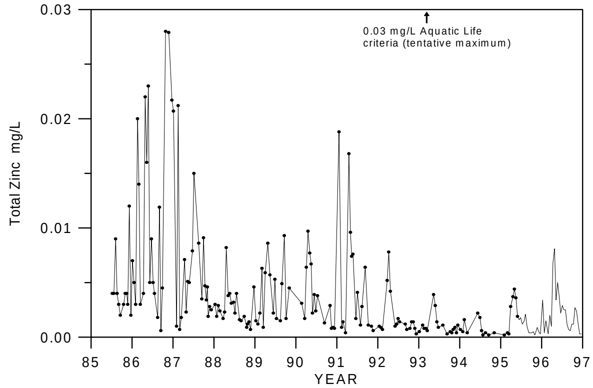

HOPE
Total Vanadium mg/L
0.000
0.004
0.008
0.012
84 85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


SUMAS
Total Vanadium mg/L
0.000
0.004
0.008
0.012
0.016
0.020
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

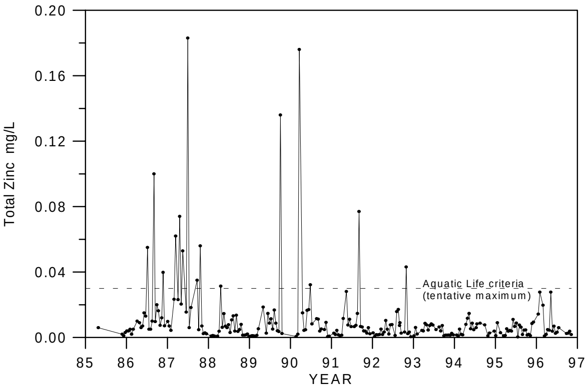
RED PASS



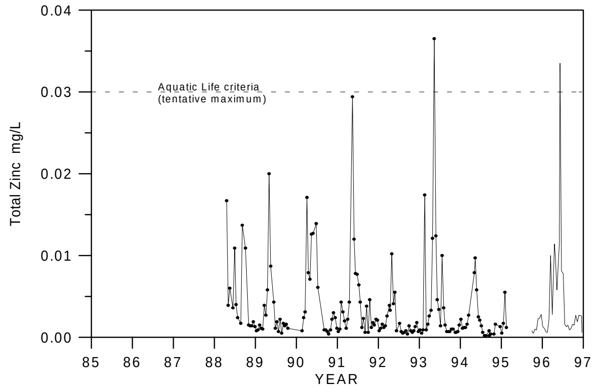
NECHAKO



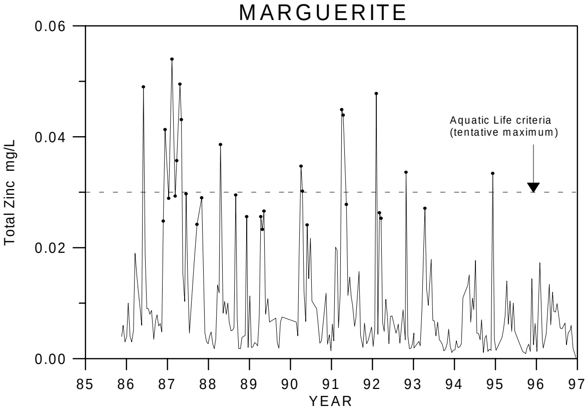
HANSARD



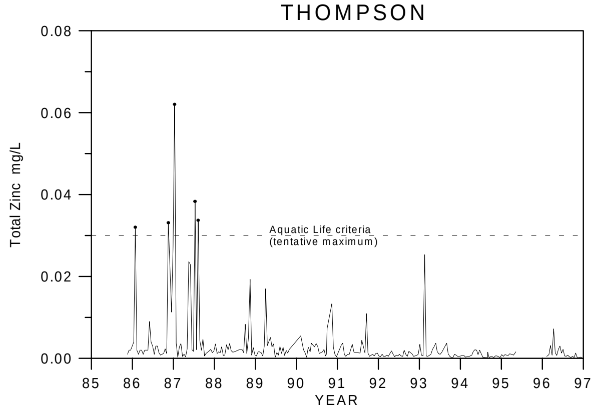
SALMON



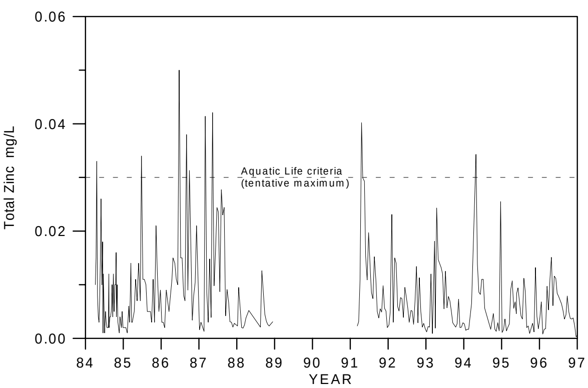
MARGUERITE



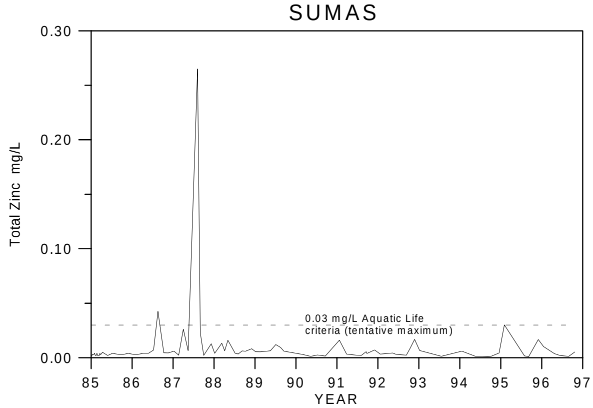
THOMPSON



HOPE

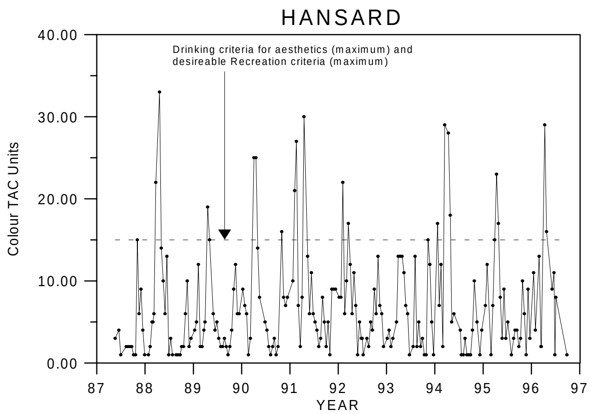


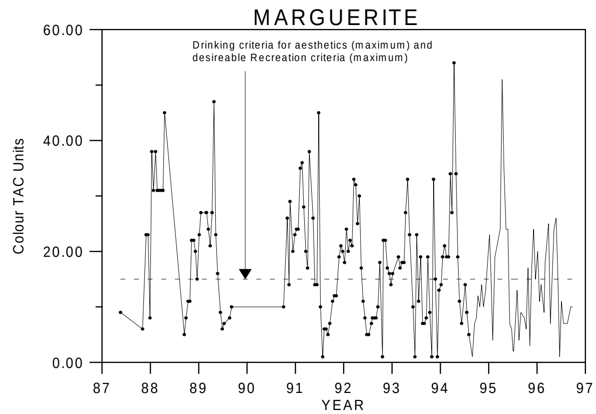
SUMAS

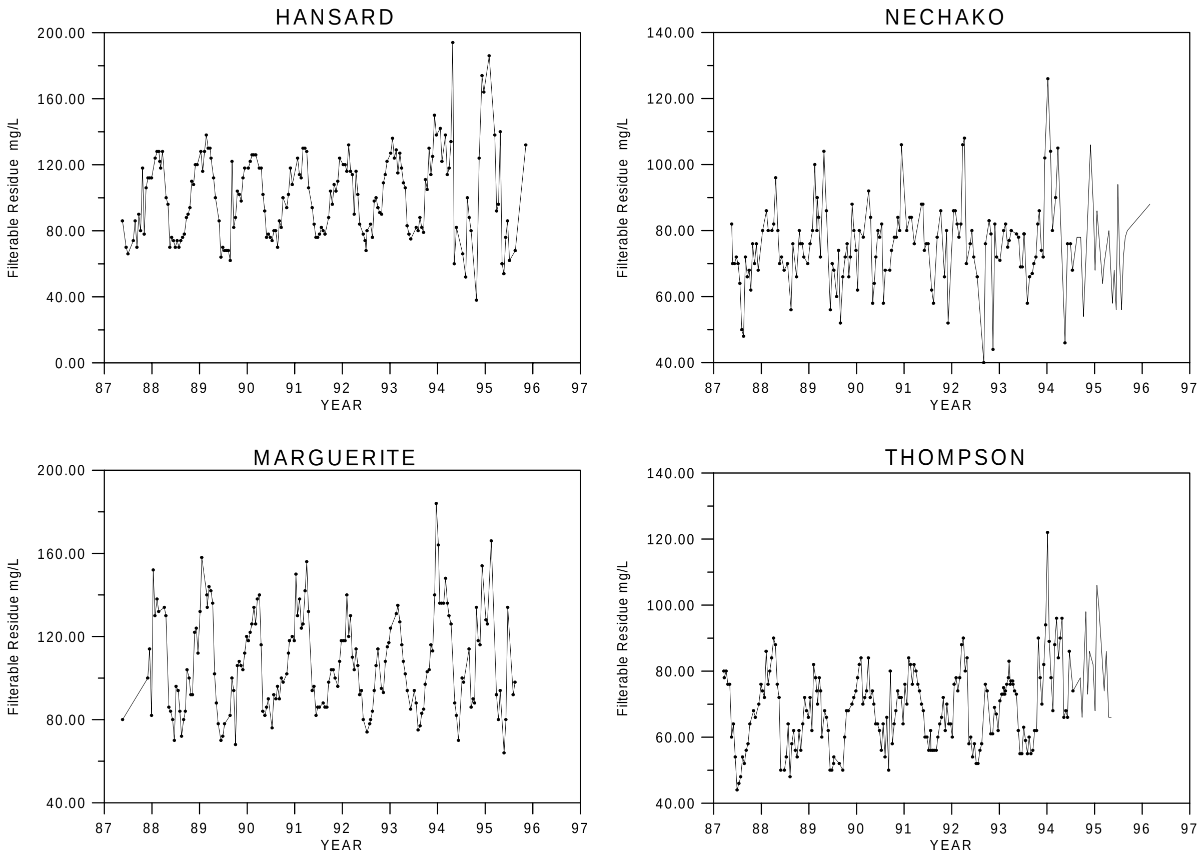


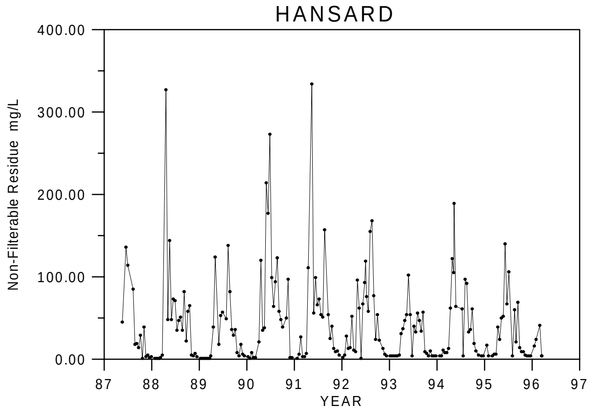
APPENDIX 5

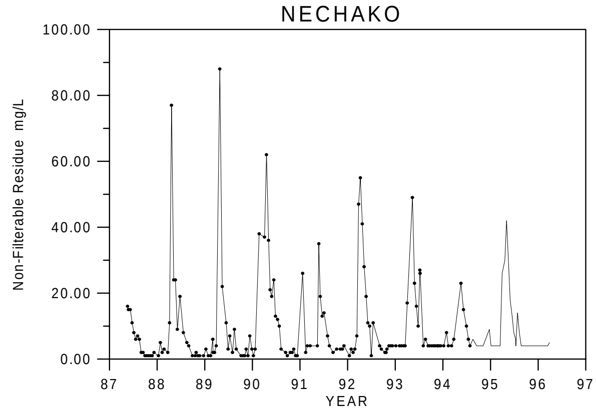
