Site-Specific Water Quality Guidelines for Skeena River at Usk for the Purpose of National Reporting

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Executive Summary

THIS DOCUMENT is one in a series that presents ambient site-specific water quality guidelines (SSGs) for British Columbia and the Yukon. This Executive Summary includes tables listing site-specific water quality guidelines for the purpose of reporting on one water use: protection of aquatic life. The main report presents the details of the water quality assessment for the Skeena River at Usk, and forms the basis of the recommendations and site-specific guidelines presented here.

The Skeena River rises in the northern part of the province of British Columbia and flows about 580 km before emptying into Chatham Sound on the Pacific Ocean. It is the second largest river in the province and a premier salmon-fishing area. Forestry is the major land use within the Skeena basin which is followed by minor influences on the environment from mining, agriculture, urban land use related activities.

The following table provides a summary of the recommended site-specific water quality guidelines (SSGs). The SSGs specify a range of values for characteristics (variables) that may affect aquatic life water use. These values are maximum, mean, and/or minimum values that are not to be exceeded. Maximum concentration means that a value for a specific variable should not be exceeded; 30-day average concentration means that a value should not be exceeded during a period of 30 days, when five or more samples are collected at approximately equal time intervals. However, this statistic also can be used for yearly mean values or mean values over a period of record.

SUMMARY OF SITE-SPECIFIC WATER QUALITY GUIDELINES PROPOSED FOR

THE SKEENA RIVER AT USK

DESIGNATED WATER USES	**AQUATIC LIFE , WILDLIFE***
Characteristics	***Proposed Site-Specific Water Quality Guideline***
Arsenic, total	5 µg/L maximum (Turbidity <72.3 NTU)
Cadmium, total	$10^{(0.86[\log \{hardness\}]-3.2}$ µg/L maximum (Turbidity <5.8 NTU)
Chromium, total	6.0 µg/L maximum (Turbidity <67.7 NTU)
Copper, total	8 µg/L maximum (Turbidity <69.5 NTU)
Lead, total	$3.31 + e^{(1.273\ 1n\ (\text{mean hardness})\ -\ 4.704)}$ µg/L maximum (Turbidity <89.7 NTU)
Nitrite/Nitrate Nitrogen	2.93 mg/L maximum
pH	6.5 -9.0
Phosphorus (total)	0.03 mg/L maximum (Turbidity ≤ 10 NTU)
Selenium, total	2 µg/L maximum
Silver, total	0.05 µg/L maximum (hardness < 100 mg/L) 1.5 µg/L maximum (hardness >100)
Temperature	19.0 °C maximum daily
Zinc, total	18.8 µg/L maximum (Turbidity <76 NTU)

* SSGs proposed are for the protection of aquatic life

PREFACE

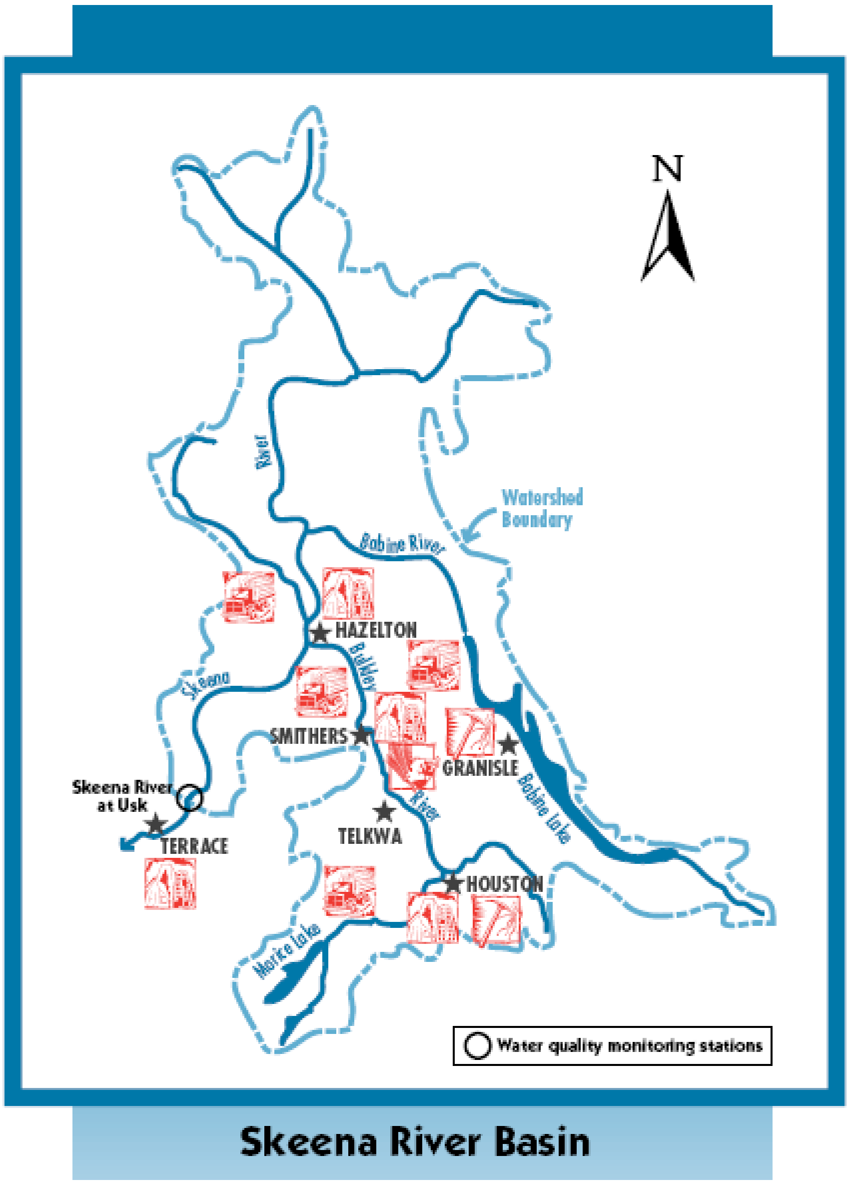
SITE-SPECIFIC WATER QUALITY GUIDELINES are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia and the Yukon as part of Environment Canada's mandate to report on water quality.

Traditionally, site-specific water quality objectives or guidelines are set to protect the most sensitive designated water use at a specific location. The most water uses generally considered in this endeavor are the following:

- raw drinking water, public water supply, and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies

The site-specific guidelines are generally prepared for those waterbodies and water quality characteristics that may be affected by human activity now or in the near future. The site-specific water quality guidelines (SSGs) proposed in this report differ from the traditional water quality objectives in that they are meant for the purpose of reporting on water quality relative to only one water use – protection of aquatic life.

The SSGs are safe limits of the physical, chemical, or biological characteristics of water, biota (plant and animal life) or sediment which protect a water use. They are based on the CCME national water quality guidelines as well as BC approved and working guidelines, by taking into consideration local water quality conditions (e.g., background water quality, local modifying characteristics, etc.), water uses, water movement, waste discharges, and socio-economic factors. In this report, only aquatic life protection is considered as the water use to be protected.



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1. Introduction

This report is one in a series that develops site-specific water quality guidelines (SSGs) for site-specific water bodies in the Yukon and British Columbia. The purpose of this series of reports is to develop SSGs in water bodies where Environment Canada has been carrying out long-term trend monitoring.

The National WQI is a reporting tool designed to condense a large amount of complex technical data into a simple description of water quality. In the 2004 federal budget, $15 million over two years was committed to develop three national indicators, including a Freshwater Quality Indicator based on the WQI. Public and political interest in the results of this WQI is high. The Deputy Minister of Environment Canada has requested the first national WQI report be complete by November 2005. National work plans require regional input by June 2005.

At a 2003 CCME WQI workshop, there was consensus among water quality experts that site-specific guidelines are necessary for the scientific defensibility of the WQI. Site-specific guidelines are numerical concentrations established by taking into account site-specific conditions to protect and maintain a specified water use, such as aquatic life. Generic national or provincial guidelines may not produce credible WQI scores because local chemical, physical and biological characteristics influence the potential adverse effects of substances. To meet the short timeline for assembling a report, a streamlined procedure, namely the Rapid Assessment Approach (RAA), was developed to establish SSGs at long term monitoring stations. Typical SSGs are established from water quality assessment data, including water uses, permitted discharges, non-point sources of pollution and the natural hydrology of the water body. Long-term monitoring sites present the unique scenario where a large data base exists for a site and current trend assessment reports already exist. The streamlined RAA takes advantage of existing knowledge for the purpose of setting SSGs.

Environment Canada has released a report outlining fourteen threats to Canadian water quality in their 2001 report titled *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada*. It is important to take these threats into account in reporting on water quality in Canada.

The Skeena Region is located in the northwestern part of the Province, bordering the Yukon and Alaska. It extends from Babine Lake in the east to the Queen Charlotte Islands in the west. Most of the rivers in the region drain to the Pacific Ocean, often passing through the Alaska panhandle in their lower reaches. The major streams, from north to south, are the Alsek, Taku, Stikine, Iskut, Unuk, Nass and Skeena rivers.
The Skeena River is the second-largest river in British Columbia. The Skeena is approximately 580 km long and drains some 60 000 km^2.

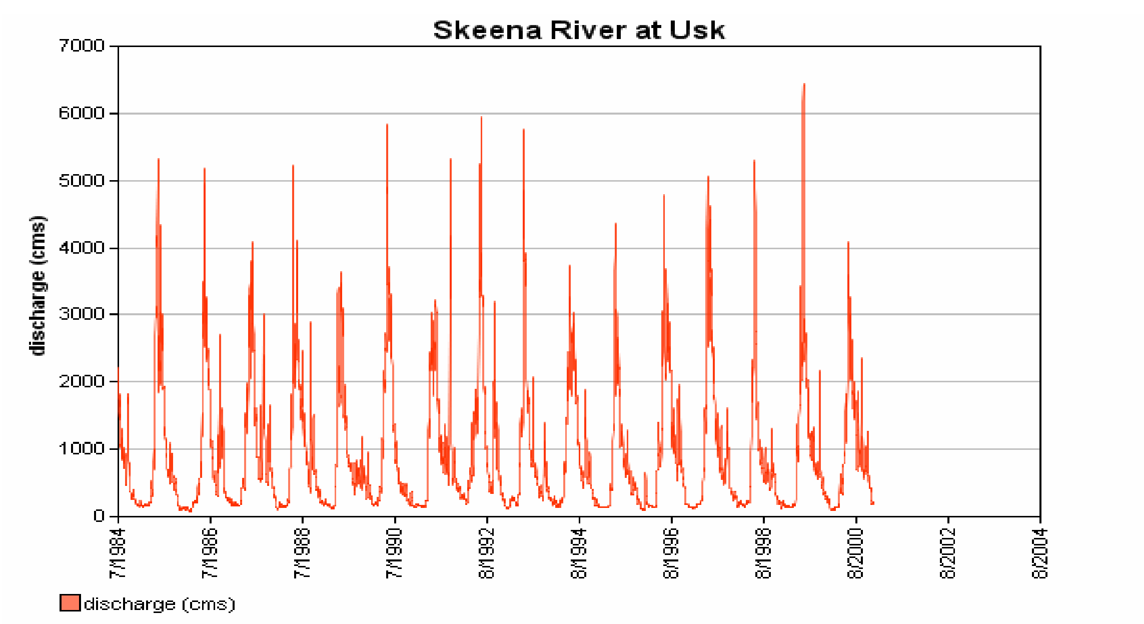
2. Water Uses, Hydrology, waste Discharges and Potential Contaminants in the Skeena River Basin

The Skeena watershed offers some of the largest steelhead and salmon in the world. Over five million salmon return to the Skeena every year, making this a premier salmon-fishing area.

The following figure shows discharge hydrograph of the Skeena River at Usk. Peak flows up to and slightly in excess of 6,000 m^3/s occur during freshet while base flows are in the order of 100 m^3/s.

Forestry and related activities constitute the major land use in the Skeena River Basin. Impacts from agricultural related activities and urbanization are relatively minor at best. Wetlands make up about 3% of the land cover within the basin. The following two maps (Map 1 and Map 2) and Table 1 show the Skeena River watershed and the predominant land uses with in the watershed.

