CANADA – BRITISH COLUMBIA
WATER QUALITY MONITORING AGREEMENT

WATER QUALITY ASSESSMENT OF Fraser River AT MARGUERITE (1984 – 2004)

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B.C. Ministry of Environment
and
Environment Canada

March 2007

Environment Canada Environnement Canada

BRITISH COLUMBIA
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Ministry of Environment

EXECUTIVE SUMMARY

The Fraser River basin is one of British Columbia's most valued ecosystems, draining one-quarter of the province. Its headwaters are located near Moose Lake in the Rocky Mountains. The northern part of the river follows a north-west path before heading south starting just north from Prince George. The Fraser River then flows 600 km before turning to the west, near Hope, B.C., and flowing in a south-westerly direction to the Pacific Ocean. The river has two major tributaries which affect its flow and water quality: the Nechako River which merges with the Fraser River at Prince George; and the Thompson River which flows into the Fraser River at Lytton, B.C., approximately 95 km north from Hope. These two tributaries contribute 41% of the total Fraser River flow at Hope: the Thompson River contributes 30% and the Nechako River contributes 11%.

There are four long-term water quality monitoring sites on the Fraser River (Red Pass, Hansard, Marguerite, and Hope), as well as sites on both the Nechako and Thompson rivers. This report deals with the site on the Fraser River at Marguerite . Marguerite is in central B.C., roughly halfway between Quesnel and Williams Lake. Water quality at this site is affected by five upstream mills producing pulp and/or paper: three in Prince George and two in Quesnel. The designated water uses for this reach of the Fraser River are aquatic life, wildlife, drinking water (with partial treatment and disinfection), livestock, irrigation, and secondary-contact recreation (e.g., boating).

This report assesses eighteen years of data from 1984 – 2004.

CONCLUSIONS

- Flows are typical of interior rivers, with peaks occurring during the spring to early summer period and low flow taking place during the late autumn through winter periods.

- Turbidity levels at this station seem to be increasing through time, and related metals (barium, cadmium, cobalt, chromium, manganese and zinc) also appear to be increasing. These apparent trends will be tested with more rigorous statistical approaches than we have used in this report. A similar trend in turbidity was apparent at the upstream Hansard station but not at the further upstream Red Pass reference station. These possible trends are not of environmental concern in this river.

- Turbidity levels were high enough that if the water were to be considered as source water for drinking, that partial treatment would be required. This was reinforced by concentrations present of dissolved organic carbon, fecal coliforms, colour,

- A number of metals exceed water quality guidelines, especially at times of high turbidity implying that the metal is in particulate form and not biologically available. These include aluminum, cadmium, chromium, cobalt, copper, lead, silver, and zinc.

- Chloride concentrations have shown a marked decrease since early 1992, likely due to the elimination of chlorine dioxide as a bleaching compound at the pulp and paper mills. Similar decreases were not apparent upstream at Hansard where there would be no influences from pulp mills.

- Extractable potassium seems to be increasing through time, although this may be due to laboratory methodology changes over the period of record. This apparent trend will be tested with more rigorous statistical approaches than we have used in this report.

- Water temperatures vary seasonally as is to be expected, peaking during the hot summer months and on occasion exceeding guidelines for the protection of aquatic life. This is not a regular occurrence but could reduce the energy levels of salmon that might be migrating upstream during these periods.

RECOMMENDATIONS

- We recommend monitoring be continued for the Fraser River at Marguerite to track the possible increases in variables that have been identified in this report. As well, either trivalent and hexavalent forms of chromium should be measured in the future, or alternately, guidelines be developed for total chromium values.

Water quality indicators that are important for future monitoring are:

- Flow because of its importance in interpreting many water quality indicators.
- water temperature, specific conductivity, pH, turbidity, and dissolved oxygen,
- appropriate forms of metals for comparison to their respective guidelines such as chromium where either trivalent and hexavalent forms of chromium need to be measured in the future, or guidelines be developed for total chromium values, and
- other variables related to drinking water such as colour and dissolved organic carbon.

ACKNOWLEDGEMENTS

The graphs in this report were prepared by Sacha Wassick of Environment Canada. The draft report was reviewed by Kim Keogh of BC Environment and Andrea Ryan from Environment Canada. We thank these individuals for their contributions to improving this document. Any errors or omissions are the responsibility of the author.

TABLE OF CONTENTS

Page

Executive Summary i
Conclusions i
Recommendations iii
Acknowledgements iv
Table of Contents v
List of Figures v
Introduction 1
Water Quality Assessment 4
References 8

LIST OF FIGURES

Page

Figure 1. Fraser River at Marguerite 2
Figure 2. Water Survey of Canada Flow Data for Fraser River at Marguerite 3
Figure 3. Adsorbable Organic Halide - AOX 9
Figure 4. Total Aluminum 10
Figure 5. Total Alkalinity 11
Figure 6. Ammonia - Dissolved 12
Figure 7. Total Antimony 13
Figure 8. Total Barium 14
Figure 9. Total Bismuth 15
Figure 10. Dissolved Bromide 16
Figure 11. Dissolved Inorganic Carbon 17
Figure 12. Dissolved Organic Carbon 18
Figure 13 Dissolved and Extractable Calcium 19
Figure 14. Total Cadmium 20

Figure 15. Total Cadmium (2003 to 2005) 21
Figure 16. Dissolved Chloride 22
Figure 17. Total Cobalt 23
Figure 18. Total Absorbance and True Colour 24
Figure 19. Apparent Colour 25
Figure 20. Total Chromium 26
Figure 21. Total Copper 27
Figure 22. Total Copper (1991-2005) 28
Figure 23. Fecal Coliforms 29
Figure 24. Fluoride 30
Figure 24 (a) Fluoride versus Turbidity 31
Figure 25. Total Gallium 32

LIST OF FIGURES

(CONTINUED)

Page

Figure 26. Hardness 33
Figure 27. Dissolved and Extractable Potassium 34
Figure 28. Total Lanthanum 35
Figure 29. Total Lead 36
Figure 30. Total Lithium 37
Figure 31. Mercury 38
Figure 32. Dissolved and Extractable Magnesium 39
Figure 33. Total Manganese 40
Figure 34. Total Molybdenum 41
Figure 35. Dissolved Nitrate Nitrogen 42
Figure 36. Nitrite Nitrogen 43
Figure 37. Total Nitrogen 44
Figure 38. Dissolve Nitrogen 45
Figure 39. Dissolved and Extractable Sodium 46

Figure 40. Total Nickel 47
Figure 41. Dissolved Nitrate / Nitrite 48
Figure 42. pH 49
Figure 43. Total Dissolved Phosphorus 50
Figure 44. Total Phosphorus 51
Figure 45. Dissolved Ortho Phosphate 52
Figure 46. Total Rubidium 53
Figure 47. Filterable Residue 54
Figure 48. Fixed Filterable Residue 55
Figure 49. Fixed Non-Filterable Residue 56
Figure 50. Non-Filterable Residue 57
Figure 51. Total Selenium 58
Figure 52. Extractable Silicon 59
Figure 53. Dissolved and Reactive Silica 60
Figure 54. Total Silver 61
Figure 55. Total Silver (2003 – 2005) 62
Figure 56. Total Tin 63
Figure 57. Specific Conductivity 64
Figure 58. Total Strontium 65
Figure 59. Air and Water Temperature 66
Figure 60. Total Thallium 67
Figure 61. Turbidity 68
Figure 62. Total Uranium 69
Figure 63. Total Vanadium 70
Figure 64. Total Zinc 71

INTRODUCTION

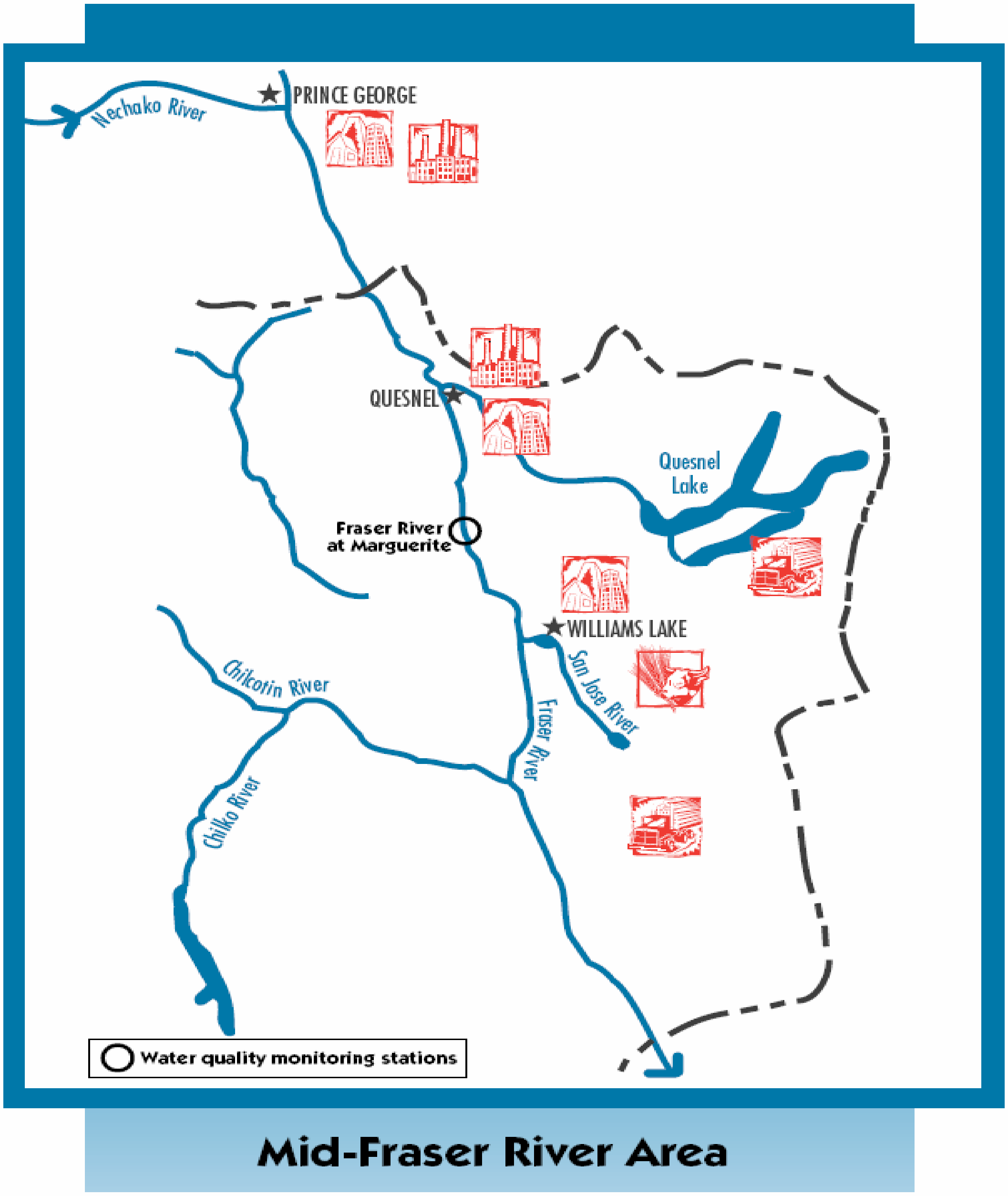
The Fraser River basin is one of British Columbia's most valued ecosystems, draining one-quarter of the province (Fraser River Action Plan, 1995). Its headwaters are located near Moose Lake in the Rocky Mountains. The northern part of the river follows a north-west path before heading south starting just north from Prince George. The Fraser River then flows 600 km before turning to the west, near Hope, B.C., and flowing in a south-westerly direction to the Pacific Ocean. The river has two major tributaries which affect its flow and water quality: the Nechako River (which merges with the Fraser River at Prince George); and the Thompson River (which flows into the Fraser River at Lytton, B.C. -approximately 95 km north from Hope). These two tributaries contribute 41% of the total Fraser River flow at Hope: the Thompson River contributes 30% and the Nechako River contributes 11%.