Time series plots of B.C. Ministry of Environment, Lands and Parks water quality monitoring data analyzed at sites in the Fraser River basin

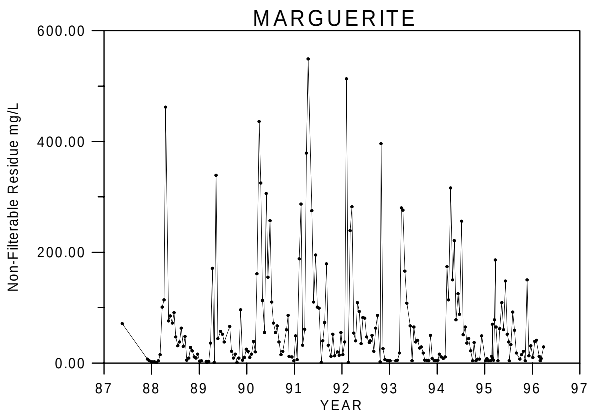

HANSARD
Drinking criteria for aesthetics (maximum) and
desireable Recreation criteria (maximum)
Colour TAC Units
YEAR
0.00
10.00
20.00
30.00
40.00
87 88 89 90 91 92 93 94 95 96 97

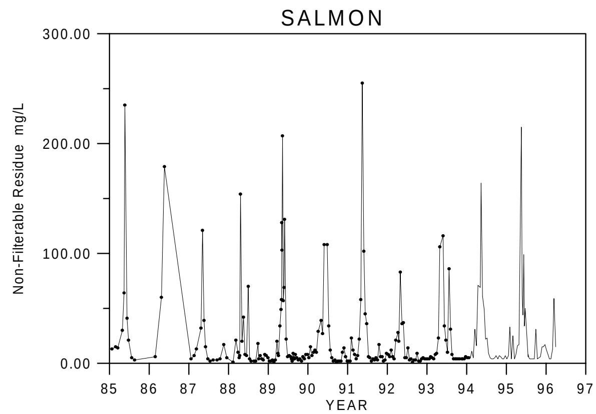

MARGUERITE
Drinking criteria for aesthetics (maximum) and
desireable Recreation criteria (maximum)
Colour TAC Units
YEAR
0.00
20.00
40.00
60.00
87 88 89 90 91 92 93 94 95 96 97

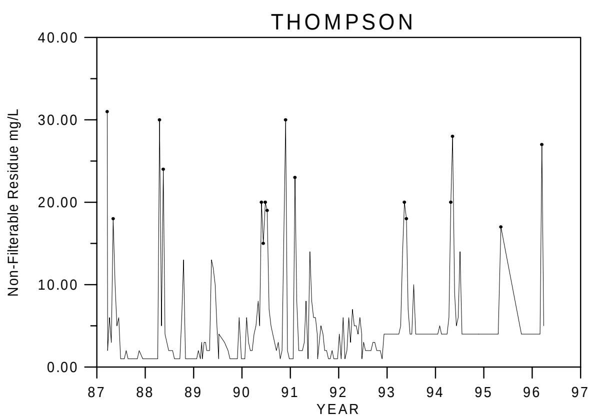

HANSARD
NECHAKO
MARGUERITE
THOMPSON
Filterable Residue mg/L
YEAR
0.00
40.00
80.00
120.00
160.00
200.00
60.00
100.00
140.00
87
88
89
90
91
92
93
94
95
96
97