Flows in the



Map 1 Skeena River Basin

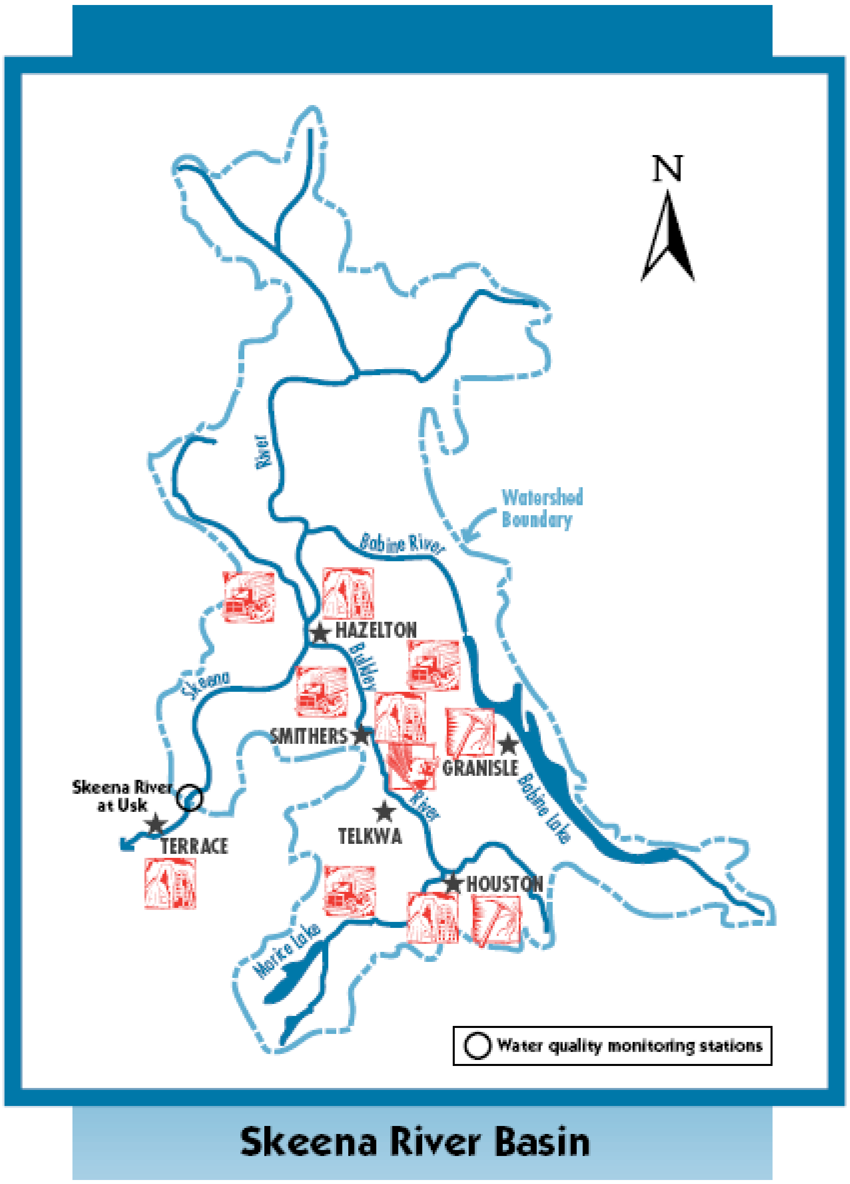
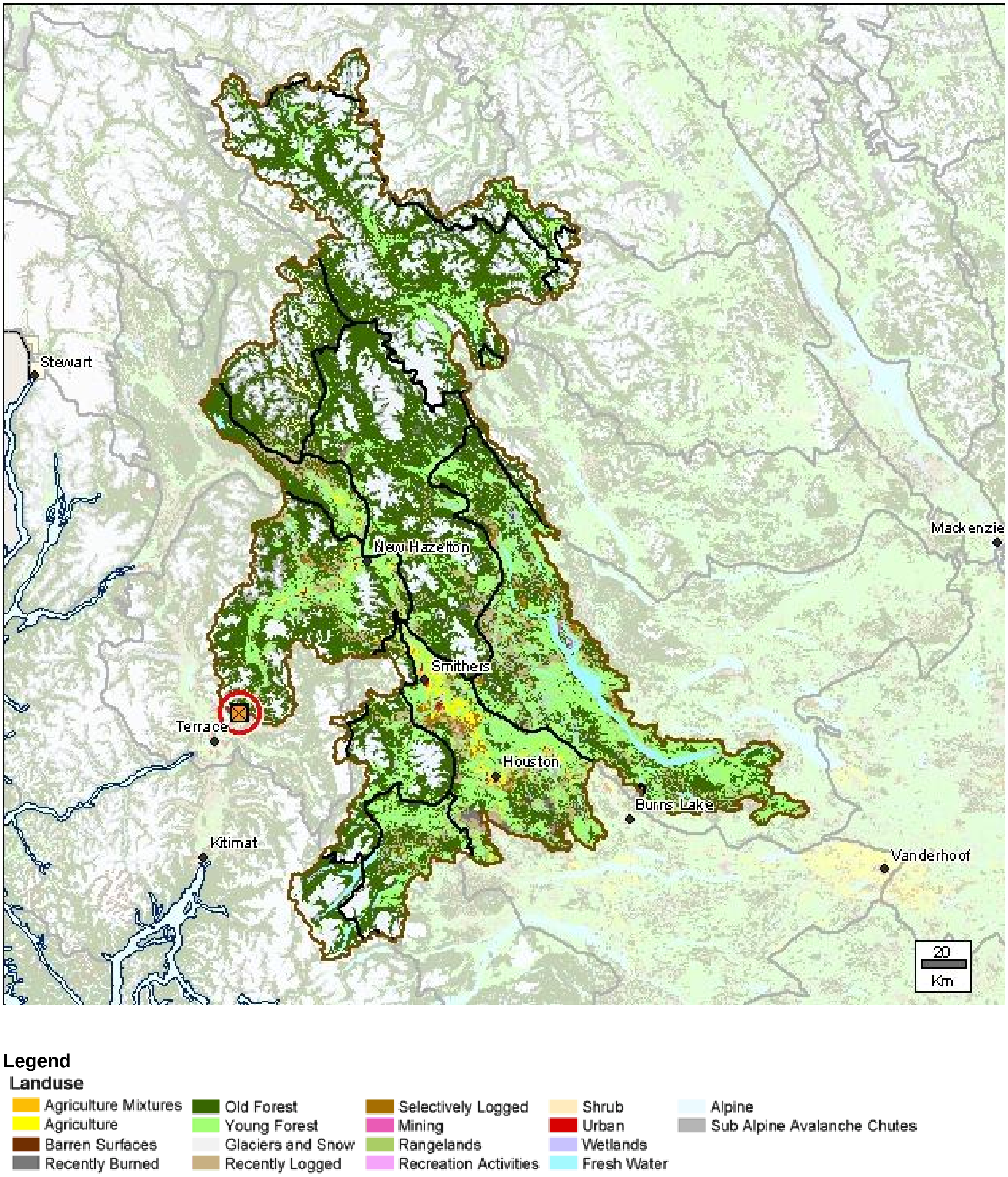


Table 1: Land uses and percent land cover in the Skeena River Watershed (See Map 2)

Land Use	% Land Cover
Agriculture	0.9
Alpine	15.5
Barren Surfaces	0.3
Fresh Water	2.4
Glaciers and Snow	1.4
Old Forest	42.2
Rangelands	0.1
Recently Burned	0.4
Recently Logged	6.0
Selectively Logged	0.8
Shrub	0.6
Sub Alpine Avalanche Chutes	5.5
Urban	0.1
Wetlands	2.8
Young Forest	19.8


Stewart
Mackenzie
New Hazelton
Smithers
Terrace
Houston
Burns Lake
Kitimat
Vanderhoof
20
Km
Legend
Landuse
Agriculture Mixtures
Agriculture
Barren Surfaces
Recently Burned
Old Forest
Young Forest
Glaciers and Snow
Recently Logged
Selectively Logged
Mining
Rangelands
Recreation Activities
Shrub
Urban
Wetlands
Fresh Water
Alpine
Sub Alpine Avalanche Chutes

3. Water Quality in the Skeena River at Usk

The Skeena River at Usk, drains 42, 200 km^2 of the Coast Mountains in north-central British Columbia and supports major runs of salmon. The Bulkley and Babine rivers are its major tributaries.

With the assistance of the BC Ministry of Water, Land and Air Protection's Smithers regional office, Environment Canada has monitored the water quality in the river at Usk ferry crossing, about 15 km north-east from Terrace, B.C. since 1984. The federal data are stored on the federal data base, ENVIRODAT, under station number BC08EF0001 (Provincial I.D. 08EF001). The purpose of the water quality monitoring has been long-term trend assessment.

Forestry, mining, agriculture, and treated sewage from townships of Houston, Telkwa, Smithers and Hazelton are potential sources of impacts on the river water quality. In an assessment of water quality in the river, Environment Canada did not find a significant change in the river environment from 1985 through 1994.

This site was chosen to set site-specific guideline for the watershed since it was a relatively pristine site and was not influenced by human activities.

4. Proposed Site-Specific Water Quality Guidelines for the Skeena River Basin

Using the rapid assessment approach to develop site-specific water quality guidelines (SSGs) for the purpose of national reporting, SSGs are proposed if:

- guidelines are exceeded, or
- values are within 90% of guideline values, or
- values have been shown to be deteriorating through time, and
- the contaminant in question has human origin.

In developing SSGs, there are many approaches that can be taken and will be within this document. These include:

1. Adopting a guideline directly for use on a site-specific basis. An example might be using the range of pH values for the protection of aquatic life of 6.5 to 9.0.
2. Modifying a guideline that is based on another variable, such as hardness, and calculating an absolute value for the SSG.
3. Calculating another statistic based on what has been measured at the site (e.g., 95^{th} percentile) after ensuring that at this new level, aquatic life will receive some degree of protection, albeit a reduced level over what the guideline originally intended. For example, the safety factor used to calculate the generic guideline might be reduced from ten to seven on a site-specific basis.
4. Using a combination of approach #2 and #3 to converge on a SSG.

Environment Canada has shown confidence in the guidelines that have been established by various jurisdictions for certain metals. The metals with CCME guidelines include arsenic, chromium, molybdenum, thallium, mercury and cadmium. Environment Canada also has confidence in the following guidelines established by BC Ministry of Water, Land and Air Protection. These include aluminum (dissolved), copper, lead, selenium, silver and zinc. It is important to note that for the British Columbia guidelines that are stated as mean (i.e., 30-day average) are based on chronic data; also the CCME guideline stated as maximum are based on this same chronic data set. The British Columbia maximum values are determined from the acute data set that is generally not used in the CCME derivation process.

Aluminum (B.C Guideline): The BC guidelines for aluminum are stated as dissolved concentrations: 50 µg/L mean concentration based on five samples collected over a thirty day period, and a maximum concentration of 100µg/L for water of pH ≥6.5.

Arsenic (CCME Guideline): The maximum guideline from CCME is 5 µg/L.

Cadmium (CCME Guideline): The CCME guideline for total cadmium (µg/L) is that the concentration should not exceeded that defined by the following equation: Guideline = $10^{(0.86[\log \{hardness\}]-3.2}$.

Chromium (CCME Guideline): The CCME guideline is based on trivalent and hexavalent chromium with a recommended maximum concentration of 8.9 µg/L for Cr (III) and 1 µg/L for Cr (VI).

Copper (B.C. Guideline): Copper guidelines are based on equations relating hardness to toxic effects of copper (BC Environment and Parks, 1987). The equations to determine mean and maximum guideline concentrations are: ≤ 0.04 (hardness) µg/L and [0.094 (hardness) + 2] µg/L.

Lead (B.C. Guideline): The BC guidelines for lead are a maximum of $e^{(1.273 \ln (hardness) - 1.460)}$ and a mean not to exceed 3.31 +$e^{(1.273\ 1n\ (mean\ hardness) - 4.704)}$.

Mercury (CCME Guideline): The CCME maximum inorganic mercury guideline is 0.026 µg/L and 0.004 µg/L methyl mercury.

Molybdenum (CCME Guideline): The CCME interim guideline is a maximum of 73 µg/L.

Selenium (B.C. Guideline): Selenium is an essential element for animal health, and food (and not water) is generally the major source of selenium in the food chain. The mean concentration of selenium in the water column (B.C. WLAP, 2001 (b)) should not exceed 2 µg/L. This will protect aquatic life both from direct toxic effects and from accumulating undesirable levels of selenium via the food chain.

Silver (B.C. Guideline): The B.C. guideline for silver is related to water hardness, with maximum and 30-d mean concentrations for values up to or exceeding 100 mg/L hardness. The guidelines are 0.05µg/L and 0.1µg/L as 30-d mean and maximum values, respectively at hardness less than 100 mg/L and 1.5 µg/L and 3.0 µg/L as 30-d mean and maximum values, respectively at hardness greater than 100 mg/L.

Thallium (CCME Guideline): The CCME guideline is 0.8µg/L. All values were well below the guidelines and there was no trend in the data.

Zinc (B.C. Guideline): Zinc guidelines are based on equations relating hardness to zinc toxicity (BC Environment, Land and Parks, 1999). The equations to determine zinc toxicity are a mean of [7.5 + 0.75 (hardness-90)] µg/L and a maximum of [33 + 0.75 (hardness-90)] µg/L.