There are four long-term water quality monitoring sites on the Fraser River (Red Pass, Hansard, Marguerite, and Hope), as well as sites on both the Nechako and Thompson rivers. This report deals with the site on the Fraser River at Marguerite (Figure 1). Marguerite is in central B.C., roughly halfway between Quesnel and Williams Lake. The Fraser River at Marguerite has a drainage area of 114 000 km^2. Water quality at this site is affected by five upstream mills producing pulp and/or paper: three in Prince George and two in Quesnel. The designated water uses for this reach of the Fraser River are aquatic life, wildlife, drinking water (with partial treatment and disinfection), livestock, irrigation, and secondary-contact recreation (e.g., boating).

This report assesses eighteen years of data from the Ministry of Environment (1987 – 2004) and twenty years of Environment Canada data (1985 – 2004). The provincial station number in EMS is 0600011 and the federal site number in ENVIRODAT is BC08MC0001. Water quality data are usually collected from shore about 50 m upstream form the old ferry dock. Flow is plotted in Figure 2, showing 1985-2004 data from Water

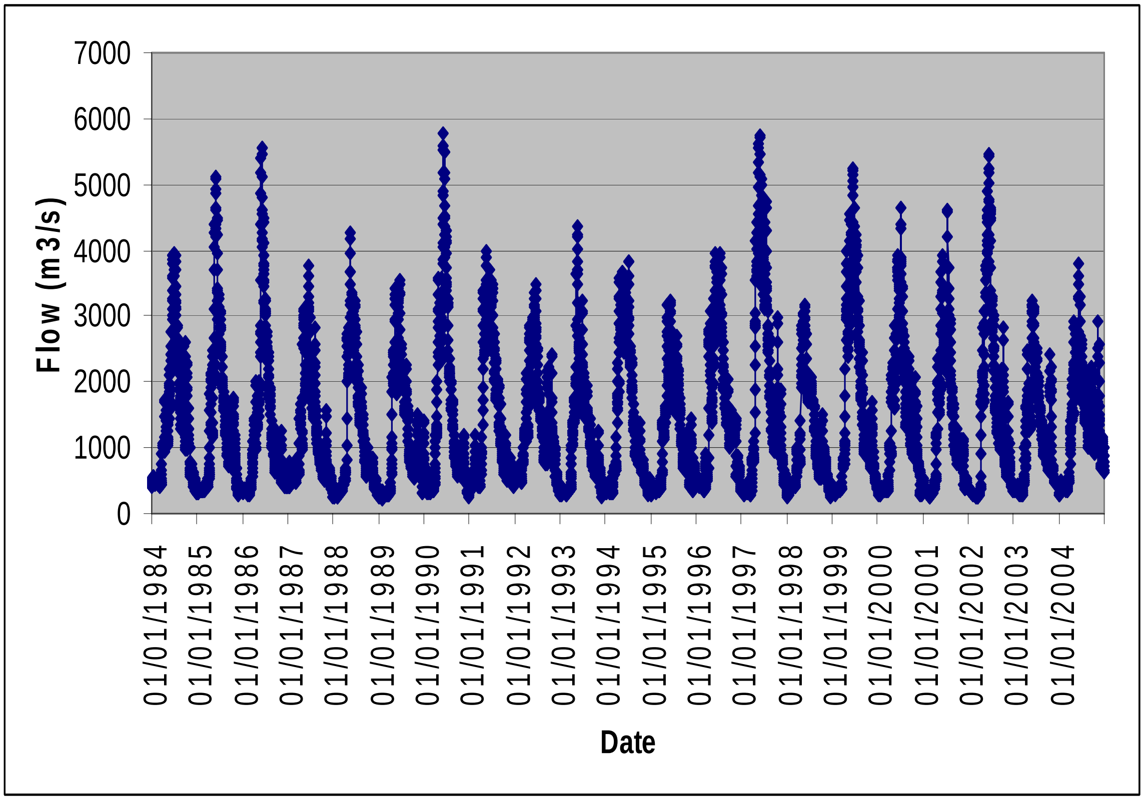
Survey of Canada station BC08MC018 at Marguerite. Water quality data are plotted in Figures 3 to 64.

FIGURE 1: Fraser River at Marguerite



This report assesses data from a station on the Fraser River at Marguerite. Data at this site have been collected on a frequency of about once every two weeks. As well, twice per year, two additional samples are collected in order to ensure that there are two periods when weekly samples are collected during five consecutive weeks, for comparison with water quality objectives. In addition, quality assurance samples (blanks and replicates) are collected three times per year.

FIGURE 2: Water Survey of Canada Flow Data for Fraser River at Marguerite



WATER QUALITY ASSESSMENT

The status and trends of various water quality indicators were assessed by plotting the indicators over time and comparing the values to the Province's objectives for this reach of the Fraser River (Swain *et al.* 1997) or its approved and working water quality guidelines (Ministry of Environment, 2006a & 2006b). Any levels or changes of the indicators over time that may have been harmful to sensitive water uses, such as drinking water, aquatic life, wildlife, recreation, irrigation, and livestock watering, are described below in alphabetical order.

When concentrations of a substance cannot be detected, we have plotted the concentration at the level of detection. We believe this to be a conservative approach to assessing possible trends. As well, there are times when measurements were not taken for some reason. In these cases, straight lines will join the two consecutive points and may give the illusion on the graph of a trend that does not exist.

In cases where we have used statistical techniques such as linear regression analysis to estimate if a trend is possibly present, a more thorough statistical analysis is necessary for verification of the trend.

In some cases, testing for the presence of a variable has been terminated after a certain period. In general, this has been because a previous data assessment and review has indicated that collections of these data are not warranted for this station. For other variables, concerns about concentrations may have only arisen in recent years.

Water quality indicators were not discussed if they were in no danger of exceeding water quality objectives or guidelines and/or showed no harmful trends. These included AOX, bromide, mercury, nitrate, nitrite, total nitrogen, pH, and ortho phosphate.

The following water quality indicators seemed to fluctuate through the year according to turbidity concentrations, but were below guideline values (where they existed) and had no other trends. These included antimony, barium, bismuth, gallium, lanthanum, manganese, nickel, total phosphorus, rubidium, non-filterable residue, fixed non-filterable residue, selenium, tin, thallium, and uranium.

Other water quality indicators seemed to fluctuate through the year according to the specific conductivity of the water, but were below guideline values (where they existed) and had no other trends. For dissolved forms of many of these indicators, they would be a part of the measured conductivity, and this is to be expected. These types of indicators that were not measured above guideline values included alkalinity, dissolved ammonia, dissolved inorganic carbon, calcium, dissolved fluoride, hardness, magnesium, dissolved nitrogen, sodium, dissolved phosphorus, filterable residue, fixed filterable residue, silicon, silica, lithium, molybdenum and strontium.

Flow (Figure 2) values are typical of interior rivers, with peaks ($\simeq$ 6,000 m^3/s) occurring during the spring to early summer period and low flows ($\simeq$ 300 - 350 m^3/s) taking place during the late autumn through winter periods. Flow monitoring should continue because of its importance in interpreting many water quality indicators.

Aluminum (Figure 4): values fluctuate with turbidity and exceed the guidelines for the dissolved form of the metal. By making a comparison to a guideline for the dissolved form of the metal, we are looking at aluminum concentrations from a conservative perspective. Values seem to fluctuate with turbidity values, meaning that the aluminum is in particulate form and not likely biologically available.

Dissolved Organic Carbon (Figure 12): values seem to fluctuate with turbidity concentrations. High values in excess of the drinking water guideline occur when solids removal would be required for water treatment.

Cadmium (Figures 14 and 15): values fluctuate with turbidity levels, and appear to be increasing over time with turbidity. Cadmium values are in excess of guidelines on occasion, however during these periods, the cadmium will likely be in particulate form and not biologically available. Apparent decreases in 2003 resulted from the introduction of a more sensitive analytical technique.

Chloride (Figure 16): values have shown a marked decrease in concentration since the mid-1980’s, due to the elimination of chlorine dioxide as a bleaching compound at the pulp and paper mills. The reduction was most noticeable in early 1992. Using a linear regression analysis, we determined that there was a significant decrease in concentration ($R^2 = 0.25$). No such trend was noted at the upstream site at Hansard (Swain, 2006). Dissolved chloride values varied with the specific conductivity in the river, with higher values when conductivity was higher.

Cobalt (Figure 17): values have exceeded the 30-day mean values on occasion. Individual cobalt concentrations varied with turbidity, and all values that exceeded the guideline (30-d mean value) took place when turbidity was high. These higher values would be associated with particulate matter and would likely not be biologically available. Being associated with turbidity, cobalt levels also appeared to be increasing over time.

Colour: apparent colour (Figure 19) values seem to fluctuate with turbidity and regularly exceeded the drinking water guideline for true colour; however, this is to be expected since true colour is measured on a filtered sample (i.e., turbidity removed). True colour values (Figure 18) were lower than apparent colour values, as expected; however, values seem to fluctuate with turbidity and regularly exceeded the drinking water guideline.

Chromium (Figure 20): values (total) varied with turbidity and exceeded the guidelines for hexavalent and trivalent chromium. We recommend that either trivalent and hexavalent forms of chromium be measured in the future, or guidelines be developed for total chromium values.

Copper (Figures 21 and 22): values seem to coincide with turbidity, occasionally exceeding guidelines for the protection of aquatic life. It should be noted that the guideline identified on the graph as being from CCME is in fact one adopted temporarily by Environment Canada from the U.S. EPA until a new guideline can be developed through the CCME process. These higher values likely reflect copper that is in particulate form, and therefore not biologically available. Similar to some other metals noted, copper appears to be increasing over time with turbidity.

Fecal Coliforms (Figure 23): exceed the guideline to protect drinking water supplies of 10 CFU/100 mL for disinfection only and 100 CFU/100 mL for partial treatment. Due to the high suspended solids loading in the Fraser River, drinking water supplies would require some form of advanced treatment. Therefore, partial treatment of drinking water supplies would be required.

Potassium (Figure 27): values measured over time were related to conductivity, and appeared to show a slightly increasing trend through time. This may perhaps be simply due to laboratory method changes over time.