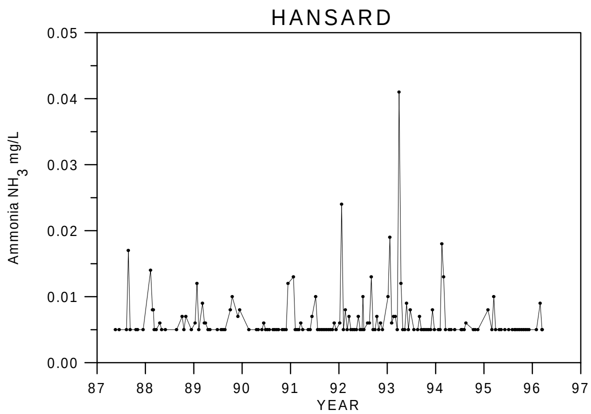

HANSARD
Non-Filterable Residue mg/L
YEAR

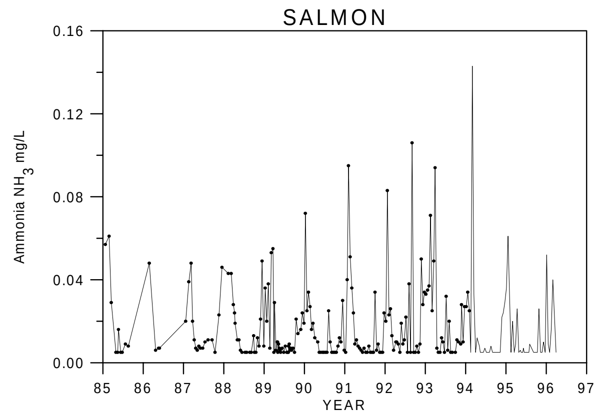

NECHAKO
Non-Filterable Residue mg/L
YEAR

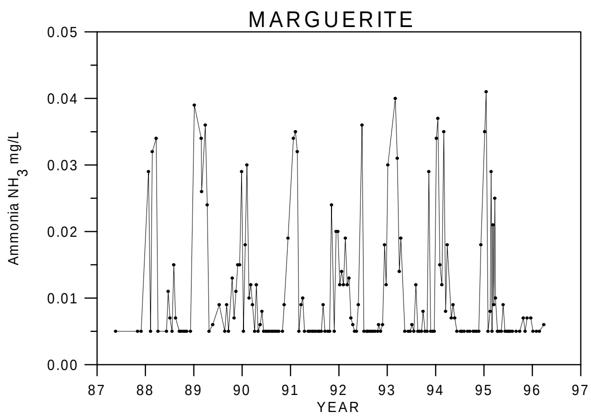

MARGUERITE
Non-Filterable Residue mg/L
YEAR

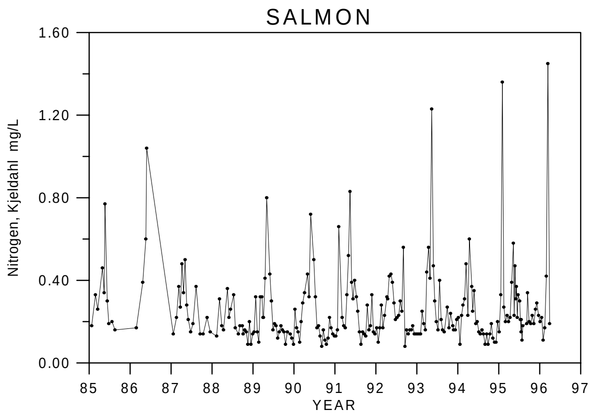

SALMON
Non-Filterable Residue mg/L
YEAR

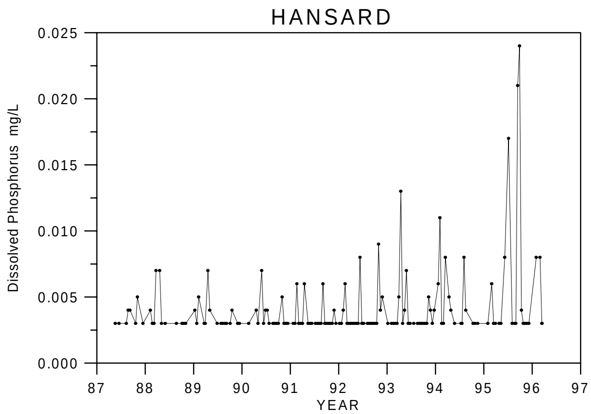

THOMPSON
Non-Filterable Residue mg/L
YEAR

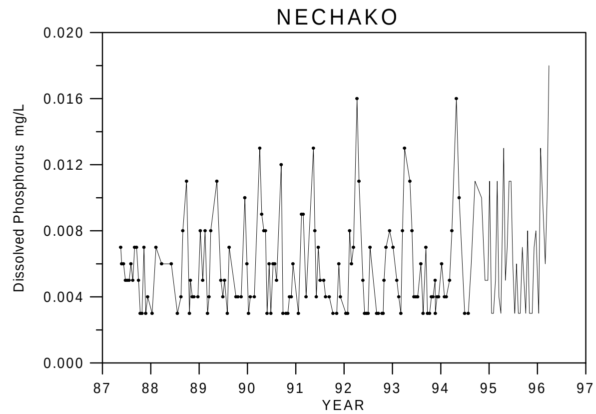

HANSARD
Ammonia NH_3 mg/L
0.05
0.04
0.03
0.02
0.01
0.00
87
88
89
90
91
92
93
94
95
96
97
YEAR

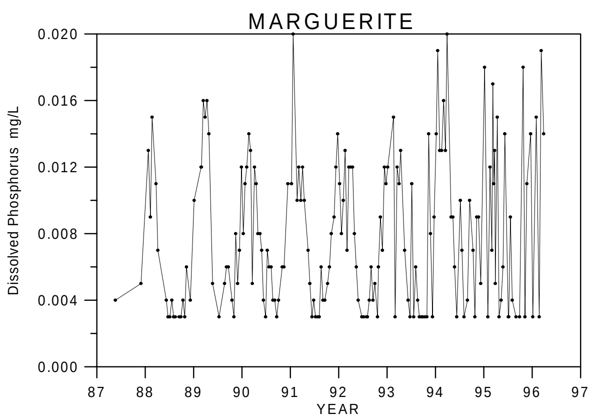

SALMON
Ammonia NH_3 mg/L
0.16
0.12
0.08
0.04
0.00
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

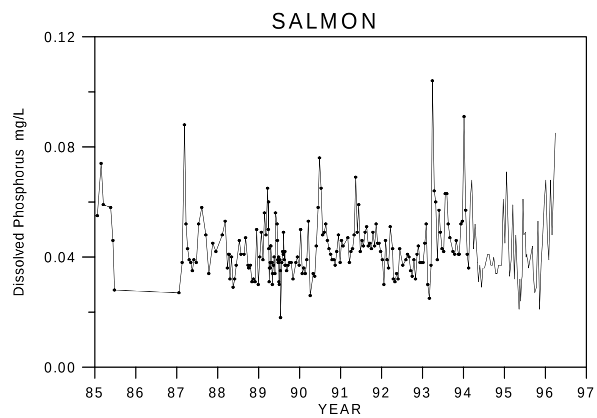

MARGUERITE
Ammonia NH_3 mg/L
0.05
0.04
0.03
0.02
0.01
0.00
87
88
89
90
91
92
93
94
95
96
97
YEAR

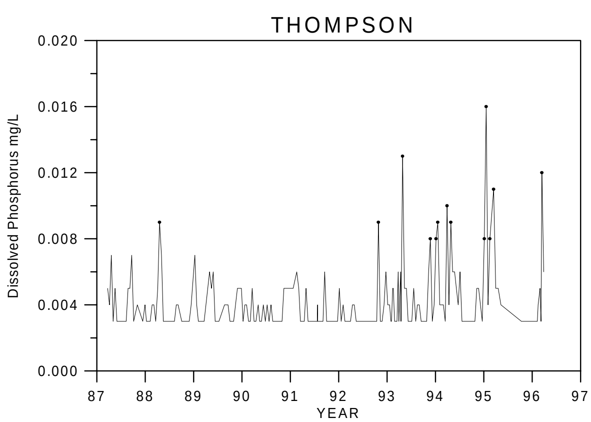

SALMON
1.60
1.20
0.80
0.40
0.00
Nitrogen, Kjeldahl mg/L
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

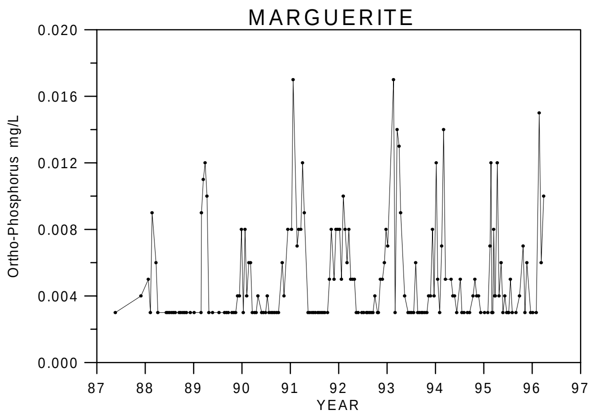

HANSARD
Dissolved Phosphorus mg/L
0.025
0.020
0.015
0.010
0.005
0.000
87 88 89 90 91 92 93 94 95 96 97
YEAR

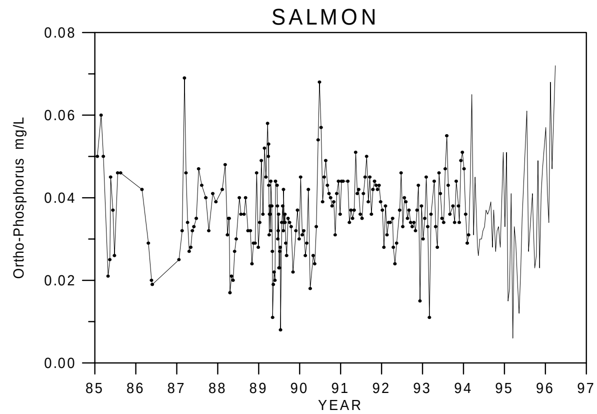

NECHAKO
Dissolved Phosphorus mg/L
0.020
0.016
0.012
0.008
0.004
0.000
87 88 89 90 91 92 93 94 95 96 97
YEAR

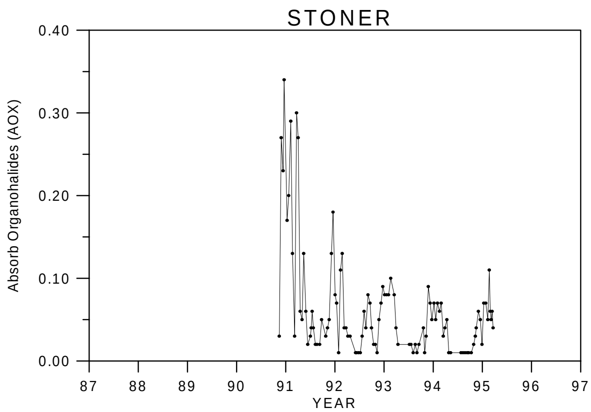

MARGUERITE
Dissolved Phosphorus mg/L
0.020
0.016
0.012
0.008
0.004
0.000
87 88 89 90 91 92 93 94 95 96 97
YEAR

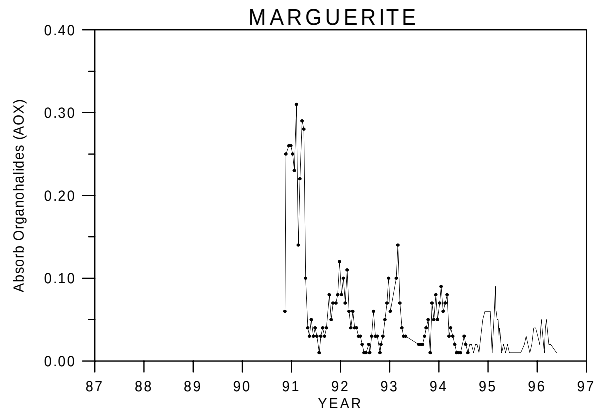

SALMON
Dissolved Phosphorus mg/L
0.12
0.08
0.04
0.00
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR

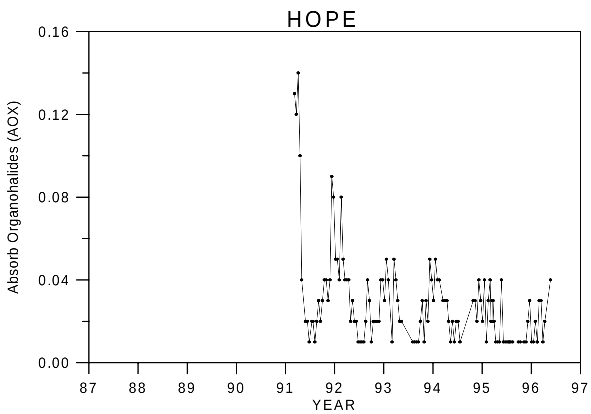

THOMPSON
Dissolved Phosphorus mg/L
0.020
0.016
0.012
0.008
0.004
0.000
87 88 89 90 91 92 93 94 95 96 97
YEAR