In addition, objectives will also be developed for certain common variables (temperature, pH, dissolved oxygen) as possible.

pH (CCME Guideline): The CCME (2003) guideline to protect aquatic life is to maintain the pH within a range from 6.5 to 9.0. This is the proposed **SSG** for reporting.

Dissolved Oxygen (B.C. Guideline): The B.C. guidelines range from a minimum of 5 to 9 mg/L DO, with 5 mg/L being the minimum concentration for all life stages other than buried embryo/alevin life stages and 9 mg/L as minimum when the buried embryo/alevin life stages occur. The respective 30-d mean values are 8 mg/L and 11 mg/L, respectively.

Temperature (B.C. Guideline): Sensitive species present include whitefish and bull trout. To protect these species (B.C. WLAP, 2001 (a)), the maximum daily temperature should not exceed 15^{o} C. For unknown species distribution, the maximum daily temperature should not exceed 19 ^{o}C. This is the **SSG**.

Total Phosphorus (Ontario Guideline): Ontario guidelines used in this review are a maximum of 20µg/L for rivers flowing into lake and 30µg/L for other rivers.

Nitrate (CCME and Alberta Guidelines): The CCME (2003) water quality guideline for the protection of aquatic life is 2.93 mg/L N. For nitrogen limited systems, the Alberta guideline of 1.0 mg/L will be applied.

Nitrite (B.C. Guideline): The incomplete nitrification of ammonia when oxygen is not available can result in nitrite existing under ice cover. Nitrite guidelines are related to chloride concentrations (which are also increasing). The BC guideline (Ministry of Environment and Parks, 1986 (b)), adopted as a site-specific objective for nitrite recognizes this relationship, and is as follows:

Chloride in mg/L	Nitrite (maximum) mg/L as Nitrogen	Nitrite (average) mg/L as Nitrogen
less than 2 mg/L	0.06 mg/L	0.02 mg/L
2 to 4 mg/L	0.12 mg/L	0.04 mg/L
4 to 6 mg/L	0.18 mg/L	0.06 mg/L
6 to 8 mg/L	0.24 mg/L	0.08 mg/L
8 to 10 mg/L	0.30 mg/L	0.10 mg/L
greater than 10 mg/L	0.60 mg/L	0.20 mg/L

4.1 Variables for Which Guidelines Have Been Exceeded

Guidelines have been exceeded for several variables. These include: pH (Figure 2), aluminum (Figure 6 (a), cadmium (Figure 7), chromium (Figure 8), copper (Figure 9), lead (Figure 10), silver (Figure 12), zinc (Figure 13), arsenic (Figure 14), nitrogen (and nitrate – Figure 16), total phosphorus (Figure 17), and temperature (Figure 18). Values that exceed guidelines seem to be the result relatively rare occurrence and may have been associated with turbidity or suspended solids levels.

pH (Figure 2): The lower range of pH was not achieved on some occasions. It is our belief that this may be due in part to the geology of the area not being able to provide adequate buffering to the acidic precipitation that falls along the coast of British Columbia. Since the 5th percentile value was 6.7, we recommend that the **SSG** for pH be maintained in the range from **6.5 to 9.0**.

Aluminum (Figure 6 (a): Total aluminum concentrations frequently exceed the guideline of 100 µg/L to protect aquatic life. These high total aluminum concentrations are strongly correlated (R^2=0.65) with turbidity (Figure 6 (b)). We do not recommend a SSG for aluminum since there are no data for the dissolved fraction.

Cadmium (Figure 7): Several cadmium values appear to exceed the guideline of 0.012 µg/L at a hardness of 31 mg/L and 0.022 µg/L at 63 mg/L hardness; however, several of these were with detection values of 0.1 µg/L and certainly values within 10 times the detection limit. The decreasing trend is likely associated with changes to detection limits over time. There is a weak correlation (R^2 = 0.24) of increasing cadmium with turbidity (Figure 7 (a)). Using this relationship and the hardness related guideline, we propose that the maximum **SSG** should not exceed the concentration given by $\mathbf{10^{(0.86[\log \{hardness\}]-3.2}}$ when turbidity is **< 5.8 NTU**. The detection limits used are not satisfactory to be able to test the achievement of the guideline; therefore, we do not recommend a SSG for cadmium at this time.

Chromium (Figure 8): Several total chromium values exceed the guideline for hexavalent chromium of 1.0 µg/L and the guideline of 8.9 µg/L for trivalent chromium. The 95th percentile value was 5.07 µg/L while the 95 percent confidence level was 6.03µg/L (Table 1) and the mean concentration was 1.39 µg/L. There was a moderately strong (R^2 = 0.50) relationship between chromium and turbidity values (Figure 8 (a). We recommend the following **SSG** for chromium: a maximum not to exceed **6.0 µg/L** when turbidity is < **67.7 NTU**. We cannot stress enough the need to obtain both trivalent and hexavalent chromium measurements in the future.

Copper (Figure 9): Several individual copper values exceeded the guidelines for the mean (1.24 µg/L) and maximum (4.91 µg/L) values at a hardness of 31 mg/L. The 95th percentile was 7.92 µg/L, the 95 percent confidence level was 8.03 µg/L, and the mean concentration was 2.68 µg/L (Table 1). There is a strong correlation (Figure 9 (a)) between total copper and turbidity (R^2 = 0.75). Based on these statistics, we recommend a **SSG** for total copper of **8.0** µg/L maximum when turbidity is < 69.5 NTU.

Lead (Figure 10): The mean guideline of 4.03 µg/L was not met by individual values; however, the maximum guideline of 18.4 µg/L was achieved. The 95th percentile was 3.0 µg/L, the 95 percent confidence level was 3.32 µg/L, and the mean concentration was 0.86µg/L (Table 1). There is a strong correlation (R^2 = 0.67) of increasing lead concentrations with increased turbidity (Figure 10 (a)). We therefore recommend a **SSG** as a **maximum** concentration defined by the **equation** for the mean concentration, knowing that the data used to develop this mean concentration are the same as would have been used by the CCME to develop a maximum concentration. This maximum concentration should apply at turbidity concentrations < 89.7 NTU.

Silver (Figure 12): The mean and maximum guidelines (**0.05** µg/L and **0.10** µg/L, respectively) for hardness of less than 100 mg/L were often not achieved, and on one occasion, the guidelines (**1.5** µg/L and **3.0** µg/L, respectively) for hardness greater than 100 mg/L. The 95th percentile value was 0.1 µg/L, the 95 percent confidence level was

1.5 µg/L, and the mean concentration was 0.15 µg/L (Table 1). We expect that values in the future will be lower because these statistics reflect higher detection limits of 0.1 µg/L that in 2003 were lowered to 0.001 µg/L. We therefore recommend the **SSGs** to be the guideline values for hardness of for both < and > 100 mg/L as noted above (0.05 and 1.5 µg/L).

Zinc (Figure 13): Several individual values exceeded the guidelines of 7.5 µg/L as a mean concentration and 33 µg/L as a maximum concentration. The 95th percentile was 18.0 µg/L, the 95 percent confidence level was 18.8 µg/L, and the mean concentration was 4.65 µg/L (Table 1). Zinc concentrations are highly correlated (Figure 13 (a)) with turbidity (R2 = 0.71). We therefore recommend the following as **SSGs** for zinc based on these statistics: maximum **18.8** µg/L to a hardness of 105 mg/L, and thereafter, the equation for the mean concentration. Recognizing the strong relationship with turbidity, these should apply when turbidity is < 76 NTU.

Arsenic (Figure 14): The guideline for arsenic of 5 µg/L was occasionally exceeded. The 95th percentile value was 2.0 µg/L, the 95 percent confidence level was 4.17 µg/L, and the mean concentration was 0.74µg/L (Table 1). There was a moderate correlation (R^2 = 0.44) between increasing arsenic and turbidity concentrations (Figure 14 (a)). Based on these statistics, we recommend that the **SSG** for arsenic should be a maximum **5** µg/L at turbidity < 72.3 NTU.

Nitrogen (and nitrate – Figure 16): One value of total dissolved nitrogen exceeded the CCME guideline for nitrate of **2.93** mg/L; however, all nitrate values met the guideline. We therefore recommend this as the **SSG** for **nitrate**.

Phosphorus (Figure 17): Several phosphorus values exceeded the guideline of 0.03 mg/L. The data in Figure 17 (b) indicate that total phosphorus is highly correlated with turbidity (R^2 = 0.70). Using the regression equation, we have determined that this guideline value should be achieved for turbidity up to about 10 NTU, thereafter it will be exceeded. When turbidity does rise, light and not nutrient availability will become the limiting factor in algal growth. As well, the phosphorus at such times will likely be in particulate form and not available for growth. We recommend a **SSG** for total phosphorus of a maximum of **0.03** mg/L for the turbidity $\leq$ 10 NTU.

Temperature (Figure 18): The maximum temperature guideline was exceeded by two values. The 95th percentile was 15^{o}C and the 95 percent confidence level was 16 ^{o}C. We therefore recommend a maximum temperature **SSG** of **19 ^{o}C**.

4.2 Variables Within 90% of Guideline Values

There were two variables, sulphate and selenium, for which the maximum concentrations came within 90% of guideline values.

Sulphate (Figure 5): One value was close to the guideline of 100 mg/L; however, all other values were $\leq$ 20 mg/L. We therefore feel that the one high value may be an outlier and do not recommend a SSG for sulphate.

Selenium (Figure 15): Two values were near 90% of the guideline (2.0 µg/L) while two other values approached this. We therefore recommend that the **SSG** be a maximum selenium concentration not exceeding **2.0** µg/L.

4.3 Variables with Increasing Trends

Increasing or decreasing trends in values (i.e. R2 $\geq$ 0.05) were noted for fluoride, cadmium, molybdenum and silver. Whether these trends are real is not clear from the data. For example, decreasing detection limits could impart the illusion of a decreasing trend. Silver and cadmium are discussed in Section 4.1.

Fluoride (Figure 4): Fluoride values seem to show a strong downward correlation; however, this is related to decreasing detection limits. We therefore do not recommend a SSG for fluoride.

Molybdenum (Figure 11): Although there may be a slightly increasing trend on molybdenum (R^2 = 0.05), values are well below the guideline and we do not recommend a SSG.

4.4 Biases Noted Within the Data Set

In reviewing the data downloaded from the Environment Canada web site for this report, it was noted that from the first samples in December 194 until 6/12/1994, there were multiple entries (often three or four) on the same day for dissolved NO2/NO3, dissolved nitrogen, and total phosphorus. We have not attempted to correct these entries, calculate a mean for the day, or recommend elimination of any of these tests. In performing subsequent data reviews (verification, flags, etc.), it will be important that these entries be considered.

5. Recommended Monitoring Program

It is expected that the highest concentrations of metals are associated with high spring flows during May and June. This is one period when samples should be collected to test objectives. A second period is during lower flows in late autumn prior to ice cover forming. During these periods, five samples should be collected in a thirty-day period for the variables for which SSGs are proposed.

We have made a number of recommendations in Section 4.1 concerning the form of different metals that should be analyzed. These included dissolved aluminum and trivalent and hexavalent chromium. Testing for total forms of metals, considering the high concentration of solids, is not providing data that can be interpreted relative to ecosystem health. We recommend that as a minimum, extractable concentrations of metals would provide more meaningful data. As well, better detection limits are required for cadmium to be able to interpret those data in a meaningful way. Greater attention also needs to be paid to the presence of sensitive aquatic mosses that may be being impacted by increasing sulphate concentrations.

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Canadian Council of Ministers of the Environment. *Canadian Environmental Quality Guidelines*. December 2003 Update.