Lead (Figure 29): concentrations varied with turbidity and occasionally exceeded guidelines to protect aquatic life. The times when these higher values were seen coincided with high turbidity levels, indicating that the lead was in particulate form and not likely biologically available.

Silver (figures 54 and 55): values have exceeded guidelines for the protection of aquatic life on occasion. Since higher silver concentrations seem to coincide with higher turbidity values, the silver would likely be in particulate form and not biologically available.

Water Temperature (Figure 59): tended to peak during the hot summer months and on occasion exceed guidelines for the protection of aquatic life (sensitive species such as Dolly Varden char). These peak temperatures occur during late July and early August when migration may be taking place; however, since samples are collected from near the shore, temperatures in mid-stream are likely somewhat lower. These high temperatures are not a regular occurrence but could reduce the energy levels of salmon that might be migrating upstream and near the shore during these periods. Other than expected seasonal variation in temperatures, there were no other long-term trends apparent.

Turbidity (Figure 61): values were consistently above drinking water guidelines, indicating that partial treatment of the water as a drinking water source would be required. Turbidity seems to be increasing though time; this is similar to what we found (Swain, 2006) at the Hansard station, however higher turbidity was found at Marguerite than at Hansard in our 1996 assessment (Ministry of Environment, Lands and Parks, 1996). The source for the turbidity is not obvious.

Vanadium (Figure 63): values increased with increasing turbidity concentrations and were often at those times above BC working water quality guidelines for aquatic life protection of 6 to 20 ug/L. The high vanadium values were likely in particulate form and not biologically available.

Zinc (Figure 64): values increased with increasing turbidity levels, and on occasion exceed hardness-dependent guidelines for the protection of aquatic life. Because the high zinc concentrations coincide with high turbidity levels, the metals are likely in particulate form and not biologically available. Zinc also appears to be increasing over time, in concert with turbidity.

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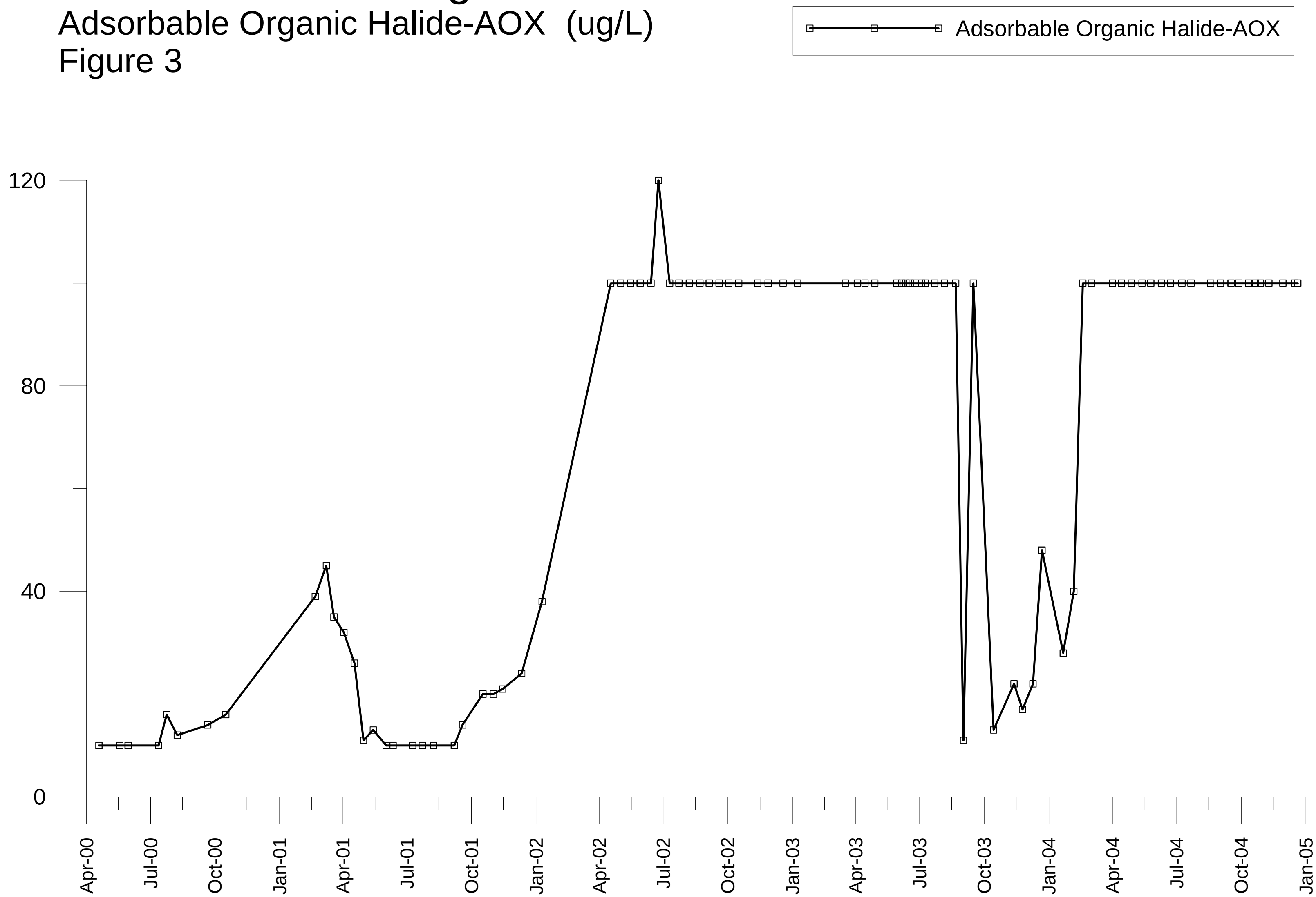
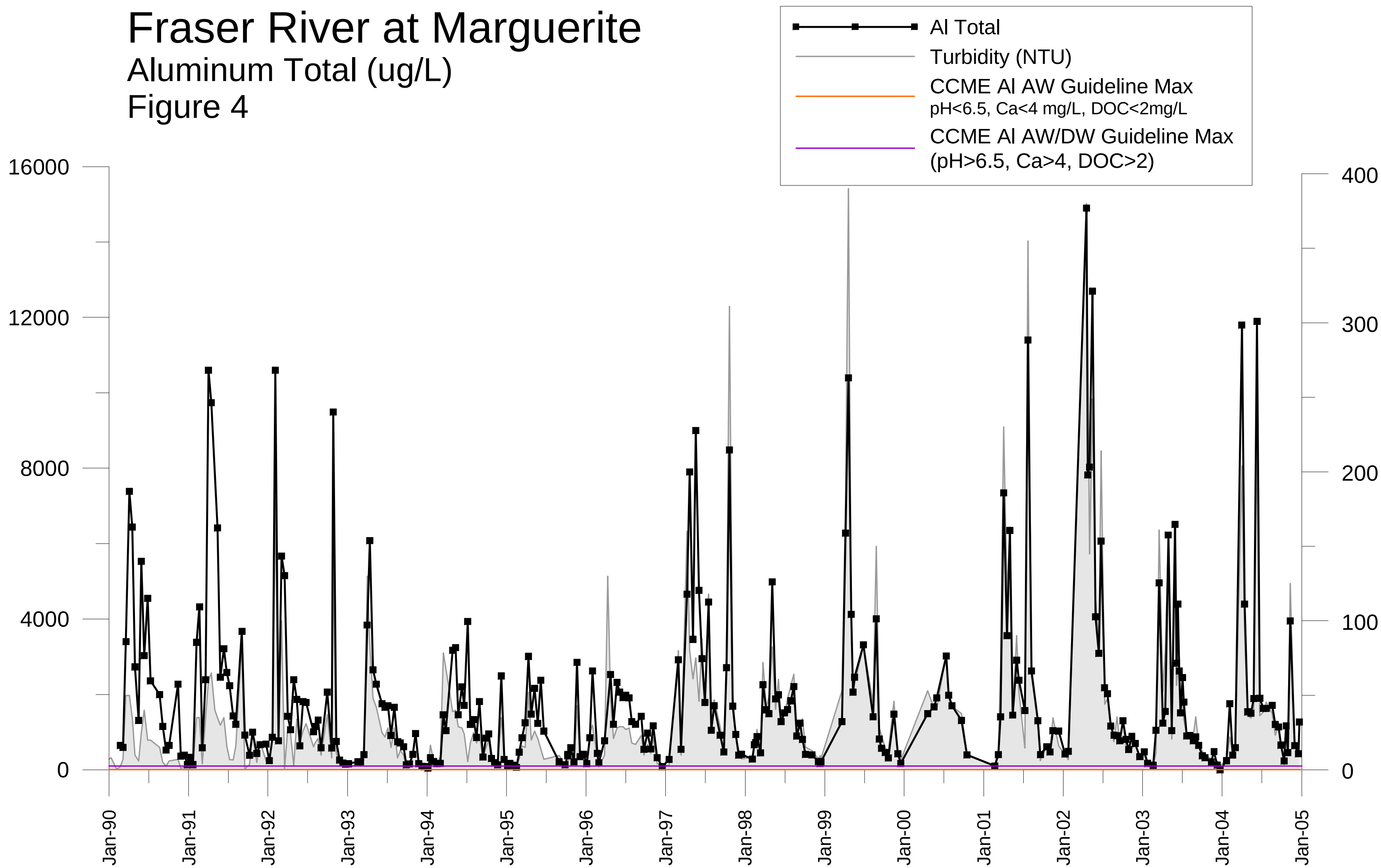
Fraser River at Marguerite