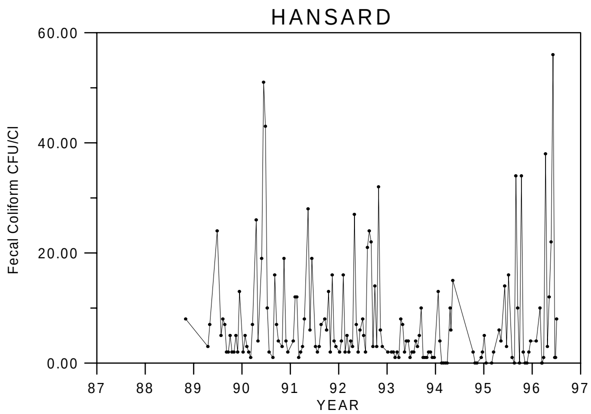

MARGUERITE
Ortho-Phosphorus mg/L
0.020
0.016
0.012
0.008
0.004
0.000
87
88
89
90
91
92
93
94
95
96
97
YEAR

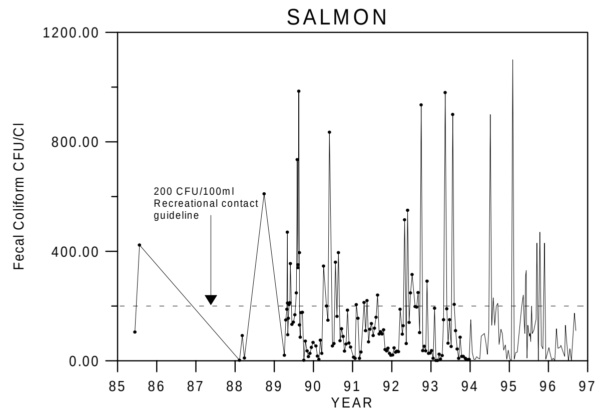

SALMON
Ortho-Phosphorus mg/L
0.08
0.06
0.04
0.02
0.00
85
86
87
88
89
90
91
92
93
94
95
96
97
YEAR

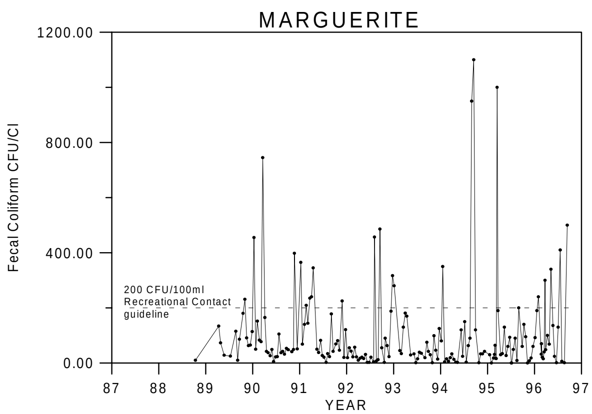

STONER
Absorb Organohalides (AOX)
0.40
0.30
0.20
0.10
0.00
87 88 89 90 91 92 93 94 95 96 97
YEAR


MARGUERITE
Absorb Organohalides (AOX)
0.40
0.30
0.20
0.10
0.00
87 88 89 90 91 92 93 94 95 96 97
YEAR


HOPE
Absorb Organohalides (AOX)
0.16
0.12
0.08
0.04
0.00
87 88 89 90 91 92 93 94 95 96 97
YEAR


HANSARD
Fecal Coliform CFU/Cl
60.00
40.00
20.00
0.00
87 88 89 90 91 92 93 94 95 96 97
YEAR


SALMON
Fecal Coliform CFU/Cl
1200.00
800.00
400.00
0.00
200 CFU/100ml
Recreational contact
guideline
85 86 87 88 89 90 91 92 93 94 95 96 97
YEAR


MARGUERITE
Fecal Coliform CFU/Cl
1200.00
800.00
400.00
0.00
200 CFU/100ml
Recreational Contact
guideline
87 88 89 90 91 92 93 94 95 96 97
YEAR

APPENDIX 6

Non-parametric and regression modelling results of Environment Canada and BC Ministry of Environment, Lands and Parks water quality monitoring data in the Fraser River basin, 1984 - 1996.

Table A6. 1 Non-parametric test results for Environment Canada monitoring data in the Fraser River at Red Pass. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	NS	NS	NS	NS	N/A	N/A	N/A
pH	NS	NS	NS	NS	N/A	N/A	N/A
Apparent Colour	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Specific Conductivity	NS	41.827*	6.453*	2.761*	0.873	0.339	1.583
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Total Alkalinity	NS	NS	NS	NS	N/A	N/A	N/A
Calcium	23.673*	3.499	1.851	NS	0.030	-0.059	0.130
Chloride	NS	15.721*	3.943*	1.772	0.007	0.000	0.0167
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	NS	46.274*	6.771*	NS	0.204	-0.120	0.465
Hardness	NS	34.372*	5.829*	NS	1.109	-0.763	2.742
SiO_2	NS	NS	NS	NS	NS	NS	NS
Potassium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	NS	6.160*	2.439*	NS	0.001	0.000	0.007
Dissolved Sulphate	NS	35.093*	5.909*	2.189*	0.217	0.025	0.386
NO_2/NO_3	NS	3.271	1.799	NS	0.001	-0.001	0.002
Dissolved Nitrogen	NS	NS	NS	NS	N/A	N/A	N/A
Total Phosphorus	NS	NS	NS	NS	N/A	N/A	N/A
Aluminum	NS	4.283*	-2.041*	NS	-0.003	-0.016	0.002
Arsenic	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Barium	NS	3.907*	-1.930	NS	-0.000	-0.001	0.000
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	NS	8.277*	-2.840*	NS	-0.000	-0.000	0.000
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	NS	NS	NS	NS	N/A	N/A	N/A
Manganese	NS	NS	NS	NS	N/A	N/A	N/A
Molybdenum	NS	NS	NS	NS	N/A	N/A	N/A
Nickel	NS	NS	NS	NS	N/A	N/A	N/A
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A

* - Significant at the 5 % level. N/A - Not adequate for analysis

NS - Non-significant ($p > 0.10$)

Table A6. 2 Regression modelling results for Environment Canada monitoring data in the Fraser River at Red Pass.

CONSTITUENTS	b_0	flow b_1	linear trend b_2	quadratic trend b_3	seasonality α_1	seasonality α_2	seasonality ω	fit r^2
Flow	3.0787	N/A	NS	---	0.2812	NS	0.0204	0.03
Water Temperature	-0.451	0.678	-0.146	0.0135	-0.349	0.239	0.033	0.73
pH*	7.966	NS	NS	---	0.029	NS	0.010	0.08
Apparent Colour	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Specific Conductivity	4.789	NS	0.034	-0.0021	0.044	0.141	0.019	0.84
Turbidity	NS	NS	NS	---	-0.345	-1.154	0.019	0.60
Total Alkalinity	3.894	NS	0.005	---	0.061	0.164	0.019	0.86
Calcium	2.798	NS	0.011	---	0.028	0.130	0.020	0.77
Chloride	-1.225	NS	0.128	-0.008	NS	0.309	0.019	0.65
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	5.195	-0.117	0.158	---	0.197	0.783	0.019	0.84
Hardness	4.128	NS	0.016	---	0.034	0.133	0.019	0.81
SiO_2	0.611	-0.050	-0.126	0.018	NS	NS	0.047	0.32
Potassium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	-0.461	NS	0.057	-0.005	0.060	0.292	0.019	0.73
Dissolved Sulphate	14.705	-1.231	0.450	---	-0.250	0.388	0.057	0.73
NO_2/NO_3	-2.078	-0.282	0.039	---	NS	-0.389	0.031	0.41
Dissolved Nitrogen	-1.886	-0.198	NS	---	-0.072	-0.282	0.029	0.33
Total Phosphorus	-5.794	NS	NS	---	NS	-0.241	0.022	0.22
Aluminum	-2.761	0.120	-0.058	---	NS	-0.572	0.020	0.78
Arsenic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Barium	-4.212	-0.037	NS	---	NS	0.024	0.055	0.47
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	-7.456	NS	-0.212	---	NS	0.220	0.017	0.27
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	-5.040	0.684	0.132	-0.021	0.176	0.333	0.027	0.68
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	-6.147	-0.068	0.074	-0.009	NS	0.016	0.053	0.55
Manganese	-5.288	0.091	NS	---	0.099	-0.343	0.021	0.60
Molybdenum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	-6.607	NS	0.051	---	NS	-0.219	0.019	0.31
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	-1.753	-0.086	NS	---	0.044	NS	0.044	0.69
Vanadium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Not log transformed   N/A - Not adequate for analysis

NS - Non-significant ($p > 0.05$)