Table 2: Summary of Data Results: 12/17/1984 – 8/13/2004

Substance	Unit	No. of Values	Max	Min	Mean	Std Dev	95th %ile	5th %ile	Mean + 2 SD
Hardness	mg/L	434	79.03	0.4	46.1848848	11.144612	62.974	30.90	68.47
pH	pH units	500	8.18	5.31	7.56872	0.41187576	8	6.70	8.39
Chloride	mg/L	502	27.5	0.029	0.57	1.25	1.2	0.11	3.07
Fluoride	mg/L	349	0.15	0.01	0.04	0.02	0.07	0.02	0.08
Sulphate	mg/L	502	92.2	0.5	8.11	4.30	11	4.50	16.71
Aluminum, total	µg/L	375	13900	2	1008.7	1705.9	3937.0	45.0	4420.5
Cadmium, total	µg/L	380	2.2	0.001	0.235	0.311	1.000	0.013	0.857
Chromium, total	µg/L	354	19.6	0.103	1.389	2.320	5.070	0.200	6.028
Copper, total	µg/L	380	27.9	0.2	2.684	3.073	7.920	0.600	8.830
Lead, total	µg/L	380	7.9	0.006	0.858	1.231	3.000	0.200	3.320
Molybdenum, total	µg/L	375	1.9	0.1	0.700	0.213	1.023	0.400	1.125
Silver, total	µg/L	221	10	0.001	0.147	0.674	0.100	0.003	1.500
Silver, ext.	µg/L	97	0.2	0.005	0.098	0.020	0.100	0.100	0.137
Zinc, total	µg/L	380	63.7	0.05	4.645	7.057	18.020	0.200	18.800
Arsenic, total	µg/L	312	25.1	0.1	0.742	1.712	2.000	0.150	4.170
Selenium, total	µg/L	300	1.9	0.05	0.220	0.195	0.400	0.100	0.611
Nitrate-Nitrite, (N)	mg/L	821	0.4	0.002	0.086	0.057	0.179	0.015	0.200
Phosphorus, total	mg/L	1052	0.935	0.002	0.060	0.107	0.242	0.004	0.273
Temperature	˚C	491	26	-5	6.03	5.00	15	0.00	16.00
Turbidity	NTU	499	341	0.1	17.21	33.74	57.92	0.65	84.70

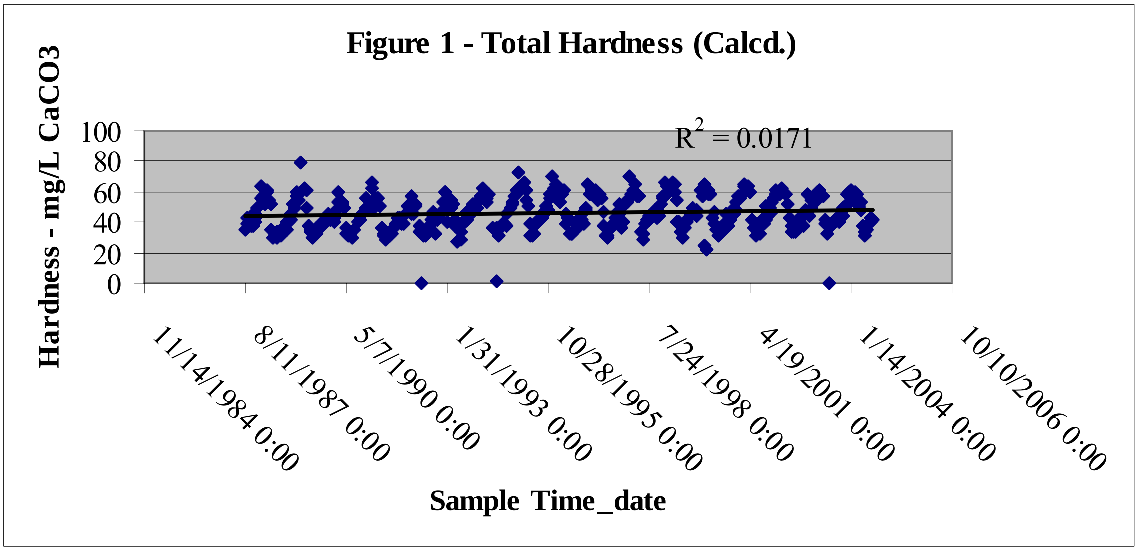


Figure 1 - Total Hardness (Calcd.)
Hardness - mg/L CaCO3
100
80
60
40
20
0
R^2 = 0.0171
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
Sample Time_date

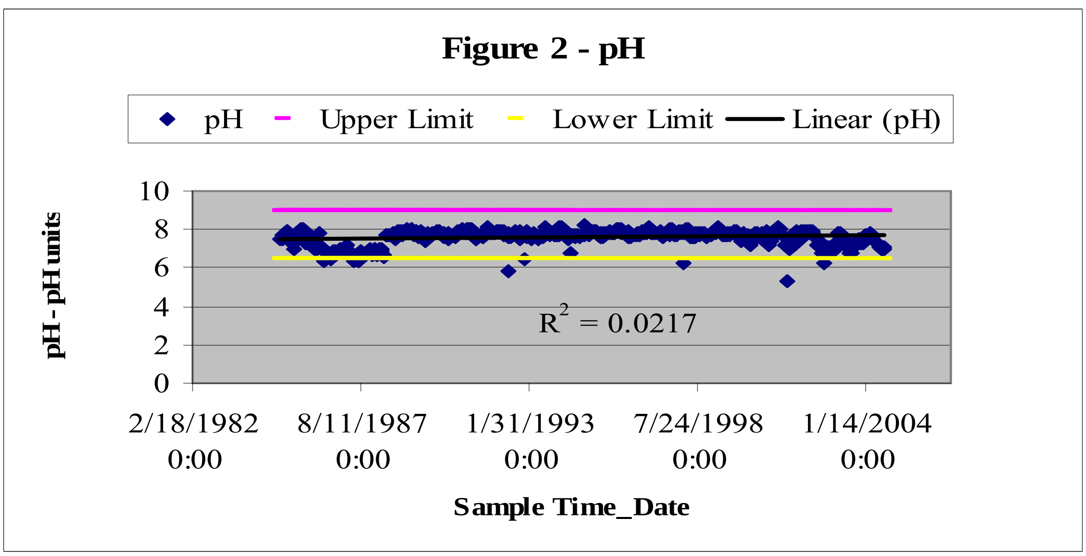


Figure 2 - pH
pH
Upper Limit
Lower Limit
Linear (pH)
pH - pH units
10
8
6
4
2
0
R^2 = 0.0217
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date

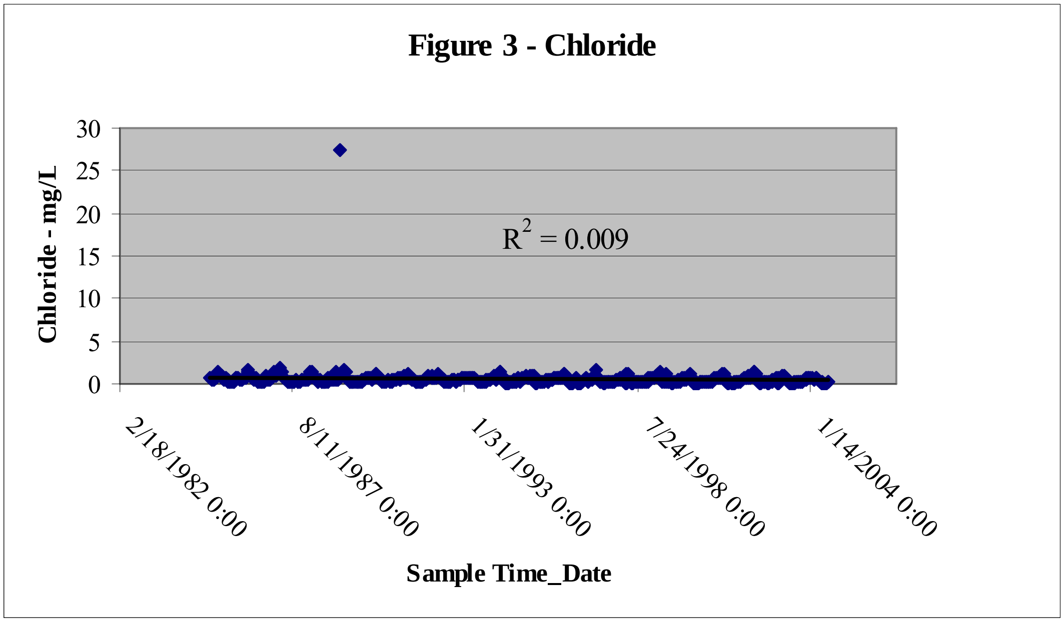


Figure 3 - Chloride
Chloride - mg/L
30
25
20
15
10
5
0
R^2 = 0.009
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date

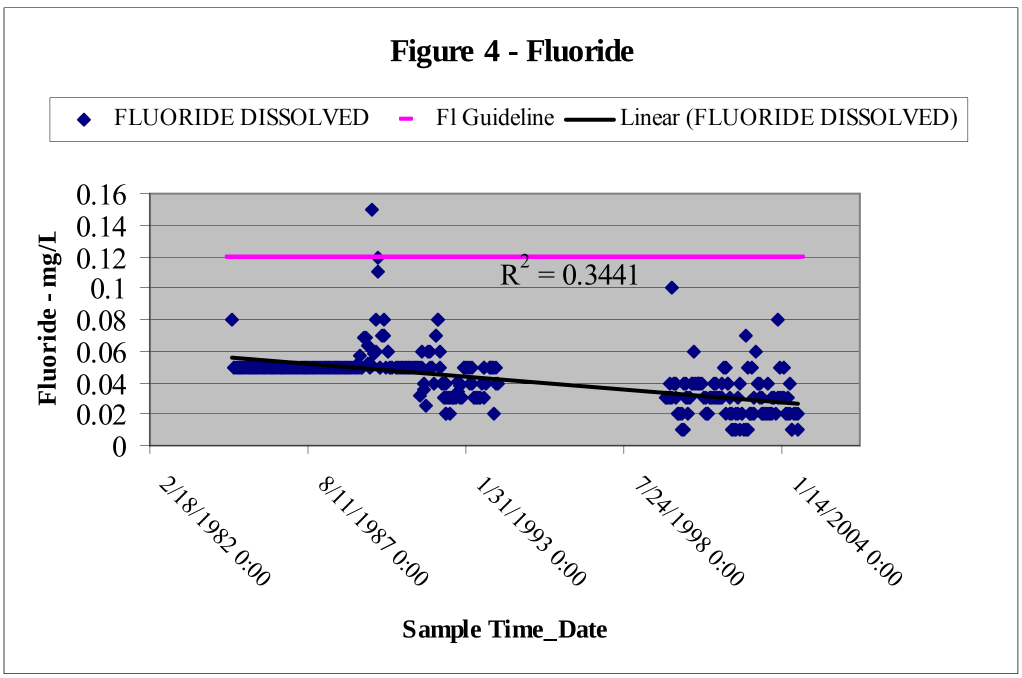


Figure 4 - Fluoride
FLUORIDE DISSOLVED
Fl Guideline
Linear (FLUORIDE DISSOLVED)
Fluoride - mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
R^2 = 0.3441
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date

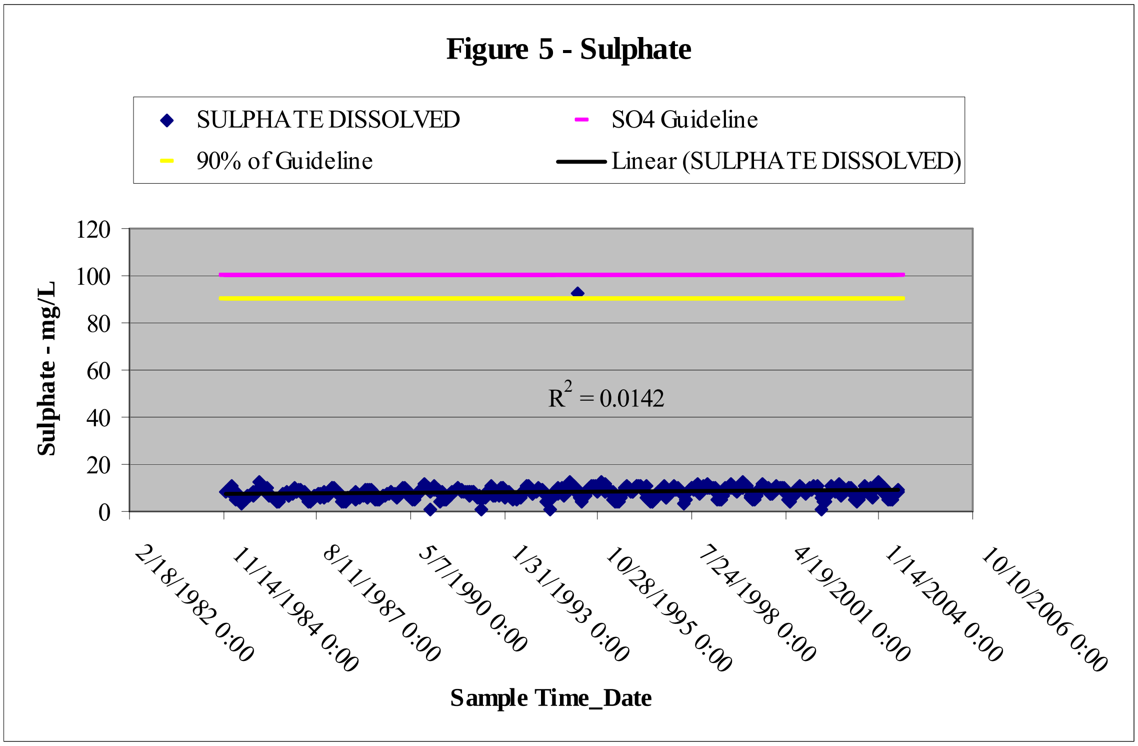


Figure 5 - Sulphate
SULPHATE DISSOLVED
SO4 Guideline
90% of Guideline
Linear (SULPHATE DISSOLVED)
120
100
80
60
40
20
0
Sulphate - mg/L
R2 = 0.0142
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
Sample Time_Date