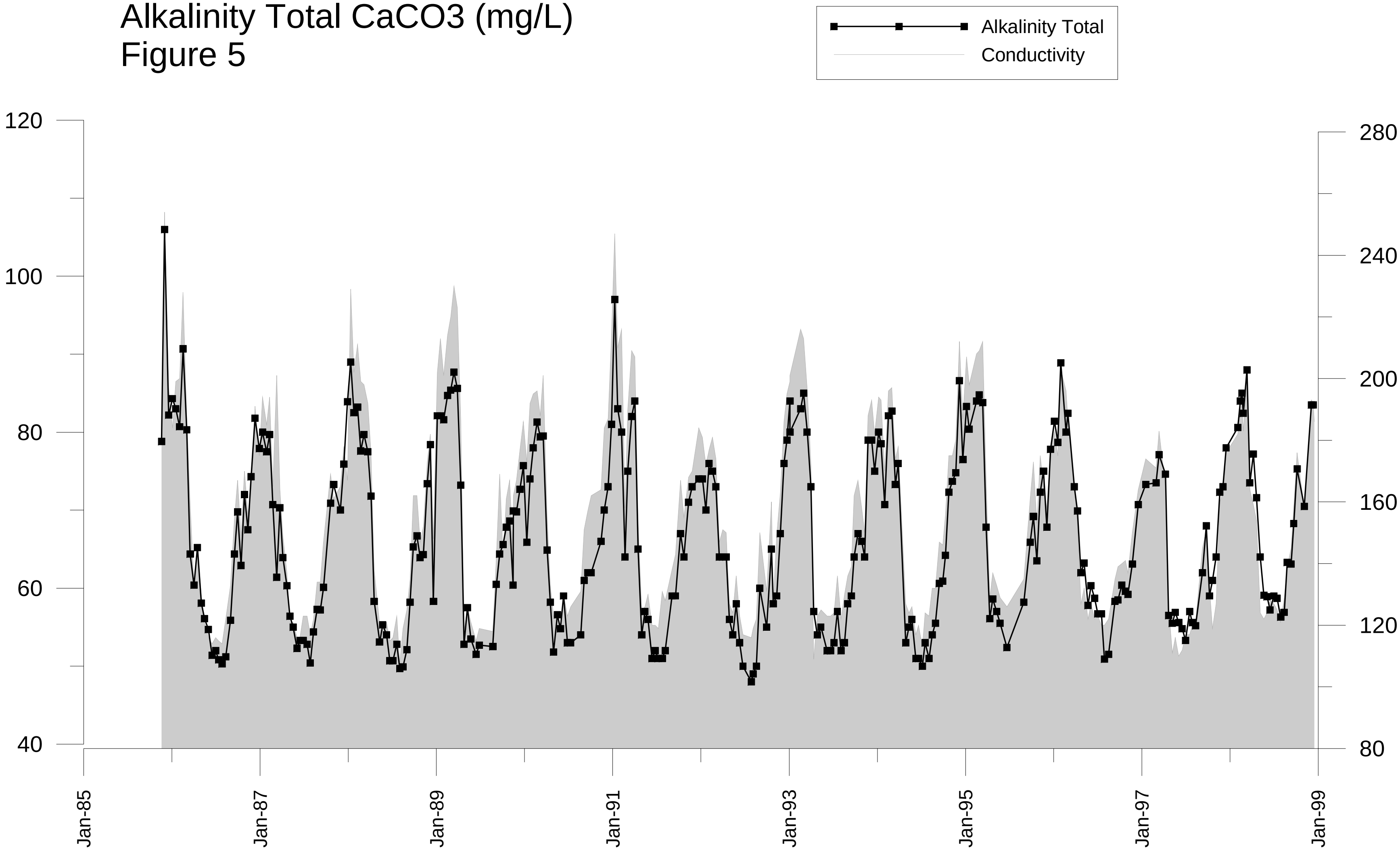
Adsorbable Organic Halide-AOX (ug/L)

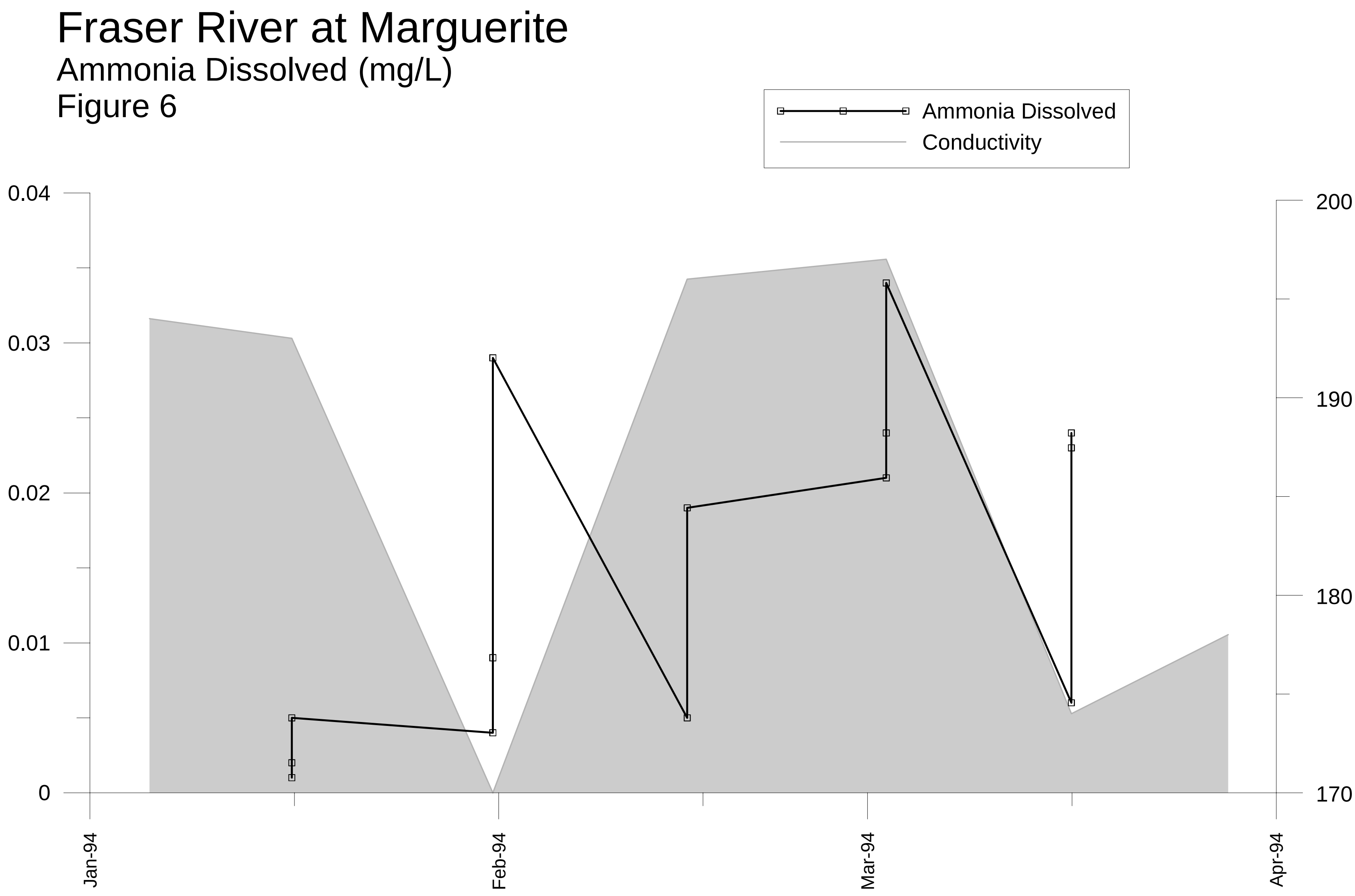
Figure 3




Fraser River at Marguerite
Aluminum Total (ug/L)
Figure 4
Al Total
Turbidity (NTU)
CCME Al AW Guideline Max
pH<6.5, Ca<4 mg/L, DOC<2mg/L
CCME Al AW/DW Guideline Max
(pH>6.5, Ca>4, DOC>2)
16000
12000
8000
4000
0
400
300
200
100
0
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

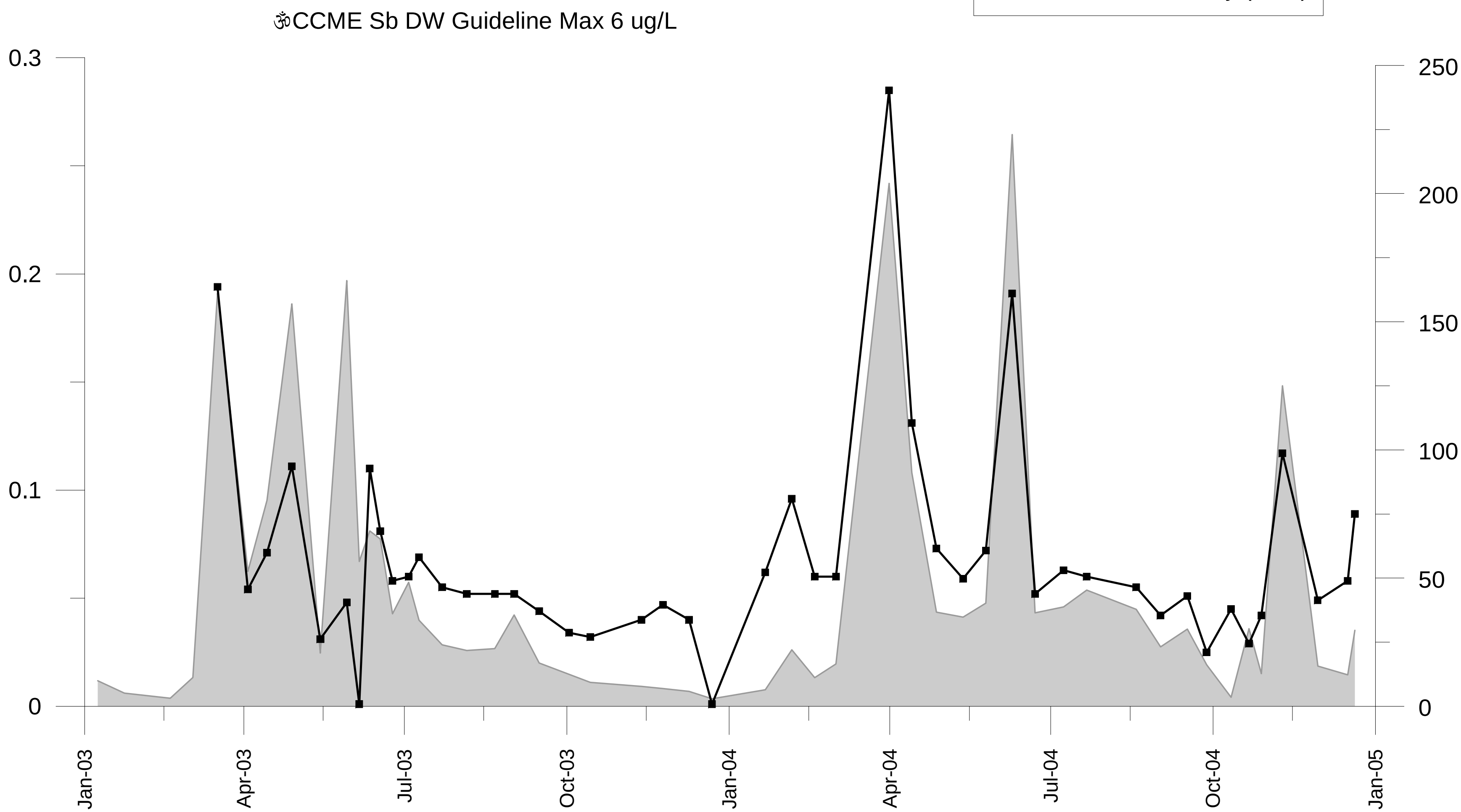
Fraser at Marguerite
Alkalinity Total CaCO3 (mg/L)
Figure 5