Table A6. 3 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Hansard. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	17.419	NS	NS	NS	N/A	N/A	N/A
pH	NS	NS	NS	NS	N/A	N/A	N/A
Colour TAC[3]	NS	NS	NS	NS	N/A	N/A	N/A
Apparent Colour	NS	4.973*	2.213*	NS	0.500	0.000	1.250
Specific Conductivity	NS	22.570*	4.728*	2.490*	1.364	0.471	2.629
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Filterable[3]	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Non-filterable[3]	NS	NS	NS	NS	N/A	N/A	N/A
Total Alkalinity	NS	NS	NS	NS	N/A	N/A	N/A
Calcium	NS	NS	NS	NS	N/A	N/A	N/A
Chloride	NS	4.499*	2.135*	NS	0.007	0.000	0.017
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	NS	14.674*	3.801*	1.724	0.080	-0.018	0.176
Hardness	NS	12.438*	3.496*	1.901	0.775	-0.005	1.798
SiO_2	NS	4.320*	2.027*	NS	0.047	-0.057	0.135
Potassium	NS	30.135*	5.475*	2.643*	0.012	0.002	0.022
Sodium	NS	7.749*	2.730*	NS	0.010	0.000	0.025
Dissolved Sulphate	NS	17.315*	4.143*	2.410*	0.184	0.034	0.350
NH_3, Ammonia[3]	NS	NS	NS	NS	N/A	N/A	N/A
NO_2/NO_3	NS	2.948	1.686	NS	0.001	-0.001	0.003
Dissolved Nitrogen	NS	4.861*	2.184*	NS	0.002	-0.001	0.005
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	NS	NS	NS	NS	N/A	N/A	N/A
Aluminum	NS	NS	NS	NS	N/A	N/A	N/A
Arsenic	NS	2.855	NS	NS	N/A	N/A	N/A
Barium	NS	NS	NS	NS	N/A	N/A	N/A
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	NS	3.117	-1.765	NS	0.000	-0.000	0.000
Chromium	NS	4.522*	-2.083*	NS	-0.000	-0.000	0.000
Cobalt	NS	6.169*	-2.468*	-1.676	-0.000	-0.000	0.000
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	NS	17.699	-4.192*	-2.112*	-0.000	-0.000	0.000
Lithium	NS	NS	NS	NS	N/A	N/A	N/A
Manganese	NS	3.092	-1.732	NS	-0.001	-0.002	0.000
Molybdenum	NS	NS	NS	NS	N/A	N/A	N/A
Nickel	NS	NS	NS	NS	N/A	N/A	N/A
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	NS	NS	NS	NS	N/A	N/A	N/A

* - Significant at the 5 % level.
N/A - Not adequate for analysis

[3] - Constituent monitored by BC MoELP
NS - Non-significant ($p > 0.10$)

Table A6. 4 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Hansard.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	5.613	N/A	NS	---	0.251	-0.188	0.041	0.06
Water Temperature	-2.466	0.896	-0.459	0.038	-0.226	-0.321	0.041	0.53
pH*	7.918	NS	NS	---	NS	NS	0.020	0.06
Colour TAC[3]	-3.159	0.752	NS	NS	0.529	1.166	0.020	0.39
Apparent Colour	NS	0.340	0.044	---	NS	-0.219	0.047	0.22
Specific Conductivity	6.270	-0.228	0.011	---	0.031	-0.026	0.038	0.85
Turbidity	-3.285	0.937	NS	---	-0.237	-0.522	0.042	0.64
Residue, Filterable[3]	5.011	-0.080	NS	---	0.130	0.158	0.019	0.66
Residue, Non-filterable[3]	-4.940	1.316	0.242	-0.024	-0.286	-0.514	0.041	0.74
Total Alkalinity	4.875	-0.122	NS	---	0.138	0.138	0.019	0.84
Calcium	3.891	-0.123	-0.019	0.002	0.111	0.103	0.019	0.86
Chloride	NS	-0.180	NS	---	0.153	0.420	0.020	0.56
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	2.925	-0.272	0.020	---	0.045	NS	0.037	0.82
Hardness	5.104	-0.143	0.011	---	0.103	0.085	0.019	0.86
SiO_2	1.740	-0.106	-0.295	0.048	NS	0.090	0.062	0.28
Potassium*	0.604	-0.033	0.013	---	-0.046	0.025	0.036	0.27
Sodium	1.762	-0.317	0.012	---	0.068	0.243	0.020	0.85
Dissolved Sulphate	3.622	-0.227	0.017	---	0.108	-0.179	0.022	0.54
NH_3, Ammonia[3]	-4.425	-0.120	NS	---	NS	NS	0.230	0.10
NO_2/NO_3	-3.713	0.190	0.102	-0.010	0.317	0.845	0.020	0.79
Dissolved Nitrogen	-3.321	0.245	-0.064	0.007	0.330	0.914	0.020	0.71
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	-5.950	NS	0.037	---	NS	-0.099	0.117	0.09
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	-9.520	1.046	NS	---	-0.207	-0.207	0.040	0.75
Aluminum	-5.799	0.985	-0.108	---	NS	-0.450	0.043	0.64
Arsenic	-10.763	0.490	0.151	-0.016	NS	-0.202	0.044	0.47
Barium	-3.755	NS	-0.219	0.027	NS	0.101	0.061	0.11
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	-9.673	0.295	-0.257	0.019	NS	0.141	0.054	0.22
Chromium	-9.673	0.665	-0.154	---	NS	-0.264	0.046	0.43
Cobalt	-11.888	0.857	-0.079	---	NS	-0.334	0.045	0.63
Iron	-5.541	1.008	NS	---	NS	-0.407	0.044	0.65
Lead	-9.837	0.663	-0.126	---	NS	-0.339	0.044	0.52
Lithium	-7.230	0.318	-0.051	---	NS	NS	0.054	0.32
Manganese	-7.065	0.658	NS	---	NS	-0.237	0.046	0.57
Molybdenum	-7.391	-0.254	NS	---	NS	0.096	0.035	0.31
Nickel	-10.145	0.719	NS	---	0.278	NS	0.054	0.56
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	-0.868	-0.195	NS	---	NS	NS	0.044	0.66
Vanadium	-11.365	0.825	-0.066	---	-0.185	-0.287	0.039	0.59
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	-1.319	0.516	NS	---	NS	NS	0.151	0.21

* - Not log transformed
N/A - Not adequate for analysis
[3] - Constituent monitored by BC MoELP
NS - Non-significant ($p > 0.05$)

Table A6. 5 Non-parametric test results for BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Stoner. AOX was the only constituent deemed adequate for analysis at this site. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Adsorb Organohalides	NS	19.372*	-4.300*	NS	-0.011	-0.048	0.003

* - Significant at the 5 % level. NS - Non-significant ($p > 0.10$)

Table A6. 6 Regression modelling results for BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Stoner. AOX was the only constituent deemed adequate for analysis at this site.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Adsorb Organohalides	2.317	-0.766	-0.383	---	NS	0.200	0.038	0.57

NS - Non-significant ($p > 0.05$)

Table A6. 7 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Marguerite. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	NS	5.913*	-2.412*	NS	-0.375	-0.754	0.125
pH	NS	NS	NS	NS	N/A	N/A	N/A
Colour TAC[3]	NS	NS	NS	NS	N/A	N/A	N/A
Apparent Colour	NS	NS	NS	NS	N/A	N/A	N/A
Specific Conductivity	NS	NS	NS	NS	N/A	N/A	N/A
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Filterable[3]	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Non-filterable[3]	NS	NS	NS	NS	N/A	N/A	N/A
Total Alkalinity	NS	NS	NS	NS	N/A	N/A	N/A
Calcium	NS	7.060*	-2.635*	NS	-0.100	-0.244	0.029
Chloride	NS	75.046*	-8.641*	-2.954*	-0.217	-0.509	-0.083
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	NS	28.020*	5.272*	2.259*	0.067	0.012	0.117
Hardness	NS	NS	NS	NS	N/A	N/A	N/A
SiO_2	NS	NS	NS	NS	N/A	N/A	N/A
Potassium	NS	26.488*	5.127*	2.706*	0.011	0.003	0.022
Sodium	NS	NS	NS	NS	N/A	N/A	N/A
Dissolved Sulphate	NS	14.707*	3.811*	2.096*	0.105	0.000	0.225
NH_3, Ammonia[3]	NS	3.309	-1.727	NS	0	-0.001	0
NO_2/NO_3	NS	6.423*	2.500*	NS	0.002	-0.001	0.004
Dissolved Nitrogen	NS	7.708*	2.751*	NS	0.003	-0.001	0.008
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Ortho-Phosphorus[3]	NS	10.605*	3.178*	2.197*	0	0	0.000
Total Phosphorus	NS	NS	NS	NS	N/A	N/A	N/A
Aluminum	NS	NS	NS	NS	N/A	N/A	N/A
Arsenic	NS	NS	NS	NS	N/A	N/A	N/A
Barium	NS	4.699*	-2.124*	NS	-0.001	-0.001	0.000
Beryllium	NS	NS	NS	NS	N/A	N/A	N/A
Cadmium	NS	6.857*	-2.612*	NS	-0.000	-0.000	0.000
Chromium	NS	15.662*	-3.913*	-1.748	-0.001	-0.001	0.000
Cobalt	NS	5.155*	-2.228*	NS	-0.000	-0.000	0.000
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	NS	14.877*	-3.836*	-1.914	-0.000	-0.000	0.000
Lithium	NS	9.518*	-3.049*	-1.977*	-0.000	-0.000	0.000
Manganese	NS	NS	NS	NS	N/A	N/A	N/A
Molybdenum	NS	11.537*	3.375*	1.947	0.000	0.000	0.000
Nickel	NS	6.107*	-2.430*	NS	-0.000	-0.001	0.000
Selenium	NS	10.283*	-3.292*	-1.867	0.000	-0.000	0.000
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A
Adsorb Organohalides[3]	NS	36.290*	-5.960*	-2.079*	-.008	-0.030	0
Fecal Coliform[3]	NS	NS	NS	NS	N/A	N/A	N/A