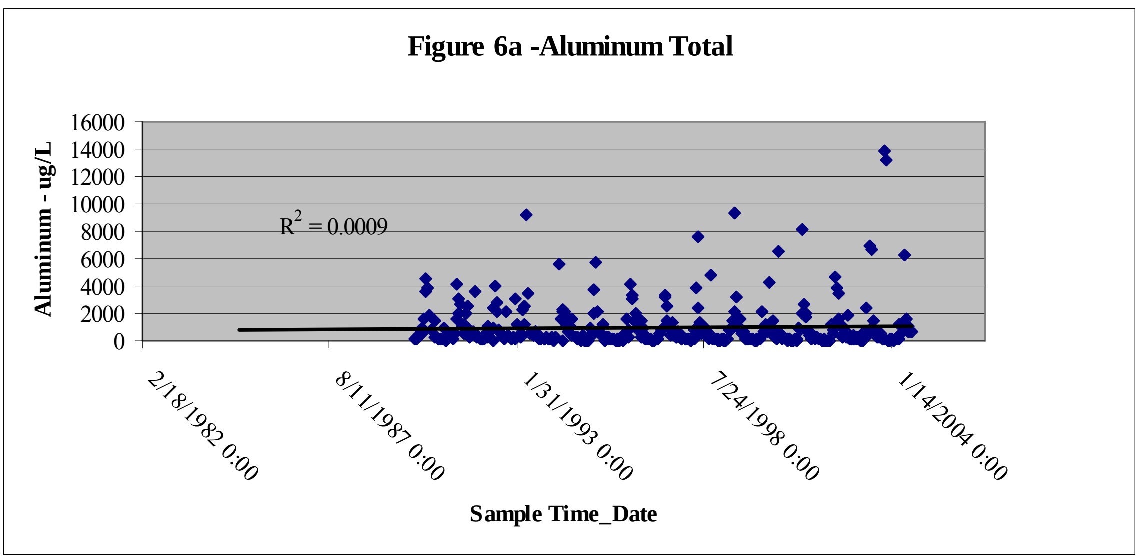


Figure 6a -Aluminum Total
16000
14000
12000
10000
8000
6000
4000
2000
0
Aluminum - ug/L
R2 = 0.0009
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date

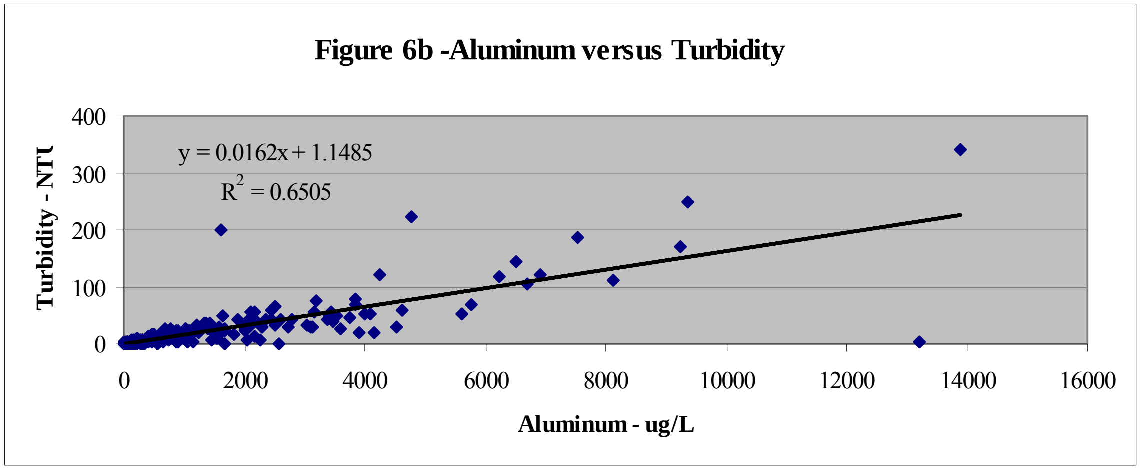


Figure 6b -Aluminum versus Turbidity
y = 0.0162x + 1.1485
R2 = 0.6505
Turbidity - NTU
0
100
200
300
400
0
2000
4000
6000
8000
10000
12000
14000
16000
Aluminum - ug/L

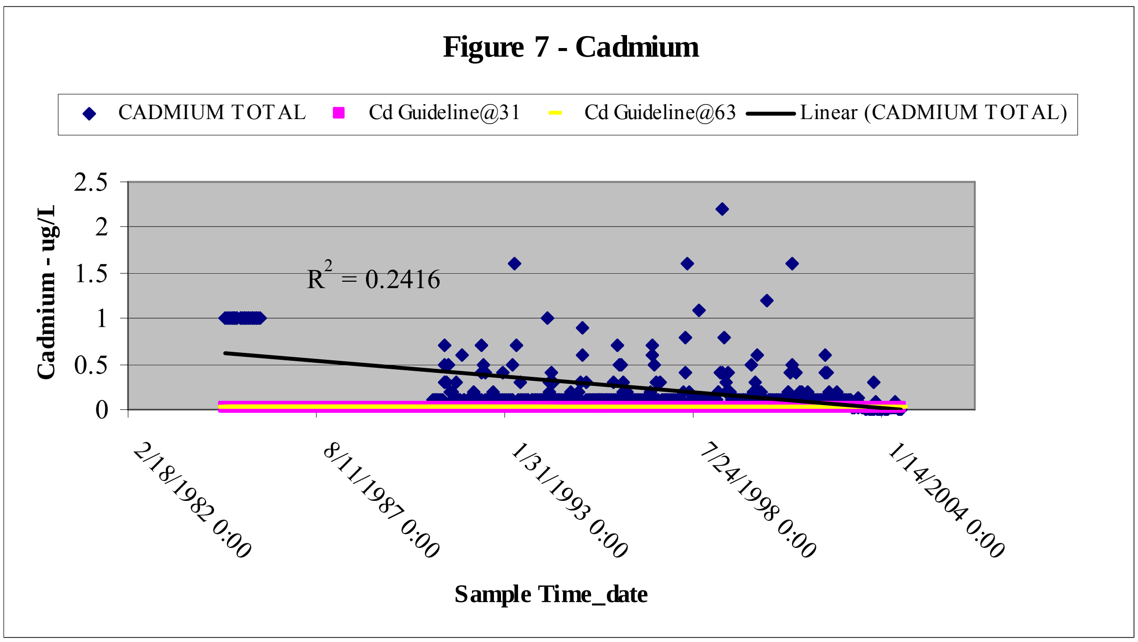


Figure 7 - Cadmium
CADMIUM TOTAL
Cd Guideline@31
Cd Guideline@63
Linear (CADMIUM TOTAL)
R2 = 0.2416
Cadmium - ug/L
0
0.5
1
1.5
2
2.5
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_date

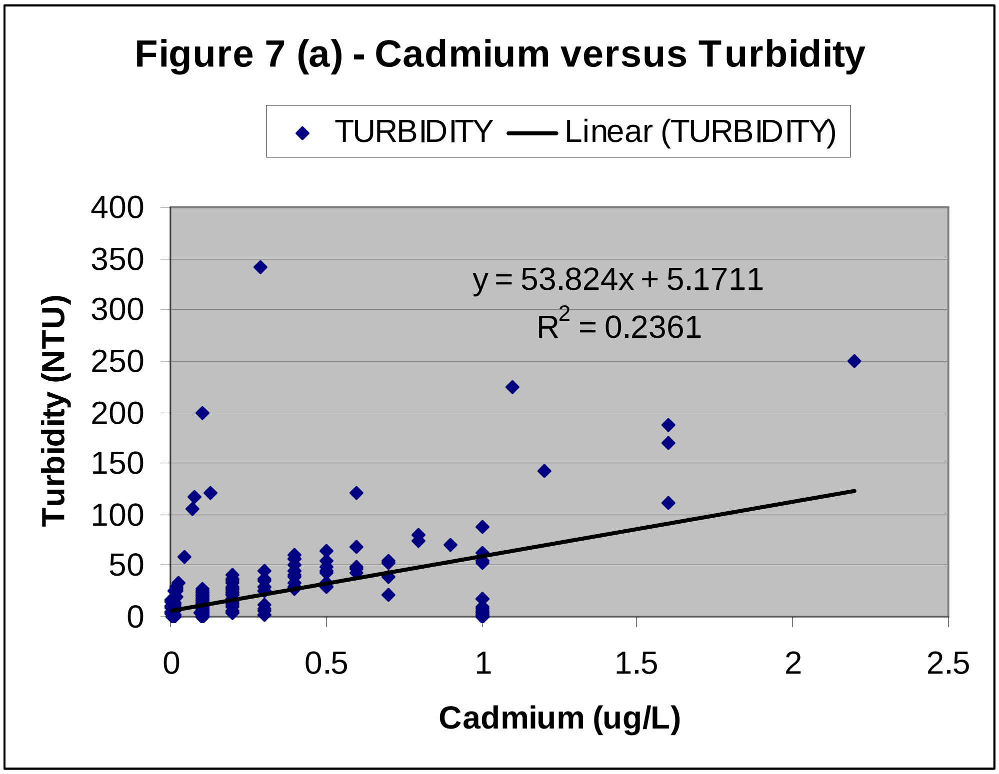


Figure 7 (a) - Cadmium versus Turbidity
TURBIDITY
Linear (TURBIDITY)
y = 53.824x + 5.1711
R^2 = 0.2361
Turbidity (NTU)
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
Cadmium (ug/L)

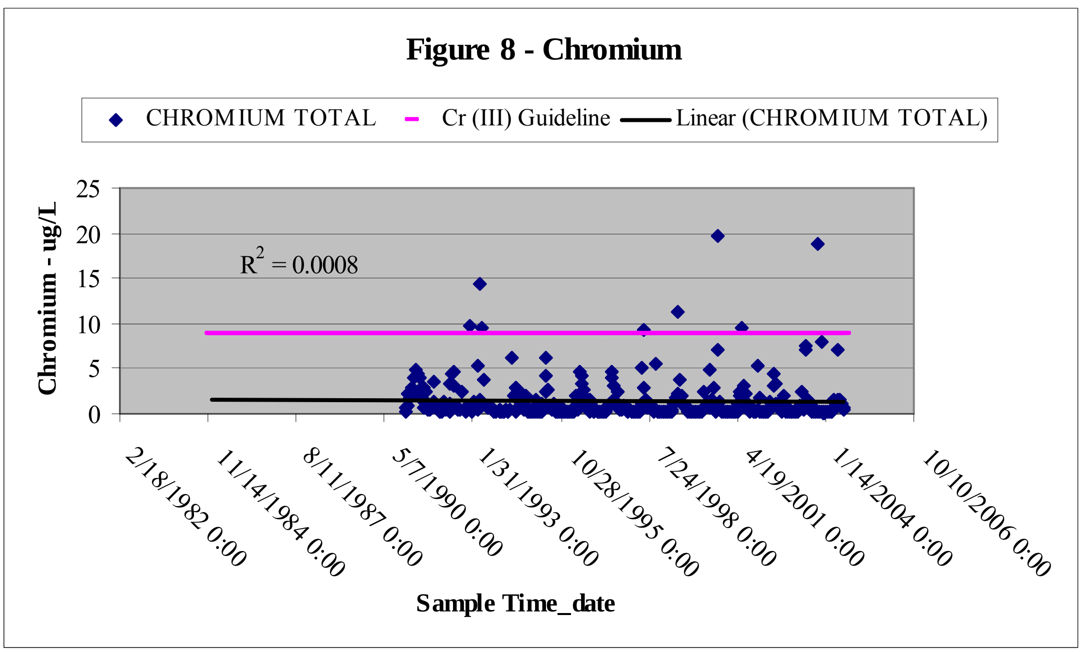


Figure 8 - Chromium
CHROMIUM TOTAL
Cr (III) Guideline
Linear (CHROMIUM TOTAL)
R^2 = 0.0008
Chromium - ug/L
25
20
15
10
5
0
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
Sample Time_date