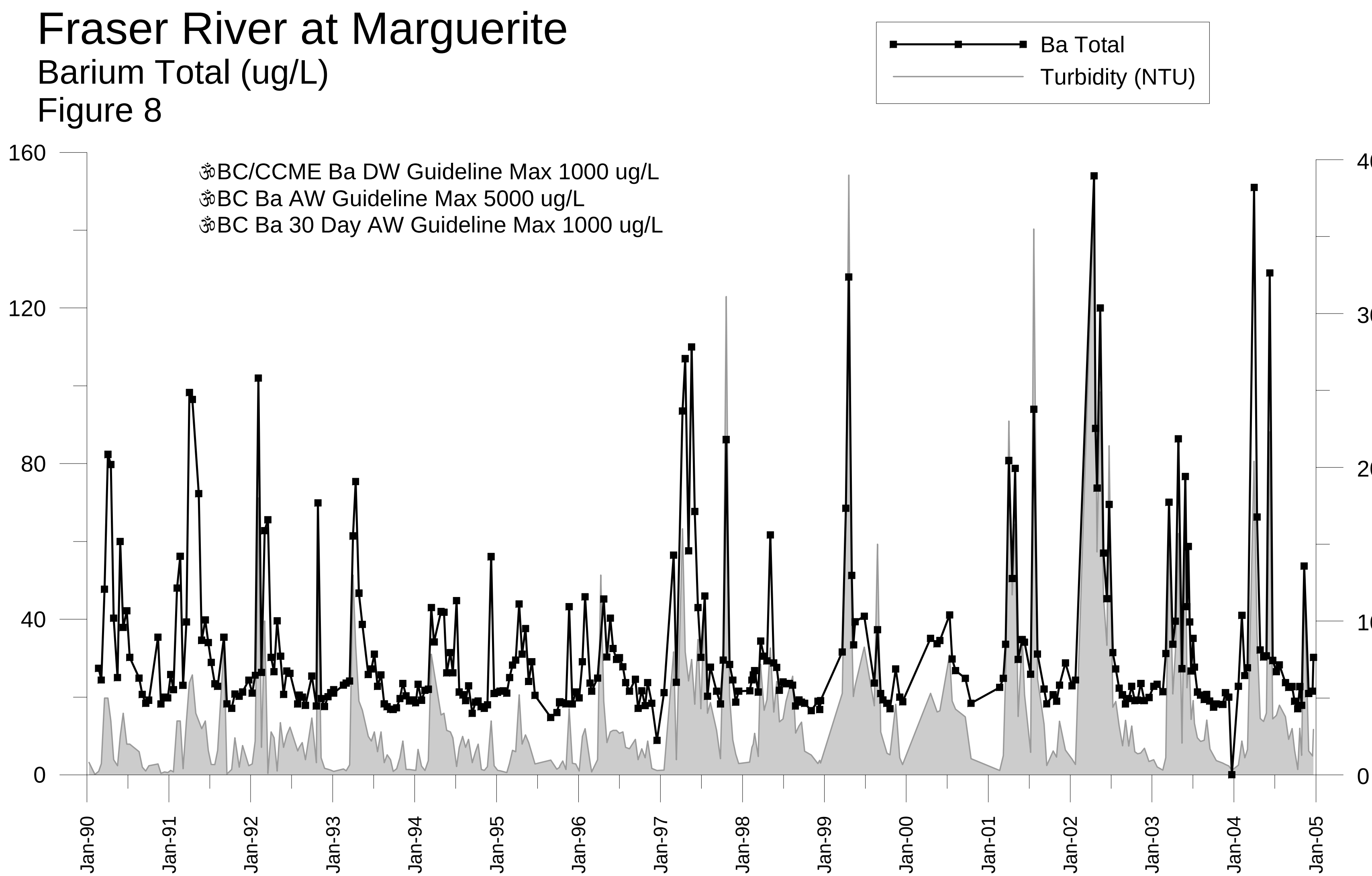




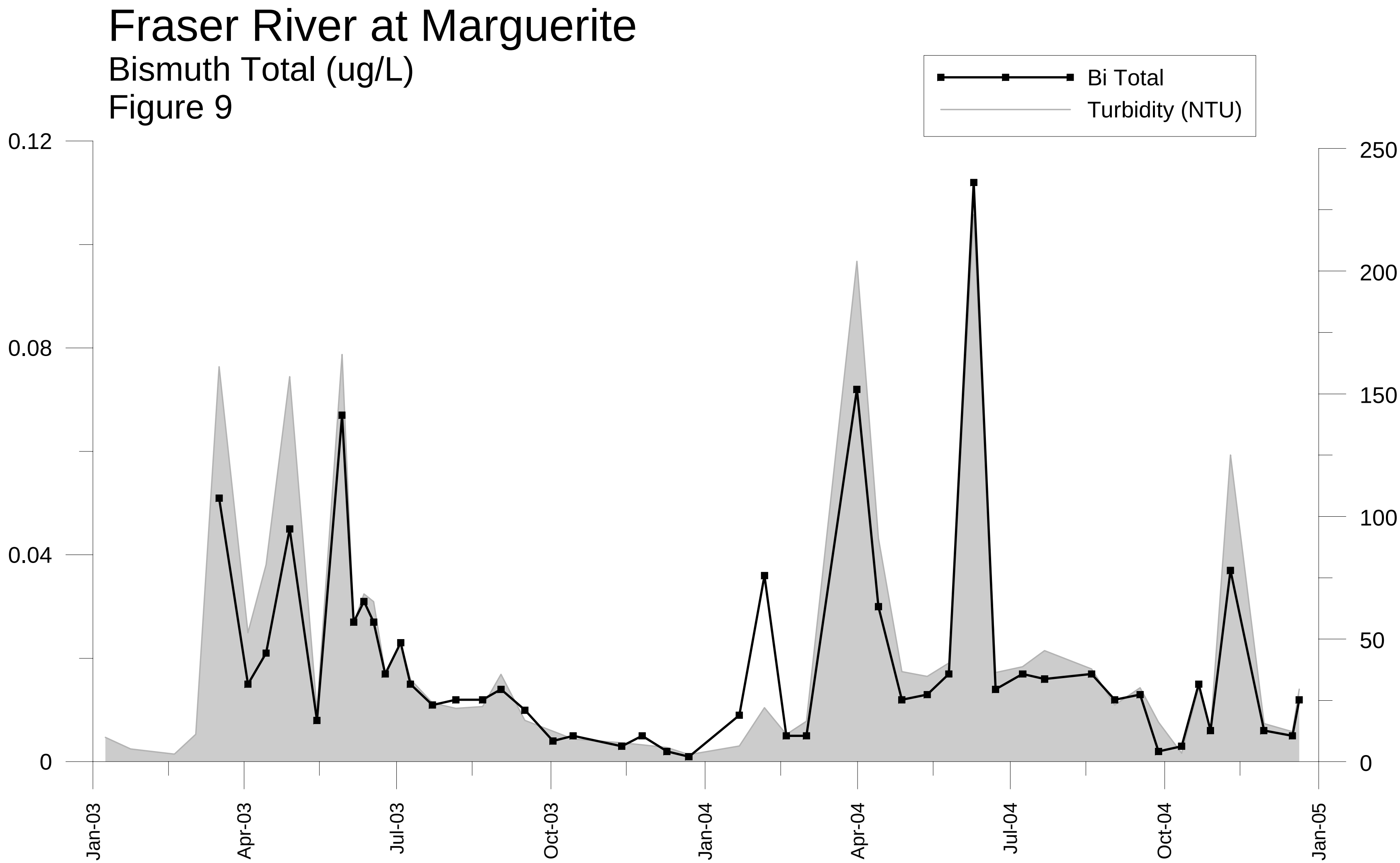
Fraser River at Marguerite
Ammonia Dissolved (mg/L)
Figure 6
Ammonia Dissolved
Conductivity
0.04
0.03
0.02
0.01
0
200
190
180
170
Jan-94
Feb-94
Mar-94
Apr-94

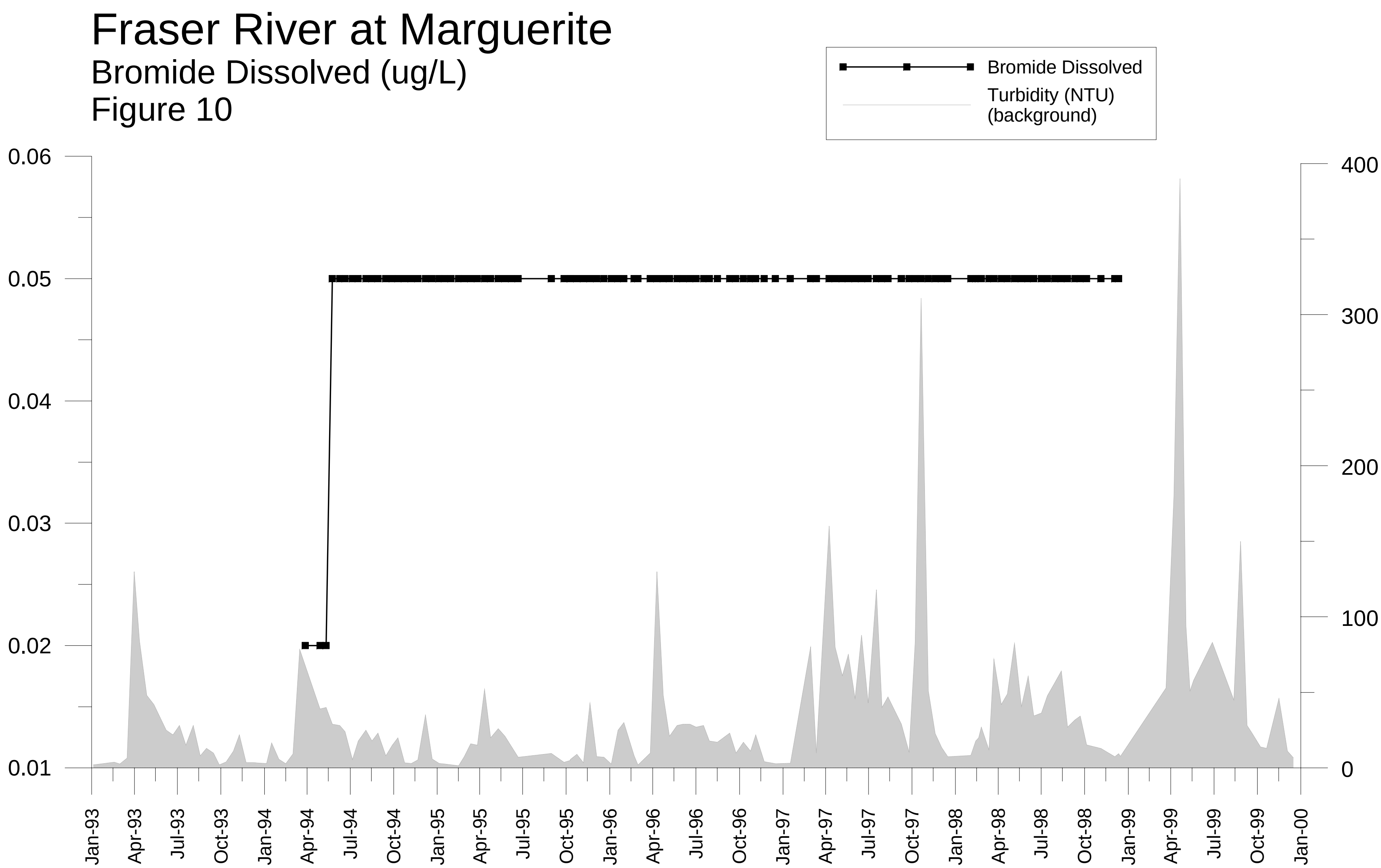
Fraser River at Marguerite
Antimony Total (ug/L)
Figure 7