* - Significant at the 5% level.
N/A - Not adequate for analysis

[3] - Constituents monitored by BC MoELP
NS - Non-significant (p > 0.10)

Table A6. 8 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Marguerite.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	0.101	N/A	NS	---	0.243	NS	0.021	0.07
Water Temperature	NS	NS	0.372	-0.040	-1.673	-0.363	0.016	0.80
pH*	8.013	NS	-0.057	0.006	NS	NS	0.050	0.09
Colour TAC[3]	NS	0.475	NS	---	0.627	0.728	0.018	0.37
Apparent Colour	2.761	NS	NS	---	NS	-0.135	0.056	0.04
Specific Conductivity	6.670	-0.243	0.004	---	NS	0.037	0.046	0.88
Turbidity	-3.864	0.913	NS	---	-0.351	-0.177	0.040	0.41
Residue, Filterable[3]	6.082	-0.216	0.012	---	0.035	NS	0.059	0.60
Residue, Non-filterable[3]	-4.805	1.131	NS	NS	-0.408	-0.326	0.042	0.40
Total Alkalinity	5.547	-0.205	0.004	---	0.031	0.020	0.041	0.83
Calcium	4.329	-0.177	-0.020	0.001	0.017	0.040	0.044	0.80
Chloride	7.036	-0.806	-0.124	---	NS	NS	0.039	0.82
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	2.805	-0.213	0.020	---	0.031	0.107	0.020	0.90
Hardness	5.664	-0.200	-0.016	0.002	0.018	0.028	0.044	0.84
SiO_2	1.677	NS	-0.240	0.037	NS	NS	0.057	0.12
Potassium*	1.242	-0.099	0.018	---	-0.045	-0.056	0.042	0.35
Sodium	5.899	-0.684	NS	---	NS	NS	0.043	0.90
Dissolved Sulphate	4.173	-0.328	-0.087	-0.006	-0.060	NS	0.053	0.68
NH_3, Ammonia[3]	-1.281	-0.498	NS	---	0.170	0.156	0.037	0.34
NO_2/NO_3	-5.865	0.457	0.031	---	0.723	0.739	0.018	0.76
Dissolved Nitrogen	-4.005	0.319	0.018	---	0.451	0.655	0.019	0.70
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	-2.762	-0.348	NS	---	NS	NS	0.055	0.22
Ortho-Phosphorus[3]	-3.989	-0.278	0.202	-0.019	-0.091	NS	0.047	0.27
Total Phosphorus	-9.497	0.979	NS	---	0.247	0.717	0.018	0.60
Aluminum	-7.704	1.079	NS	---	-0.248	NS	0.039	0.61
Arsenic	-10.901	0.492	NS	-0.010	-0.112	-0.202	0.044	0.33
Barium	-4.809	0.179	NS	---	NS	NS	0.049	0.15
Beryllium	-5.847	0.471	NS	NS	0.297	0.288	0.019	0.38
Cadmium	-12.800	0.587	0.030	---	NS	0.459	0.018	0.36
Chromium	-7.771	0.466	-0.226	---	NS	-0.184	0.053	0.37
Cobalt	-12.755	0.865	-0.082	---	NS	0.468	0.016	0.57
Iron	-8.839	1.318	NS	-0.011	NS	0.655	0.020	0.59
Lead	-12.027	0.863	-0.112	---	NS	0.412	0.017	0.47
Lithium	-8.369	0.399	-0.080	---	-0.169	NS	0.037	0.35
Manganese	-7.704	0.692	NS	---	NS	-0.233	0.055	0.40
Molybdenum	-6.907	-0.180	0.114	---	NS	-0.154	0.082	0.26
Nickel	-10.398	0.701	-0.061	---	-0.219	NS	0.040	0.41
Selenium	-8.814	NS	-0.044	---	NS	0.261	0.018	0.22
Strontium	-1.195	-0.143	-0.008	---	NS	0.027	0.043	0.75
Vanadium	-13.000	1.038	-0.062	---	NS	0.557	0.017	0.59
Adsorb Organohalides[3]	3.078	-0.802	-0.306	---	NS	NS	0.040	0.67
Fecal Coliform[3]	10.621	-0.798	-0.783	0.094	NS	NS	0.022	0.13

* - Not log transformed
N/A - Not adequate for analysis
[3] - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.05$)

Table A6. 9 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Hope. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	NS	8.396*	2.871*	1.880	0.146	0.000	0.300
pH	NS	NS	NS	NS	N/A	N/A	N/A
Colour TAC[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	NS	NS	NS	N/A	N/A	N/A
Specific Conductivity	NS	8.973*	2.972*	1.760	0.500	-0.031	0.989
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residue, Non-filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Alkalinity	NS	3.396	1.823	NS	0.141	-0.141	0.441
Calcium	NS	3.512	-1.847	NS	-0.042	-0.100	0.010
Chloride	22.654*	48.204*	-6.918*	-2.345*	-0.120	-0.236	-0.027
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	NS	35.708*	5.953*	2.614*	0.060	0.017	0.109
Hardness	NS	NS	NS	NS	N/A	N/A	N/A
SiO_2	NS	NS	NS	NS	N/A	N/A	N/A
Potassium	NS	39.491*	6.264*	2.548*	0.015	0.004	0.026
Sodium	NS	NS	NS	NS	N/A	N/A	N/A
Dissolved Sulphate	NS	17.875*	4.209*	2.175*	0.105	0.010	0.211
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Nitrogen	NS	NS	NS	NS	N/A	N/A	N/A
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	NS	5.365*	2.295*	1.764	0.001	-0.000	0.003
Aluminum	NS	3.012	-1.681	NS	-0.084	-0.301	0.047
Arsenic	NS	3.995*	-1.971*	NS	-0.000	-0.000	0.000
Barium	NS	3.231	-1.738	NS	-0.001	-0.002	0.001
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	NS	NS	NS	NS	N/A	N/A	N/A
Chromium	NS	NS	NS	NS	N/A	N/A	N/A
Cobalt	NS	NS	NS	NS	N/A	N/A	N/A
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	NS	15.502*	-3.909*	-2.381*	-0.000	-0.000	-0.000
Lithium	NS	11.492*	-3.328*	-2.082*	-0.000	-0.000	0.000
Manganese	NS	NS	NS	NS	N/A	N/A	N/A
Molybdenum	NS	NS	NS	NS	N/A	N/A	N/A
Nickel	NS	NS	NS	NS	N/A	N/A	N/A
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	NS	10.691*	-3.209*	NS	-0.001	-0.003	0.000
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A
Adsorb Organohalides[3]	NS	23.848*	-4.835*	-1.961*	-0.003	-0.001	0.000
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Significant at the 5% level.
N/A - Not adequate for analysis

[3] - Constituents monitored by BC MoELP
NS - Non-significant (p > 0.10)

Table A6. 10 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Fraser River at Hope.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	7.656	N/A	NS	---	-0.008	NS	0.041	0.04
Water Temperature	-4.586	0.821	0.173	-0.015	-0.338	-0.112	0.038	0.62
pH[*]	7.758	0.044	-0.105	0.015	0.021	0.03	0.028	0.28
Colour TAC[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	1.854	0.205	-0.157	0.013	NS	NS	0.052	0.08
Specific Conductivity	5.984	-0.154	0.006	---	0.030	0.062	0.018	0.85
Turbidity	-4.577	0.921	NS	---	NS	-0.277	0.053	0.41
Residue, Filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residue, Non-filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Alkalinity	4.597	-0.091	0.006	---	0.053	0.075	0.018	0.73
Calcium	3.632	-0.096	-0.020	0.002	0.031	0.027	0.017	0.63
Chloride	4.018	-0.396	-0.107	---	NS	0.315	0.020	0.84
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	2.630	-0.198	0.026	---	NS	0.114	0.020	0.81
Hardness	4.986	-0.125	0.004	---	NS	0.053	0.018	0.72
SiO_2	1.127	NS	-0.174	0.029	NS	NS	0.053	0.17
Potassium[*]	1.358	-0.092	0.020	---	-0.023	-0.028	0.044	0.39
Sodium	4.756	-0.480	-0.035	0.004	NS	NS	0.044	0.83
Dissolved Sulphate	4.302	-0.303	0.063	-0.005	NS	0.039	0.035	0.84
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Nitrogen	-3.509	0.237	-0.065	0.006	0.230	0.600	0.020	0.66
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	-10.209	0.944	0.031	---	-0.130	NS	0.044	0.59
Aluminum	-10.949	1.468	-0.105	---	NS	0.551	0.020	0.68
Arsenic	-9.729	0.338	NS	---	NS	0.406	0.019	0.34
Barium	-6.253	0.369	-0.155	0.017	0.122	0.229	0.018	0.59
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	-12.745	0.555	NS	---	NS	NS	0.059	0.45
Chromium	-12.788	0.913	-0.093	---	-0.176	-0.234	0.044	0.54
Cobalt	-16.468	1.310	-0.415	0.048	NS	0.485	0.020	0.66
Iron	-8.099	1.103	NS	---	-0.160	-0.255	0.046	0.53
Lead	-11.890	0.732	-0.107	---	NS	NS	0.043	0.47
Lithium	-8.601	0.358	-0.061	---	-0.119	0.076	0.033	0.47
Manganese	-10.638	0.969	NS	---	-0.141	-0.160	0.045	0.60
Molybdenum[*]	0.001	-0.000	-0.000	0.000	-0.000	0.000	0.057	0.29
Nickel	-11.455	0.816	-0.394	0.050	-0.137	NS	0.043	0.59
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium[*]	0.162	-0.008	-0.002	---	NS	NS	0.044	0.40
Vanadium	-12.113	0.897	-0.516	0.071	NS	NS	0.058	0.60
Adsorb Organohalides[3]	NS	-0.499	-0.223	---	NS	NS	0.052	0.47
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[*] - Not log transformed