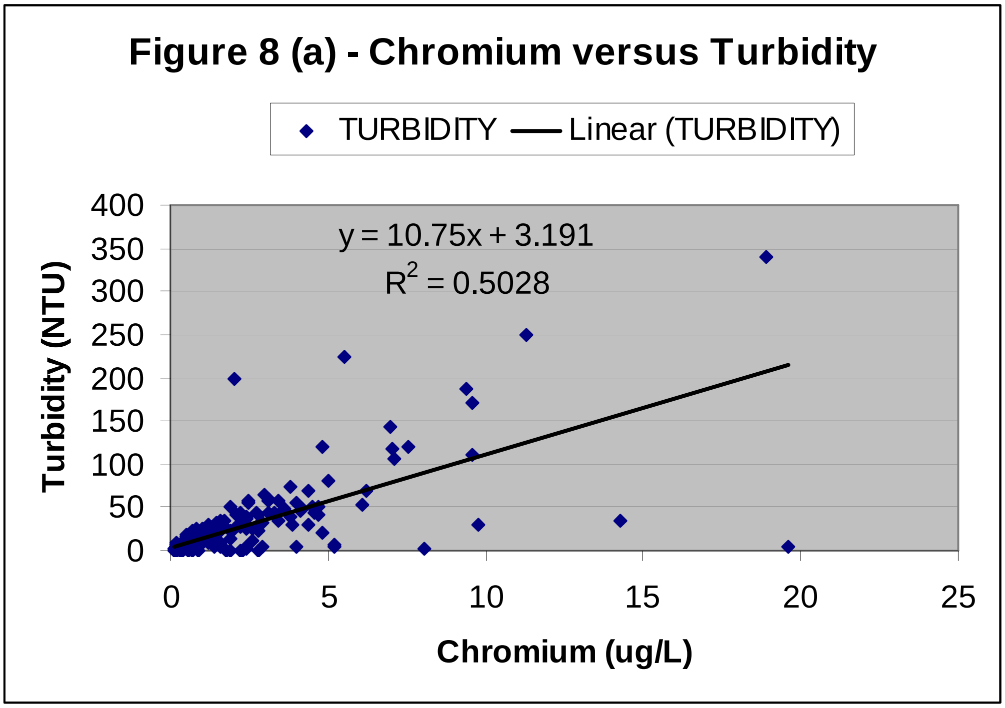


Figure 8 (a) - Chromium versus Turbidity
TURBIDITY
Linear (TURBIDITY)
y = 10.75x + 3.191
R2 = 0.5028
Turbidity (NTU)
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
Chromium (ug/L)

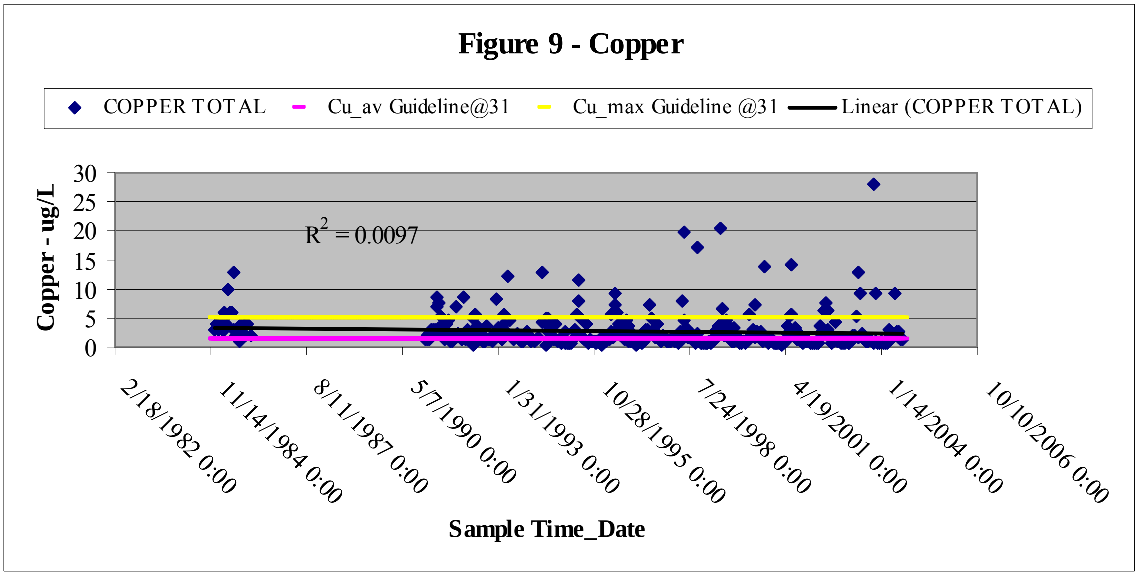


Figure 9 - Copper
COPPER TOTAL
Cu_av Guideline@31
Cu_max Guideline @31
Linear (COPPER TOTAL)
R2 = 0.0097
Copper - ug/L
30
25
20
15
10
5
0
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
Sample Time_Date

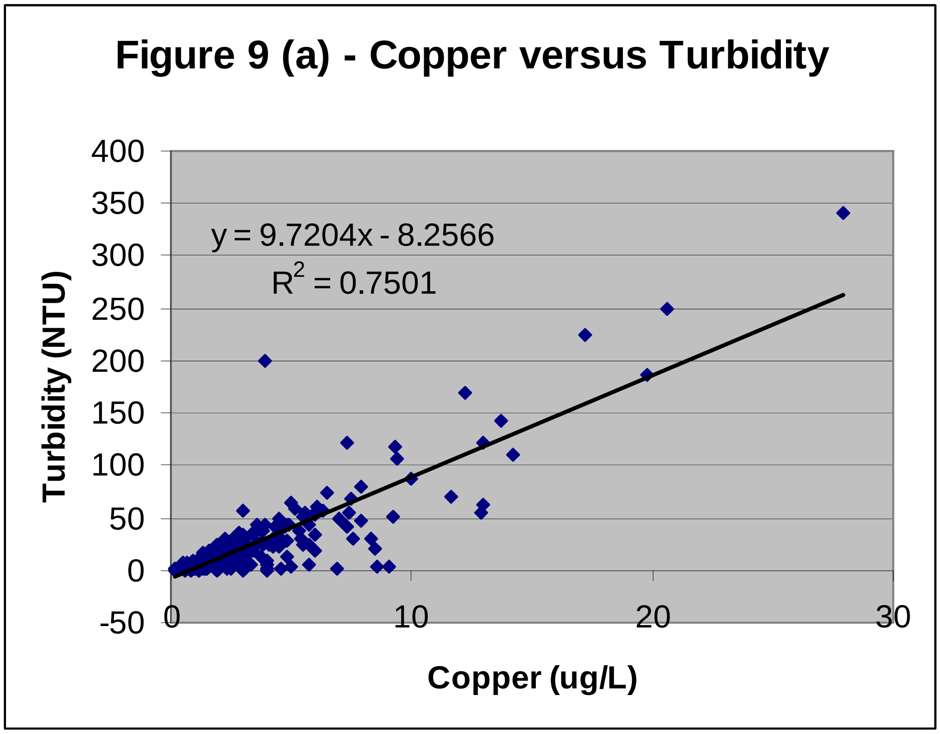


Figure 9 (a) - Copper versus Turbidity
y = 9.7204x - 8.2566
R2 = 0.7501
Turbidity (NTU)
400
350
300
250
200
150
100
50
0
-50
0
10
20
30
Copper (ug/L)

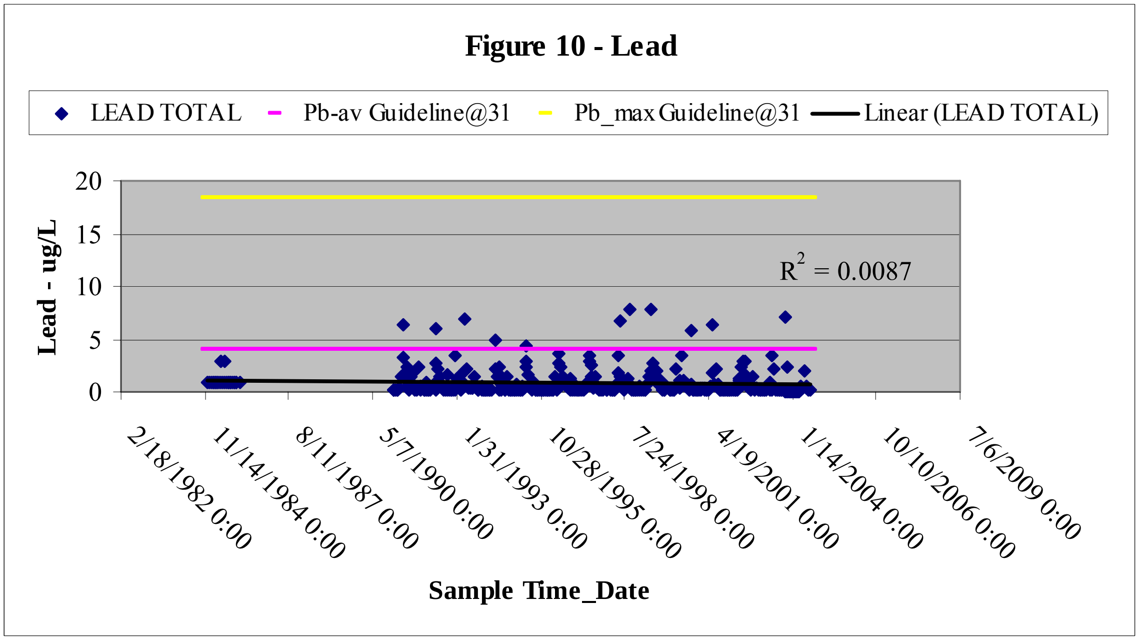


Figure 10 - Lead
LEAD TOTAL
Pb-av Guideline@31
Pb_max Guideline@31
Linear (LEAD TOTAL)
R2 = 0.0087
Lead - ug/L
20
15
10
5
0
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
7/6/2009 0:00
Sample Time_Date

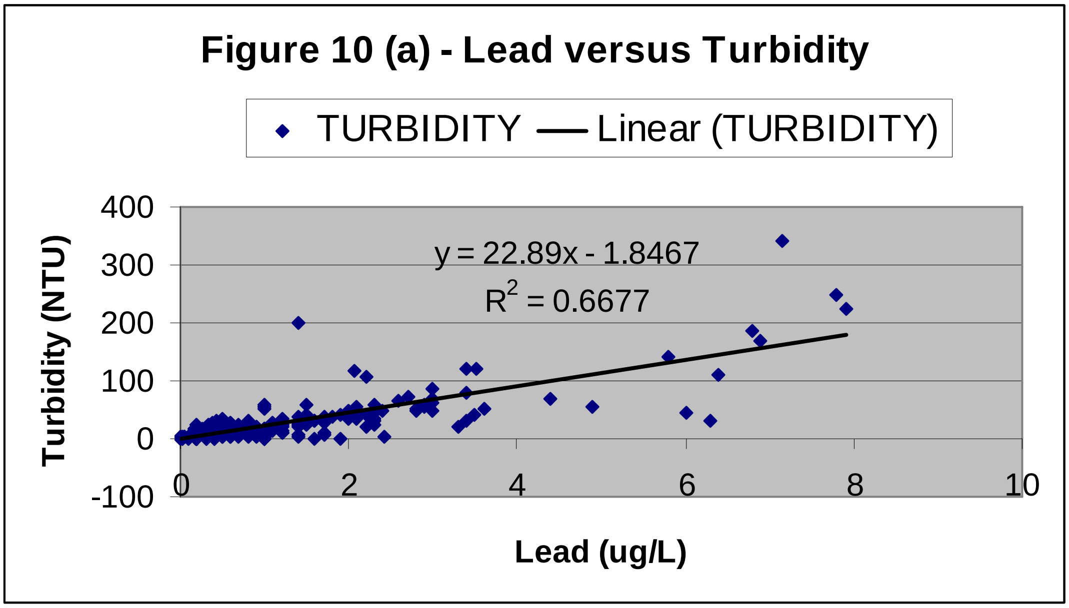


Figure 10 (a) - Lead versus Turbidity
TURBIDITY
Linear (TURBIDITY)
y = 22.89x - 1.8467
R2 = 0.6677
Turbidity (NTU)
400
300
200
100
0
-100
0
2
4
6
8
10
Lead (ug/L)