Fraser River at Marguerite
Barium Total (ug/L)
Figure 8
Ba Total
Turbidity (NTU)
ॐBC/CCME Ba DW Guideline Max 1000 ug/L
ॐBC Ba AW Guideline Max 5000 ug/L
ॐBC Ba 30 Day AW Guideline Max 1000 ug/L
160
120
80
40
0
400
300
200
100
0
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Bismuth Total (ug/L)
Figure 9
Bi Total
Turbidity (NTU)
0.12
0.08
0.04
0
250
200
150
100
50
0
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05



Fraser River at Marguerite
Bromide Dissolved (ug/L)
Figure 10
Bromide Dissolved
Turbidity (NTU) (background)
0.06
0.05
0.04
0.03
0.02
0.01
400
300
200
100
0
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
Apr-94
Jul-94
Oct-94
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
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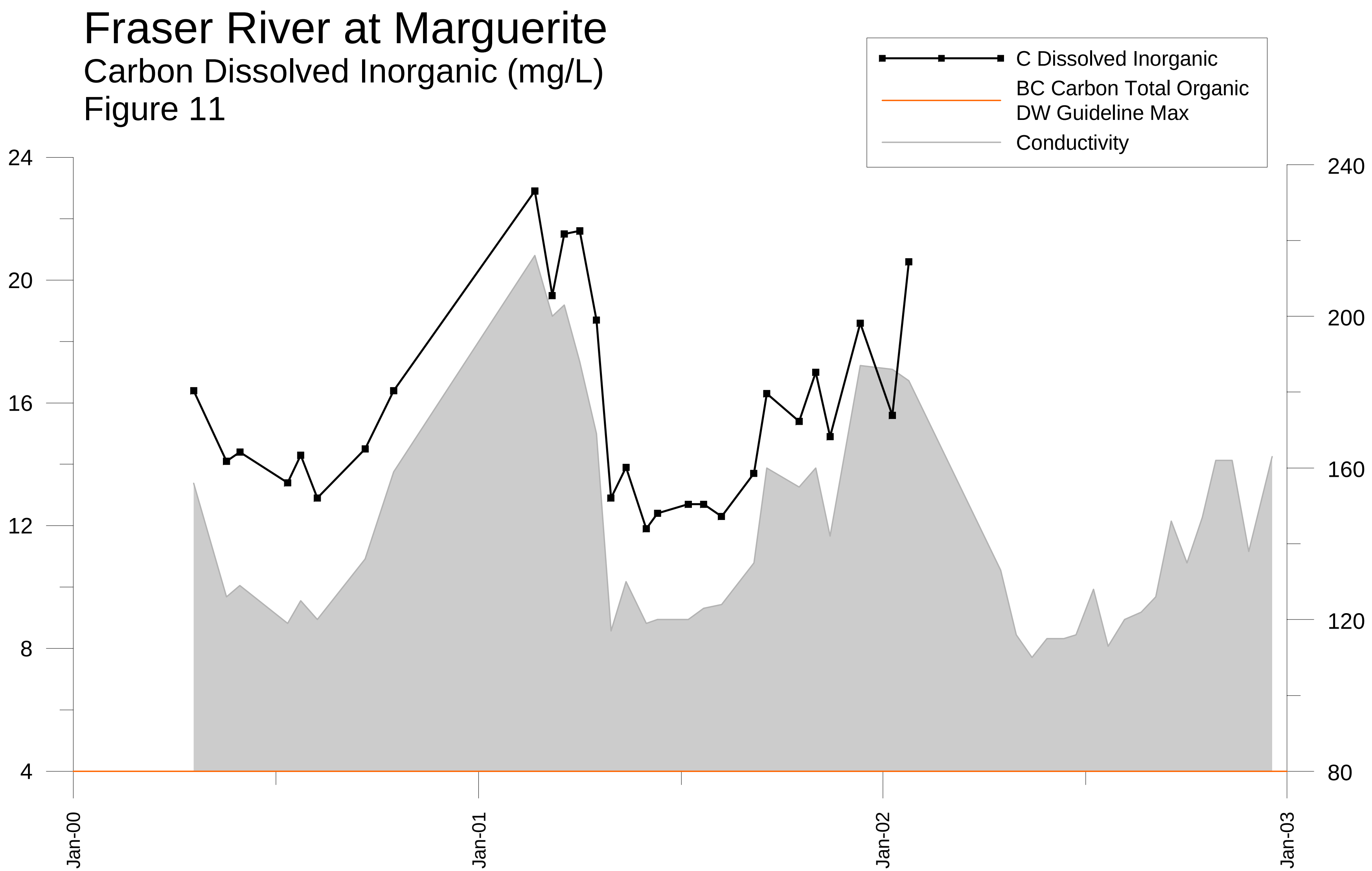
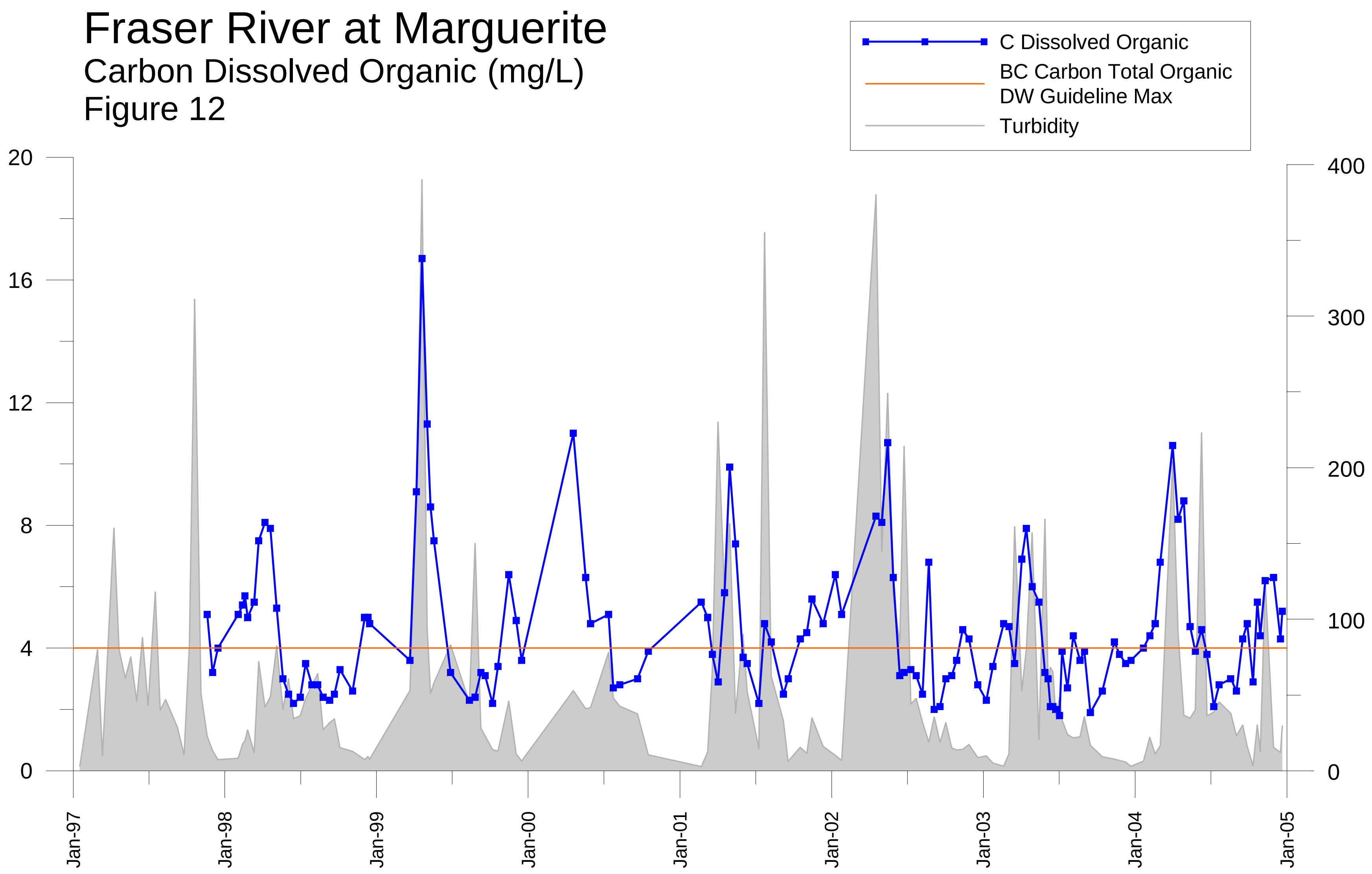
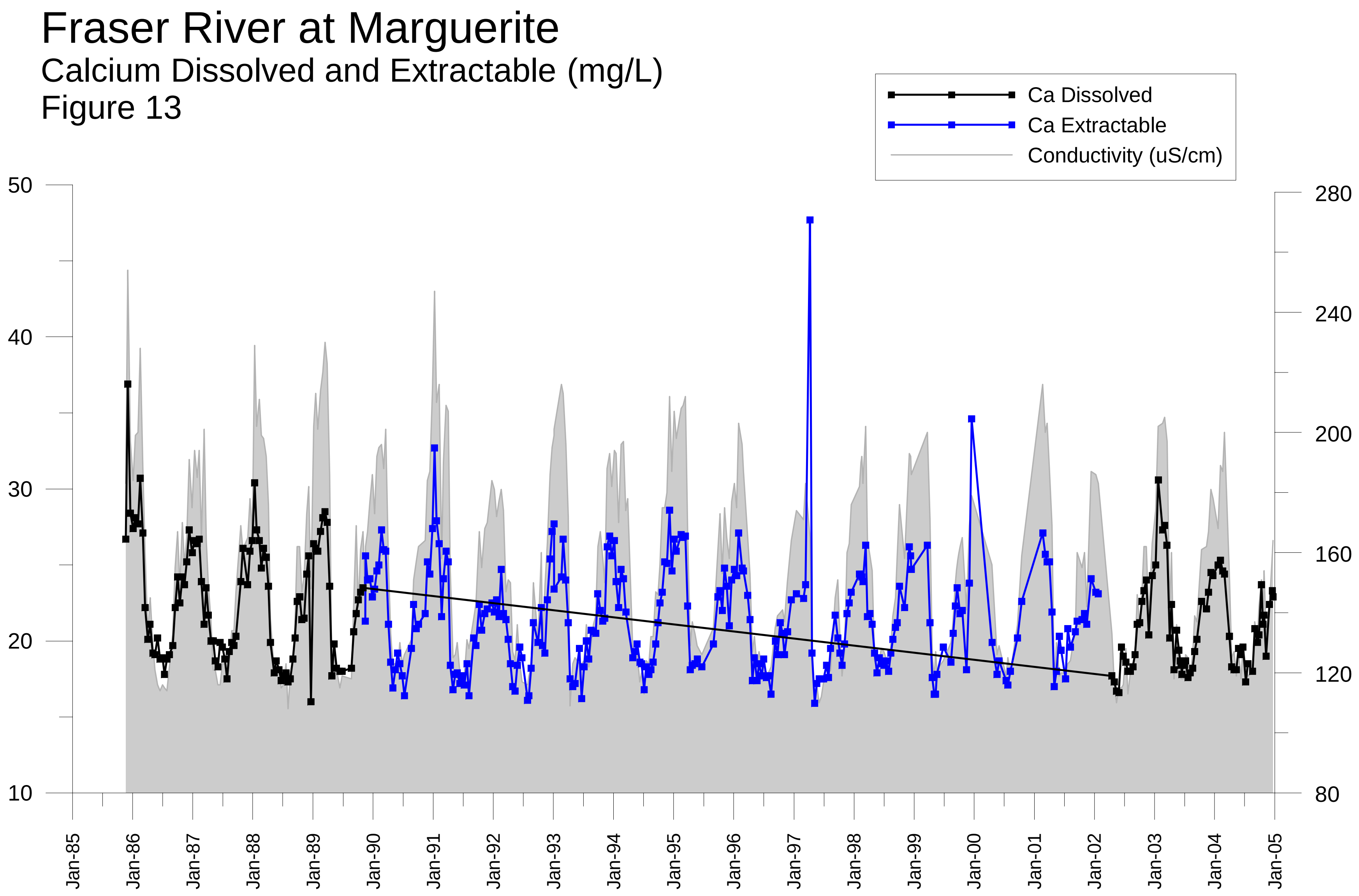
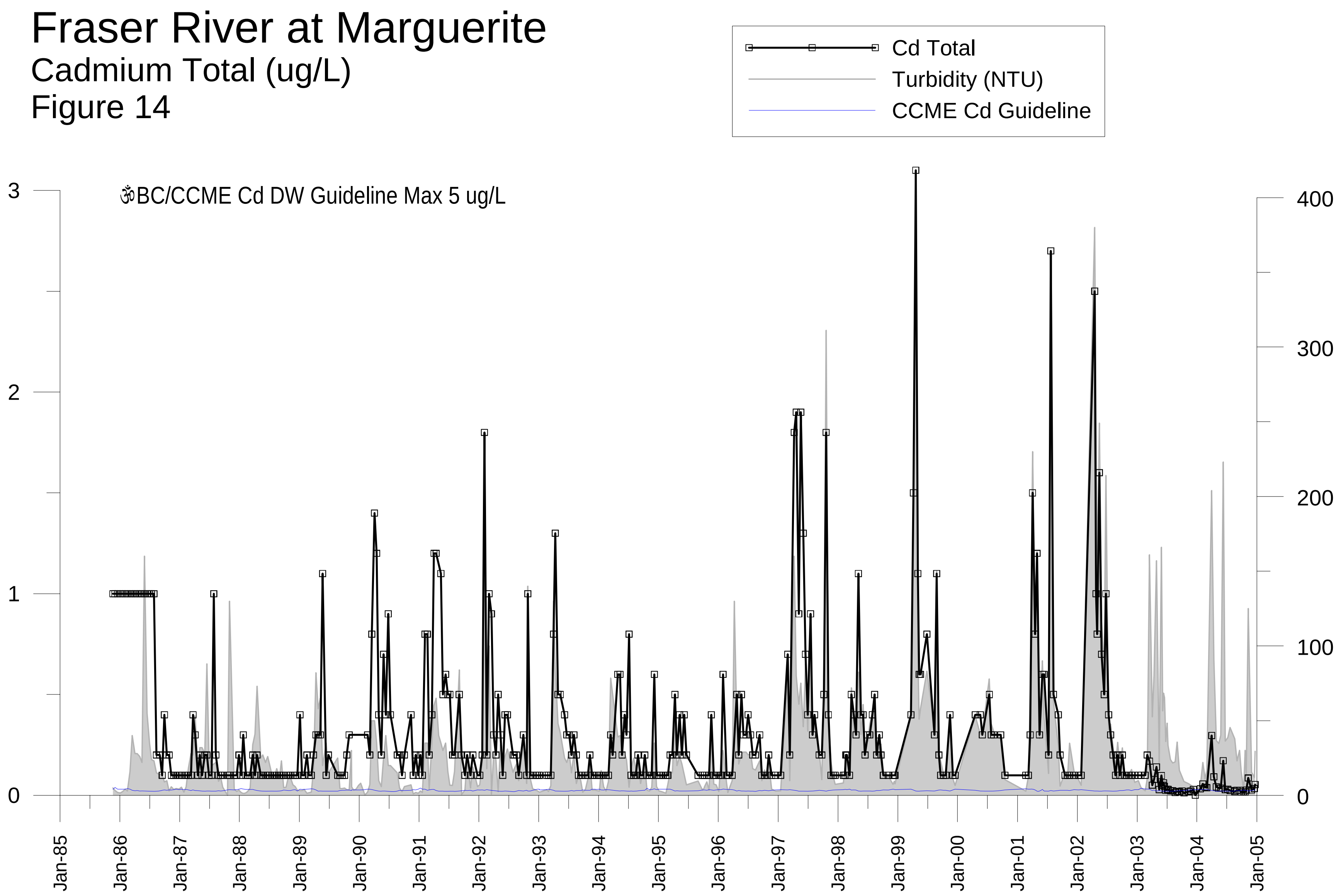
Apr-99
Jul-99
Oct-99
Jan-00