N/A - Not adequate for analysis

[3] - Constituents monitored by BC MoELP

NS - Non-significant ($p > 0.05$)

Table A6. 11 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Nechako River. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	4.769*	2.166*	NS	1.175	-1.226	5.489
Water Temperature	NS	NS	NS	NS	N/A	N/A	N/A
pH	NS	NS	NS	NS	N/A	N/A	N/A
Colour TAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	NS	NS	NS	N/A	N/A	N/A
Specific Conductivity	NS	9.667*	3.086*	1.834	0.442	0.000	0.833
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Filterable[3]	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Non-filterable[3]	NS	10.223*	3.135*	1.975*	0.204	0	0.5
Total Alkalinity	NS	NS	NS	NS	N/A	N/A	N/A
Calcium	NS	NS	NS	NS	N/A	N/A	N/A
Chloride	NS	NS	NS	NS	N/A	N/A	N/A
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	NS	14.193*	3.743*	1.799	0.034	0.000	0.074
Hardness	NS	NS	NS	NS	N/A	N/A	N/A
SiO_2	NS	NS	NS	NS	N/A	N/A	N/A
Potassium	NS	12.619*	3.522*	1.933	0.006	0.000	0.016
Sodium	NS	9.638*	3.086*	1.643	0.014	0.000	0.027
Dissolved Sulphate	NS	NS	NS	NS	N/A	N/A	N/A
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3	NS	NS	NS	NS	N/A	N/A	N/A
Dissolved Nitrogen	NS	NS	NS	NS	N/A	N/A	N/A
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	NS	NS	NS	NS	N/A	N/A	N/A
Aluminum	NS	4.283*	-2.041*	NS	-0.003	-0.016	0.002
Arsenic	NS	NS	NS	NS	N/A	N/A	N/A
Barium	NS	3.907*	-1.930	NS	-0.000	-0.001	0.000
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	NS	8.277*	-2.840*	NS	-0.000	-0.000	0.000
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	NS	NS	NS	NS	N/A	N/A	N/A
Manganese	NS	NS	NS	NS	N/A	N/A	N/A
Molybdenum	NS	NS	NS	NS	N/A	N/A	N/A
Nickel	NS	NS	NS	NS	N/A	N/A	N/A
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Significant at the 5% level.
N/A - Not adequate for analysis

3 - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.10$)

Table A6. 12 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Nechako River.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	5.0180	N/A	.0327	---	NS	NS	.0638	.03
Water Temperature	-4.8170	1.3084	-.0533	---	NS	NS	.0829	.59
pH*	8.766	-0.157	NS	0.008	0.077	-0.105	0.027	0.22
Colour TAC[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	.6665	NS	---	-.4411	.4803	.0229	.47
Specific Conductivity	5.6560	-.1817	-.0214	.0022	-.0445	NS	.0565	.62
Turbidity	-3.519	.7990	NS	---	-.5263	.7162	.0211	.42
Residue, Filterable[3]	4.7811	-.0928	NS	---	NS	.0438	.0755	.16
Residue, Non-filterable[3]	-2.6275	.7711	.0741	---	NS	-.3425	.0440	.32
Total Alkalinity	4.9446	-.1836	-.0511	.0045	-.0400	NS	.0562	.61
Calcium	3.5967	-.1582	-.0719	.0059	-.0222	.0456	.0465	.60
Chloride	.6325	-.2286	NS	---	-.0898	.0889	.0579	.13
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	8.8016	-.8781	-.2061	.0217	NS	NS	.0629	.49
Hardness	4.9995	-.1852	-.0594	.0053	-.0391	NS	.0567	.59
SiO_2	1.9055	-.1127	-.2322	.0357	NS	.0672	.0597	.26
Potassium	.5862	-.1916	.0137	---	-.2008	.1792	.0203	.51
Sodium*	4.4296	-.3698	-.0606	.0068	-.0814	NS	.0607	.41
Dissolved Sulphate*	5.8869	-.3965	.3786	-.0319	.4496	.2017	.0162	.37
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3	NS	-.7328	NS	---	.3092	NS	.0537	.15
Dissolved Nitrogen	-2.6246	.2009	-.0682	.0061	NS	.4022	.0199	.37
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	-5.5591	NS	NS	---	.1336	NS	.15	.05
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	-6.7439	.5716	NS	---	NS	-.3417	.0443	.33
Aluminum	-6.4012	.8927	-.1076	---	-.8245	.4536	.0217	.68
Arsenic	-7.3910	NS	.0746	-.0085	-.2786	NS	.0227	.25
Barium	-3.9825	.0827	-.1846	.0194	NS	.0946	.0707	.23
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	-9.6264	.5515	-.1701	---	.1879	NS	.0603	.28
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	-5.3899	.7335	NS	-.0111	-.7245	.6732	.0211	.59
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	-7.8277	NS	NS	---	NS	NS	.0744	.06
Manganese	-7.0103	.5848	NS	---	.1860	-.2211	.0479	.27
Molybdenum*	.0029	-.0003	NS	---	-.0002	-.0005	.0269	.24
Nickel	-8.0858	.3810	-.3586	.0391	NS	.1593	.0696	.31
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium*	.1073	-.0071	NS	---	-.0019	.0017	.0563	.50
Vanadium	-10.0161	.5604	-.0546	---	.5420	.4672	.0208	.65
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Not log transformed
N/A - Not adequate for analysis
[3] - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.05$)

Table A6. 13 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Salmon River. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	NS	NS	NS	NS	N/A	N/A	N/A
pH	NS	10.736*	-3.230*	NS	-0.020	-0.042	0.007
Colour TAĈ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	3.711	1.903	NS	0.321	0.000	0.754
Specific Conductivity	NS	NS	NS	NS	N/A	N/A	N/A
Turbidity	NS	15.146*	3.861*	2.074*	0.163	0.005	0.350
Residue, Filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residue, Non-filterable[3]	NS	20.929*	4.503*	2.225*	0.417	0	0.667
Total Alkalinity	NS	NS	NS	NS	N/A	N/A	N/A
Calcium	NS	NS	NS	NS	N/A	N/A	N/A
Chloride	NS	12.746*	3.538*	1.836	0.065	0.000	0.144
Fluoride	NS	NS	NS	NS	N/A	N/A	N/A
Magnesium*	NS	3.611	1.872	NS	0.100	-0.031	0.280
Hardness	NS	NS	NS	NS	N/A	N/A	N/A
SiO_2	NS	2.971	-1.643	NS	-0.103	-0.475	0.322
Potassium	NS	NS	NS	NS	N/A	N/A	N/A
Sodium	NS	3.843*	1.932	NS	0.108	-0.075	0.274
Dissolved Sulphate	NS	NS	NS	NS	N/A	N/A	N/A
NH_3, Ammonia[3]	NS	NS	NS	NS	N/A	N/A	N/A
NO_2/NO_3	NS	7.252*	2.650*	NS	0.003	-0.003	0.012
Dissolved Nitrogen	NS	11.429*	3.353*	NS	0.010	-0.001	0.019
Kjeldahl Nitrogen[3]	NS	3.070	1.722	NS	0.005	-0.002	0.01
Dissolved Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Ortho-Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Total Phosphorus	NS	3.395	1.810	NS	0.002	-0.002	0.007
Aluminum	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	NS	NS	NS	NS	N/A	N/A	N/A
Barium	NS	NS	NS	NS	N/A	N/A	N/A
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	NS	NS	NS	NS	N/A	N/A	N/A
Cobalt	NS	NS	NS	NS	N/A	N/A	N/A
Iron	NS	2.858	1.660	NS	0.008	-0.010	0.029
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	NS	NS	NS	NS	N/A	N/A	N/A
Manganese	NS	NS	NS	NS	N/A	N/A	N/A
Molybdenum	NS	NS	NS	NS	N/A	N/A	N/A
Nickel	NS	NS	NS	NS	N/A	N/A	N/A
Selenium	NS	NS	NS	NS	N/A	N/A	N/A
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	NS	NS	NS	N/A	N/A	N/A
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	NS	3.189	-1.75	NS	-5.402	-12.657	3.059

* - Significant at the 5% level.
N/A - Not adequate for analysis

[3] - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.10$)