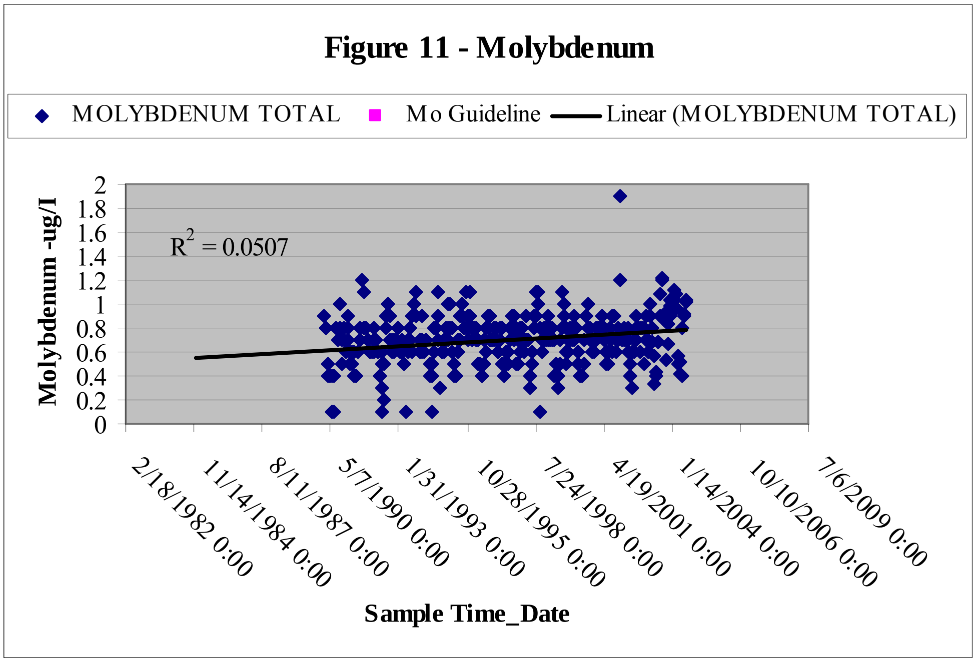


Figure 11 - Molybdenum
MOLYBDENUM TOTAL
Mo Guideline
Linear (MOLYBDENUM TOTAL)
R2 = 0.0507
Molybdenum -ug/l
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
7/6/2009 0:00
Sample Time_Date

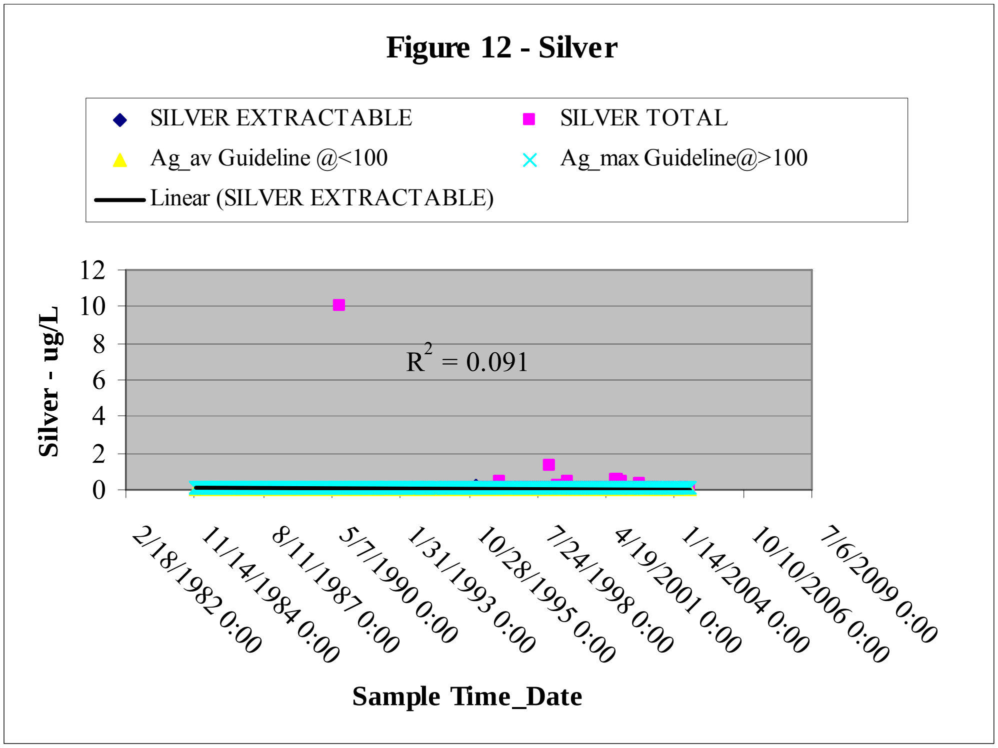


Figure 12 - Silver
SILVER EXTRACTABLE
SILVER TOTAL
Ag_av Guideline @<100
Ag_max Guideline@>100
Linear (SILVER EXTRACTABLE)
Silver - ug/L
12
10
8
6
4
2
0
R2 = 0.091
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
7/6/2009 0:00
Sample Time_Date

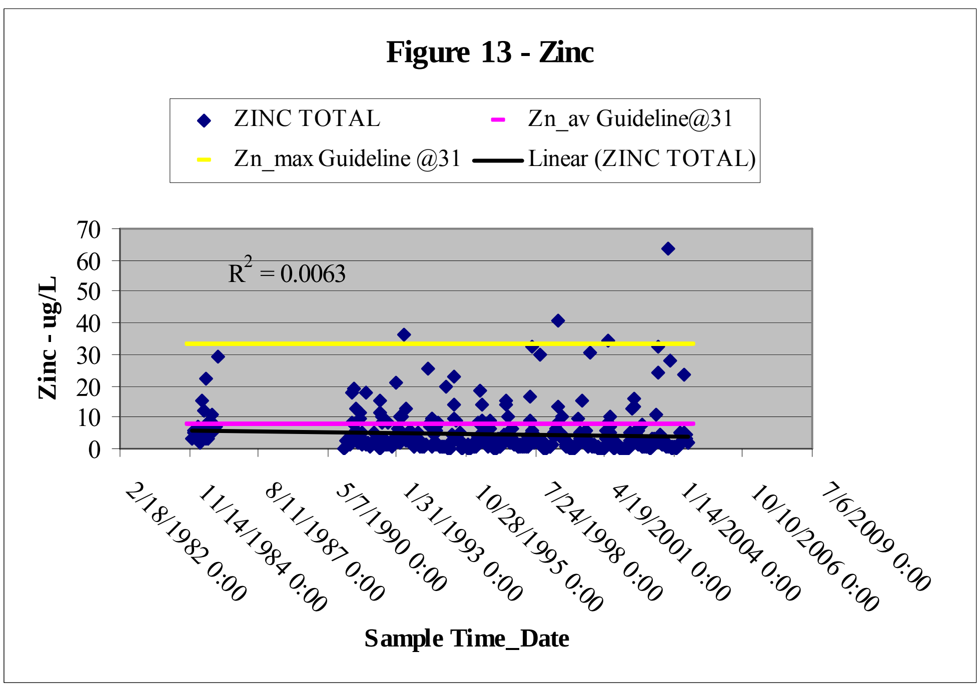


Figure 13 - Zinc
ZINC TOTAL
Zn_av Guideline@31
Zn_max Guideline @31
Linear (ZINC TOTAL)
Zinc - ug/L
70
60
50
40
30
20
10
0
R2 = 0.0063
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
7/6/2009 0:00
Sample Time_Date

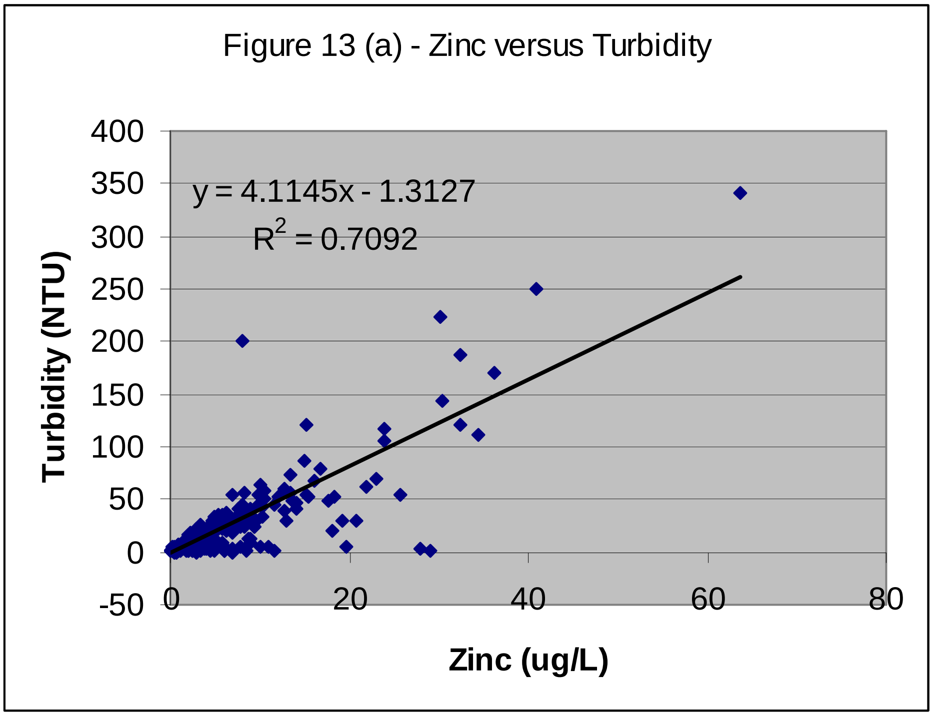


Figure 13 (a) - Zinc versus Turbidity
y = 4.1145x - 1.3127
R2 = 0.7092
Turbidity (NTU)
400
350
300
250
200
150
100
50
0
-50
0
20
40
60
80
Zinc (ug/L)

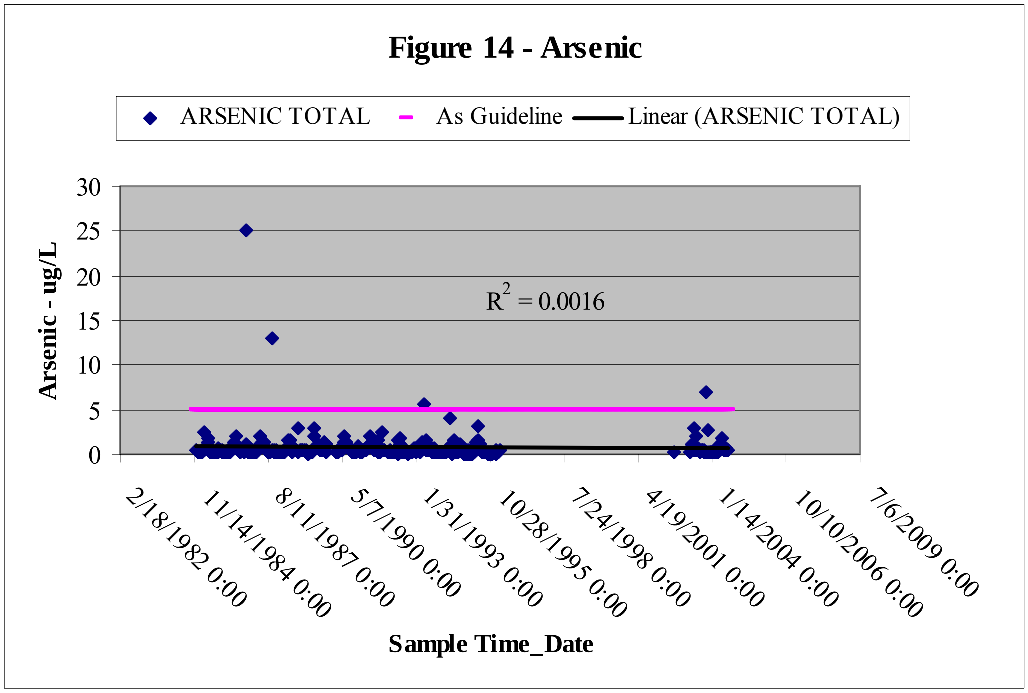


Figure 14 - Arsenic
ARSENIC TOTAL
As Guideline
Linear (ARSENIC TOTAL)
R2 = 0.0016
Arsenic - ug/L
30
25
20
15
10
5
0
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
7/6/2009 0:00
Sample Time_Date