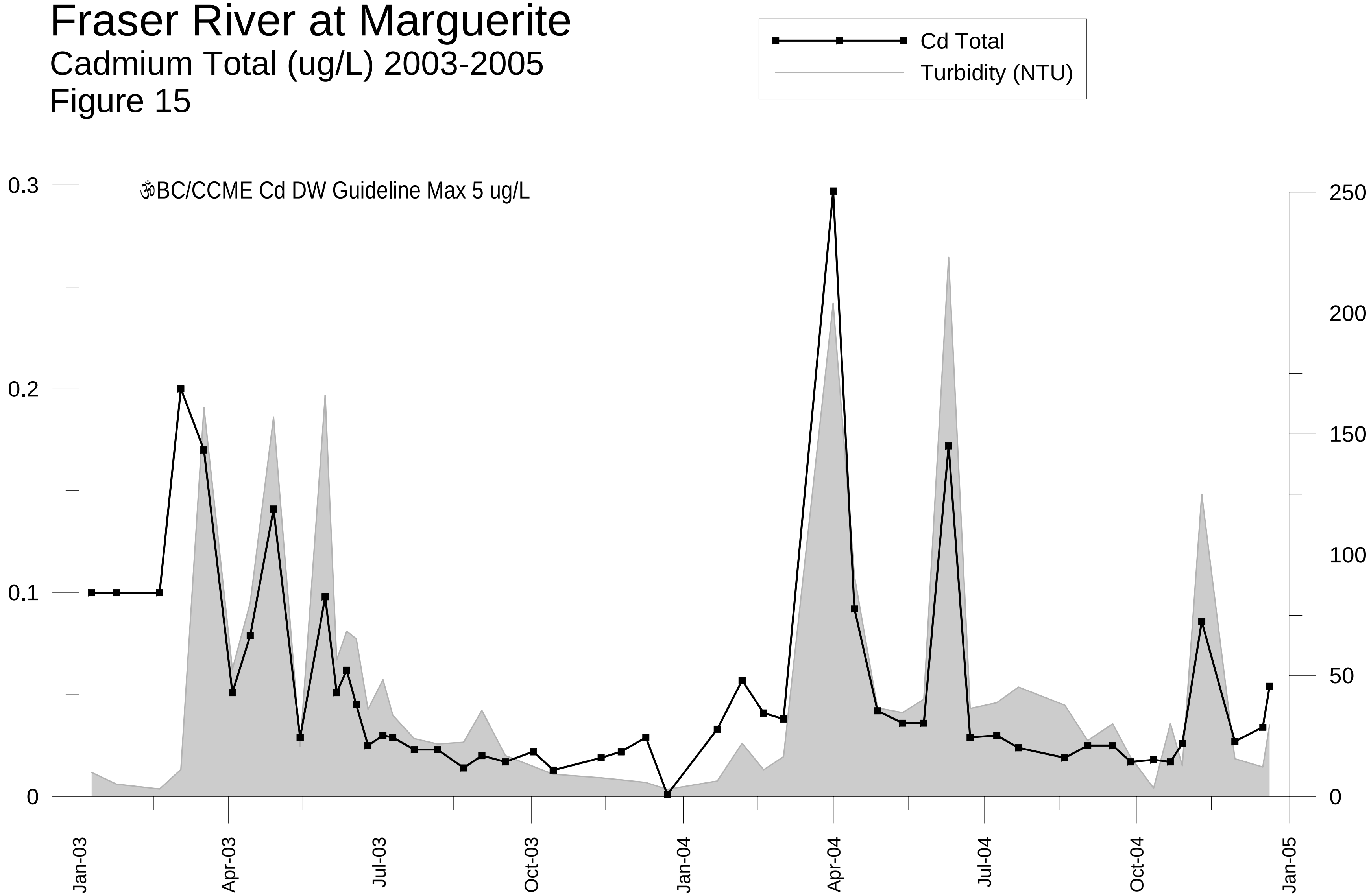

Fraser River at Marguerite
Carbon Dissolved Inorganic (mg/L)
Figure 11
C Dissolved Inorganic
BC Carbon Total Organic DW Guideline Max
Conductivity
24
20
16
12
8
4
240
200
160
120
80
Jan-00
Jan-01
Jan-02
Jan-03