Table A6. 14 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Salmon River.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	0.788	N/A	NS	---	0.368	-0.281	0.022	0.13
Water Temperature	1.519	0.219	NS	---	NS	-0.503	0.042	0.19
pH[*]	8.344	-0.119	-0.015	---	NS	-0.051	0.060	0.51
Colour TAC[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	1.732	0.774	NS	---	0.113	NS	0.054	0.66
Specific Conductivity	6.116	-0.350	0.020	---	-0.033	-0.080	0.060	0.82
Turbidity	-0.820	0.799	0.148	---	-0.207	0.215	0.020	0.66
Residue, Filterable[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residue, Non-filterable[3]	0.876	1.187	0.046	---	NS	NS	0.041	0.80
Total Alkalinity	5.252	-0.336	0.015	---	-0.079	NS	0.049	0.86
Calcium	4.038	-0.360	0.018	---	-0.074	NS	0.050	0.88
Chloride	1.228	-0.359	0.039	---	-0.111	NS	0.046	0.70
Fluoride[*]	0.179	-0.028	0.018	-0.003	-0.007	0.007	0.046	0.61
Magnesium	2.822	-0.377	0.028	---	-0.088	NS	0.048	0.85
Hardness	5.353	-0.365	0.021	---	-0.077	NS	0.049	0.87
SiO_2	2.437	NS	NS	---	NS	NS	0.022	0.07
Potassium[*]	3.549	-0.559	0.038	---	NS	0.162	0.032	0.72
Sodium	2.678	-0.305	0.018	---	-0.087	0.030	0.048	0.82
Dissolved Sulphate	3.951	-0.493	NS	---	-0.093	0.049	0.048	0.85
NH_3, Ammonia[3]	-4.718	-0.150	NS	-0.027	NS	0.291	0.041	0.14
NO_2/NO_3	-3.212	0.296	NS	---	NS	0.699	0.041	0.20
Dissolved Nitrogen	-2.203	0.245	0.208	-0.018	NS	0.279	0.040	0.33
Kjeldahl Nitrogen[3]	-1.970	0.409	NS	---	-0.092	0.085	0.036	0.46
Dissolved Phosphorus[3]	-3.327	0.043	NS	NS	-0.063	0.089	0.039	0.09
Ortho-Phosphorus[3]	-3.508	NS	0.103	-0.011	NS	NS	0.020	0.07
Total Phosphorus	-3.149	.561	0.038	---	-0.067	0.097	0.037	0.73
Aluminum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	-7.146	NS	0.137	-0.018	NS	NS	0.054	0.08
Barium	-3.677	0.065	NS	---	NS	0.040	0.056	0.14
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	-6.897	0.905	-0.543	0.051	NS	NS	0.038	0.74
Cobalt	-8.575	0.835	-0.053	---	NS	NS	0.039	0.81
Iron	-1.760	1.041	NS	---	-0.099	NS	0.041	0.87
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium[*]	0.006	-0.001	NS	-0.000	NS	NS	0.037	0.35
Manganese	-3.210	0.264	NS	---	NS	0.085	0.064	0.40
Molybdenum	-6.109	-0.254	-0.082	0.012	0.116	NS	0.024	0.74
Nickel	-7.424	0.810	-0.180	0.022	NS	0.109	0.038	0.79
Selenium[*]	0.001	-0.000	NS	---	NS	-0.000	0.042	0.15
Strontium	-0.629	-0.369	NS	---	-0.068	NS	0.052	0.88
Vanadium	-6.139	0.441	NS	---	-0.152	0.091	0.016	0.90
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	4.190	0.405	NS	---	NS	-0.417	0.046	0.16

[*] - Not log transformed
N/A - Not adequate for analysis

[3] - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.05$)

Table A6. 15 Non-parametric test results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Thompson River. Significant findings are at the 10% level unless noted otherwise.

CONSTITUENTS	Van Belle test for Heterogeneity	Van Belle test for Trend	Seasonal Kendall Statistic	Modified Seasonal Kendall Statistic	Sen Slope Estimator	LCL for Sen Slope	UCL for Sen Slope
Flow	NS	NS	NS	NS	N/A	N/A	N/A
Water Temperature	NS	NS	NS	NS	N/A	N/A	N/A
pH	NS	NS	NS	NS	N/A	N/A	N/A
Colour TAČ	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	NS	NS	NS	N/A	N/A	N/A
Specific Conductivity	19.247	5.416*	2.303*	1.837	0.271	0.000	0.568
Turbidity	NS	NS	NS	NS	N/A	N/A	N/A
Residue, Filterable[3]	NS	6.134*	2.439*	NS	0.817	-0.258	2
Residue, Non-filterable[3]	NS	20.929*	4.503*	2.225*	0.417	0	0.667
Total Alkalinity	NS	25.700*	5.048*	2.187*	0.243	0.037	0.518
Calcium	NS	NS	NS	NS	N/A	N/A	N/A
Chloride	NS	62.832*	-7.908*	-2.687*	-0.148	-0.300	-0.051
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium*	NS	43.003*	6.536*	2.719*	0.033	0.011	0.063
Hardness	NS	3.332	1.802	NS	0.150	-0.203	0.437
SiO_2	NS	NS	NS	NS	N/A	N/A	N/A
Potassium	NS	18.563*	4.286*	2.193*	0.007	0.000	0.017
Sodium	NS	16.567*	-4.056*	-1.799	-0.033	-0.080	0.000
Dissolved Sulphate	NS	NS	NS	NS	N/A	N/A	N/A
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3	NS	9.337*	3.020*	NS	0.002	-0.001	0.003
Dissolved Nitrogen	NS	3.332	1.808	NS	0.001	-0.001	0.003
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	NS	NS	NS	NS	N/A	N/A	N/A
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	NS	NS	NS	NS	N/A	N/A	N/A
Aluminum	NS	NS	NS	NS	N/A	N/A	N/A
Arsenic	NS	10.812*	-3.303*	-2.031*	0.000	-0.000	0.000
Barium	NS	3.591	-1.841	NS	-0.000	-0.000	0.000
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	NS	6.939*	-2.606*	NS	-0.000	-0.000	0.000
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	NS	NS	NS	NS	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	NS	NS	NS	NS	N/A	N/A	N/A
Manganese	NS	4.811*	-2.168*	NS	-0.000	-0.000	0.000
Molybdenum	NS	4.244*	2.019*	NS	0.000	0.000	0.000
Nickel	17.324	NS	NS	NS	N/A	N/A	N/A
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	NS	NS	NS	NS	N/A	N/A	N/A
Vanadium	NS	2.831	-1.643	NS	-0.000	-0.000	0.000
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Significant at the 5% level.
N/A - Not adequate for analysis
[3] - Constituents monitored by BC MoELP
NS - Non-significant ($p > 0.10$)

Table A6. 16 Regression modelling results for Environment Canada & BC Ministry of Environment, Lands and Parks monitoring data in the Thompson River.

CONSTITUENTS	PARAMETERS							
		flow	linear trend	quadratic trend	------- seasonality -------			fit
	b_0	b_1	b_2	b_3	α_1	α_2	ω	r^2
Flow	6.133	N/A	NS	---	0.274	-0.186	0.022	0.08
Water Temperature	-2.264	0.709	-0.025	---	-0.421	0.099	0.038	0.62
pH*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Colour TAC[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Apparent Colour	NS	0.399	-0.026	---	0.158	0.430	0.020	0.30
Specific Conductivity	5.153	-0.093	0.006	---	NS	0.148	0.020	0.87
Turbidity	-3.226	0.582	-0.195	0.018	NS	0.127	0.049	0.35
Residue, Filterable[3]	4.371	NS	0.020	---	NS	0.134	0.020	0.59
Residue, Non-filterable[3]	-3.810	0.692	0.153	---	NS	0.468	0.019	0.42
Total Alkalinity	3.939	-0.063	0.012	---	NS	0.136	0.019	0.82
Calcium	3.046	-0.066	-0.031	0.003	NS	0.109	0.020	0.80
Chloride	2.686	-0.264	-0.111	---	0.168	0.434	0.018	0.73
Fluoride	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	1.335	-0.102	0.023	---	0.047	0.215	0.020	0.86
Hardness	4.200	-0.079	0.007	---	NS	0.131	0.020	0.81
SiO_2	NS	0.134	NS	---	0.144	0.210	0.018	0.72
Potassium*	1.031	-0.038	0.012	---	NS	0.095	0.021	0.54
Sodium	2.406	-0.2189	-0.013	---	NS	0.323	0.020	0.86
Dissolved Sulphate*	3.260	-0.189	0.006	---	NS	0.119	0.020	0.82
NH_3, Ammonia[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NO_2/NO_3*	-0.093	0.029	0.002	---	0.043	0.043	0.018	0.75
Dissolved Nitrogen*	-0.117	0.043	NS	---	0.056	0.054	0.018	0.69
Kjeldahl Nitrogen[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dissolved Phosphorus[3]	-6.192	0.145	-0.182	0.021	0.254	0.058	0.016	0.22
Ortho-Phosphorus[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	-6.709	0.406	-0.166	0.016	0.129	NS	0.049	0.34
Aluminum	-7.7300	0.914	-0.071	---	NS	0.359	0.019	0.72
Arsenic	-10.990	0.373	-0.045	---	NS	0.408	0.022	0.20
Barium	-5.322	0.149	-0.026	---	0.122	0.161	0.018	0.39
Beryllium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	-9.679	0.466	-0.199	---	NS	NS	0.046	0.36
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	-7.016	0.865	-0.030	---	NS	0.448	0.018	0.65
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium*	0.002	-0.000	NS	---	NS	NS	0.050	0.11
Manganese	-7.259	0.387	-0.030	---	NS	0.134	0.060	0.25
Molybdenum	-7.756	NS	0.022	---	0.089	0.163	0.019	0.45
Nickel	-10.959	0.609	NS	---	NS	0.394	0.020	0.53
Selenium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	-2.168	-0.054	NS	---	NS	0.094	0.021	0.70
Vanadium	-12.191	0.773	-0.051	---	0.308	0.405	0.018	0.55
Adsorb Organohalides[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* - Not log transformed

[3] - Constituents monitored by BC MoELP

N/A - Not adequate for analysis

NS - Non-significant ($p > 0.05$)

N/A* - Laboratory pH data at this site could not be fit into the regression algorithms, as convergence could not be obtained.