Figure 14 (a) - Arsenic versus Turbidity

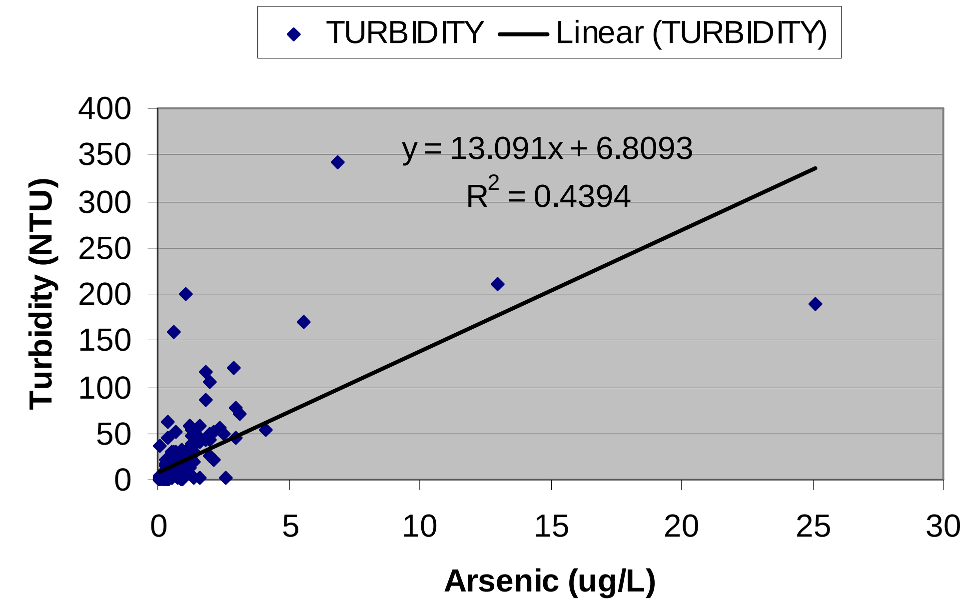
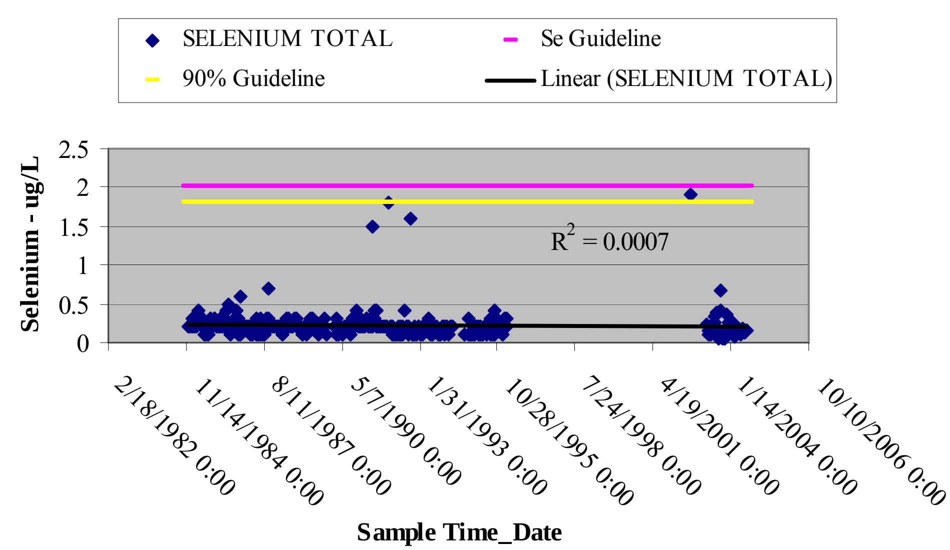


Figure 15 - Selenium



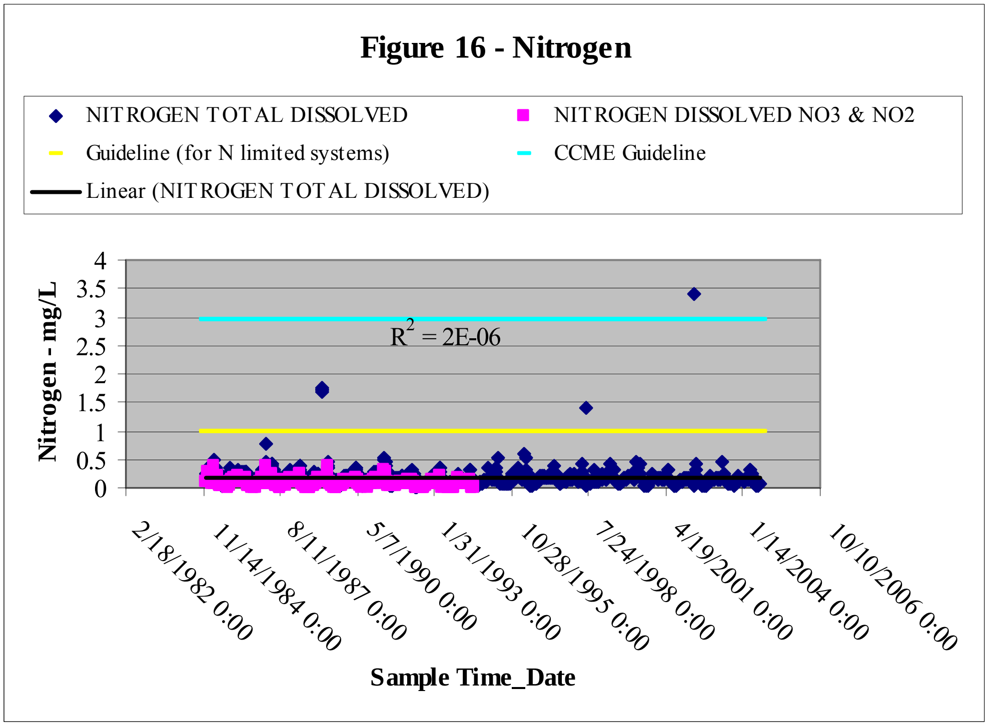


Figure 16 - Nitrogen
NITROGEN TOTAL DISSOLVED
NITROGEN DISSOLVED NO3 & NO2
Guideline (for N limited systems)
CCME Guideline
Linear (NITROGEN TOTAL DISSOLVED)
Nitrogen - mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
R2 = 2E-06
2/18/1982 0:00
11/14/1984 0:00
8/11/1987 0:00
5/7/1990 0:00
1/31/1993 0:00
10/28/1995 0:00
7/24/1998 0:00
4/19/2001 0:00
1/14/2004 0:00
10/10/2006 0:00
Sample Time_Date

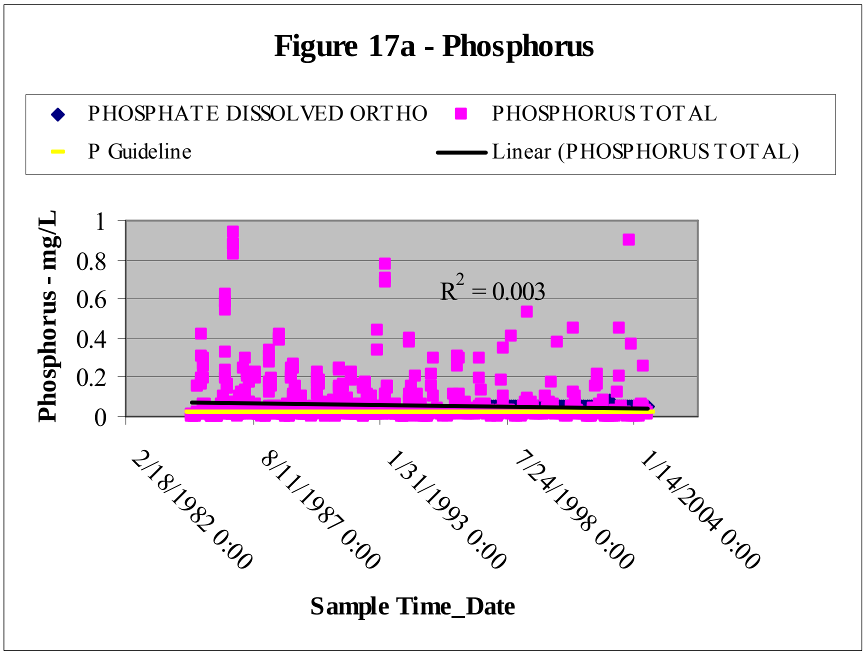


Figure 17a - Phosphorus
PHOSPHATE DISSOLVED ORTHO
PHOSPHORUS TOTAL
P Guideline
Linear (PHOSPHORUS TOTAL)
Phosphorus - mg/L
1
0.8
0.6
0.4
0.2
0
R2 = 0.003
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date

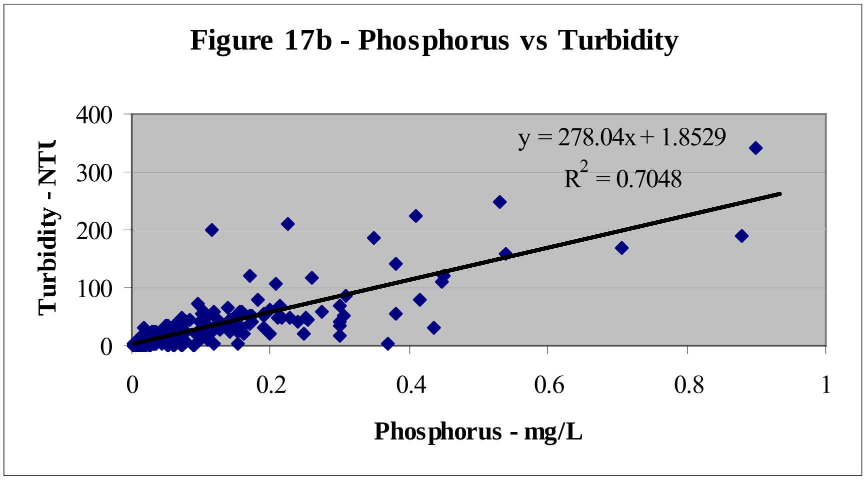


Figure 17b - Phosphorus vs Turbidity
y = 278.04x + 1.8529
R2 = 0.7048
Turbidity - NTU
Phosphorus - mg/L
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1

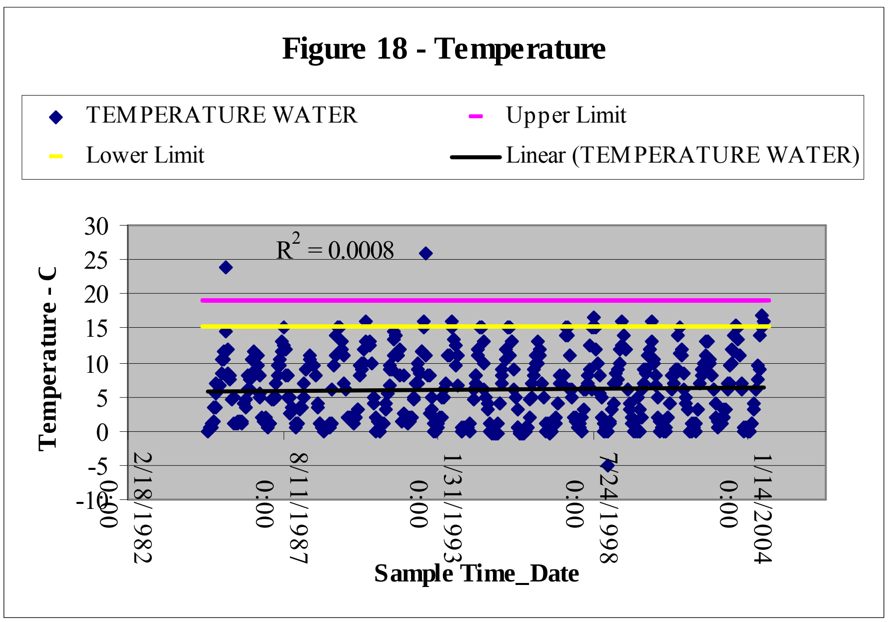


Figure 18 - Temperature
TEMPERATURE WATER
Upper Limit
Lower Limit
Linear (TEMPERATURE WATER)
R2 = 0.0008
Temperature - C
Sample Time_Date
30
25
20
15
10
5
0
-5
-10
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004

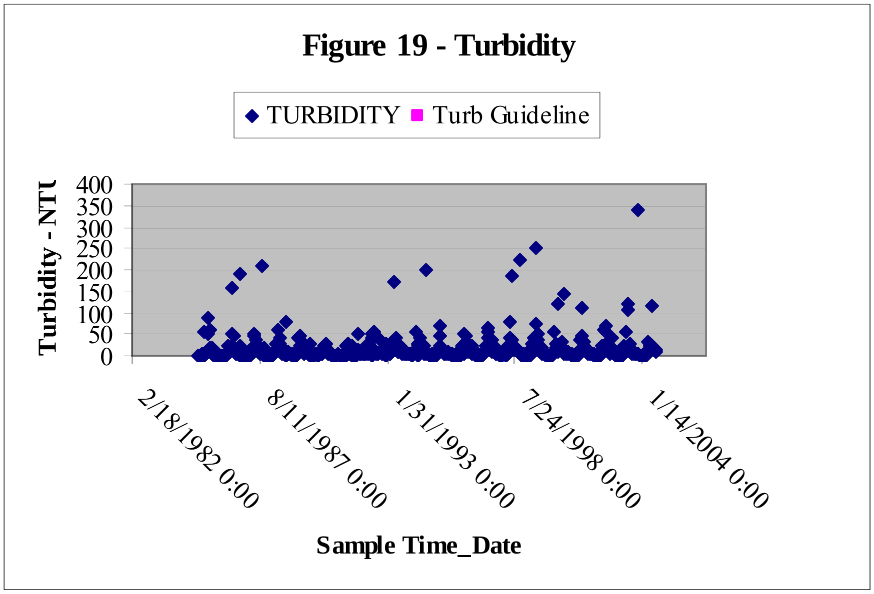


Figure 19 - Turbidity
TURBIDITY
Turb Guideline
Turbidity - NTU
400
350
300
250
200
150
100
50
0
2/18/1982 0:00
8/11/1987 0:00
1/31/1993 0:00
7/24/1998 0:00
1/14/2004 0:00
Sample Time_Date