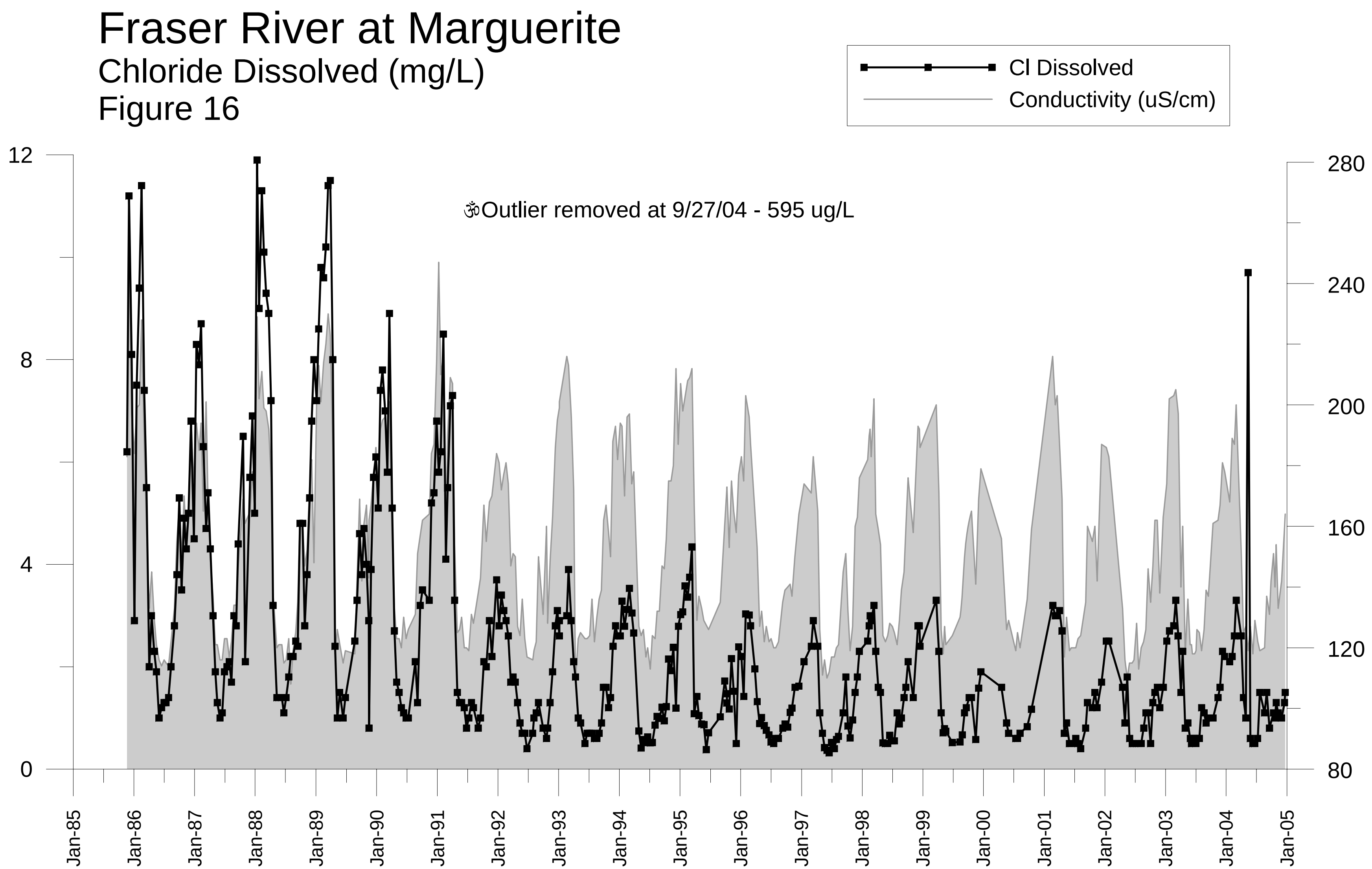

Fraser River at Marguerite
Carbon Dissolved Organic (mg/L)
Figure 12
C Dissolved Organic
BC Carbon Total Organic DW Guideline Max
Turbidity
20
16
12
8
4
0
400
300
200
100
0
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Calcium Dissolved and Extractable (mg/L)
Figure 13
Ca Dissolved
Ca Extractable
Conductivity (uS/cm)
50
40
30
20
10
280
240
200
160
120
80
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

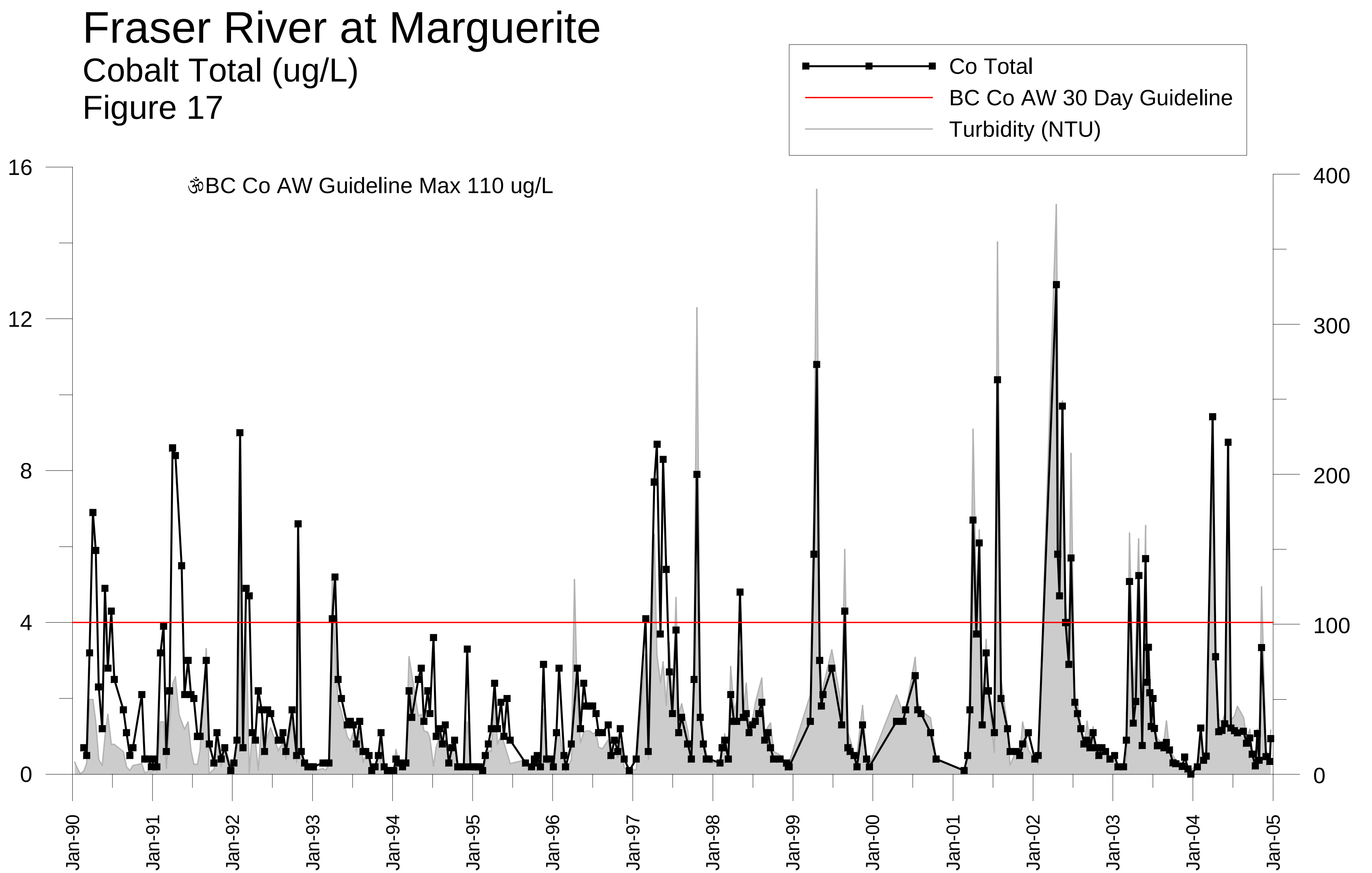

Fraser River at Marguerite
Cadmium Total (ug/L)
Figure 14
Cd Total
Turbidity (NTU)
CCME Cd Guideline
ॐBC/CCME Cd DW Guideline Max 5 ug/L
0
1
2
3
0
100
200
300
400
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

Fraser River at Marguerite
Cadmium Total (ug/L) 2003-2005
Figure 15

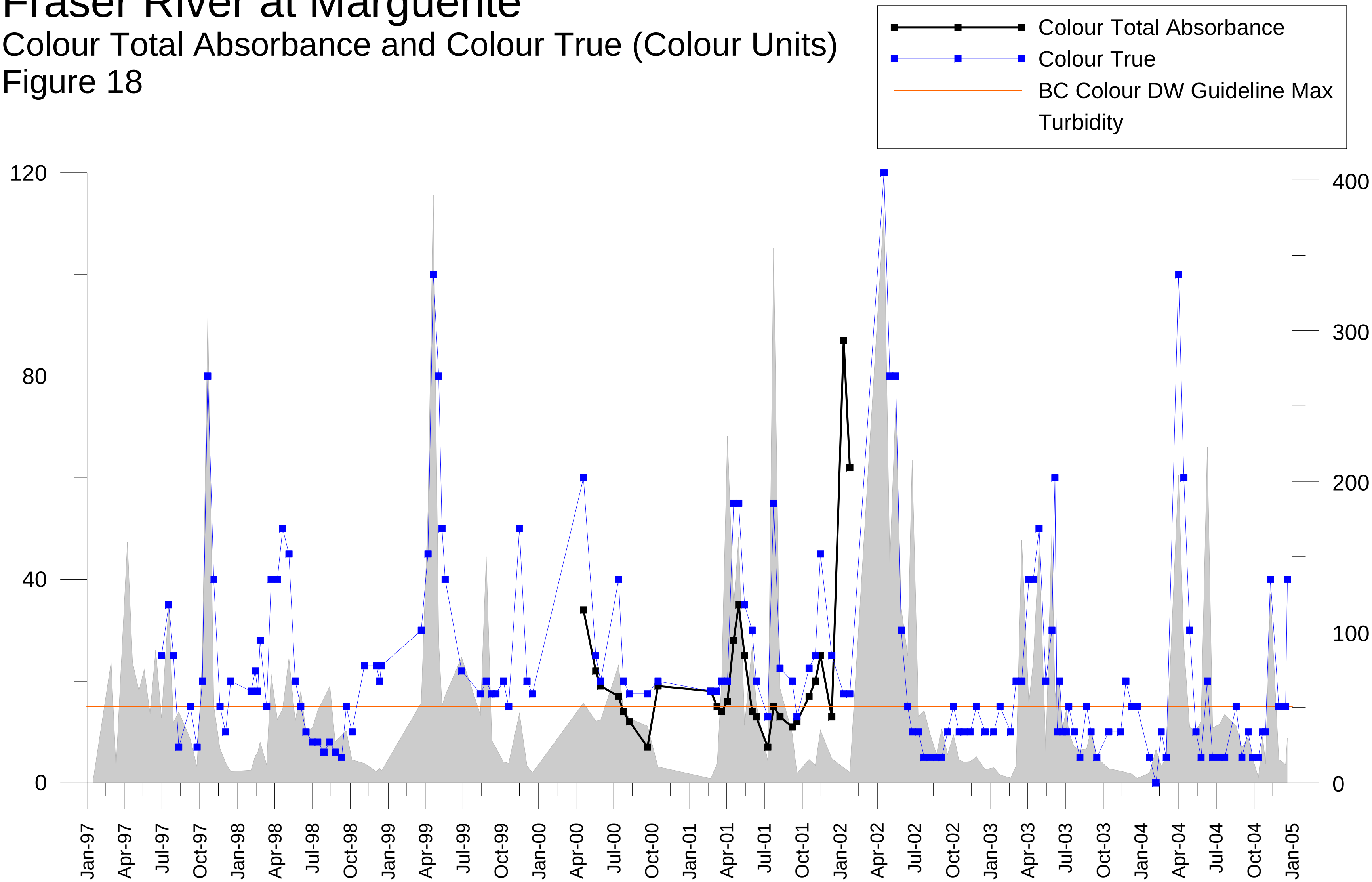


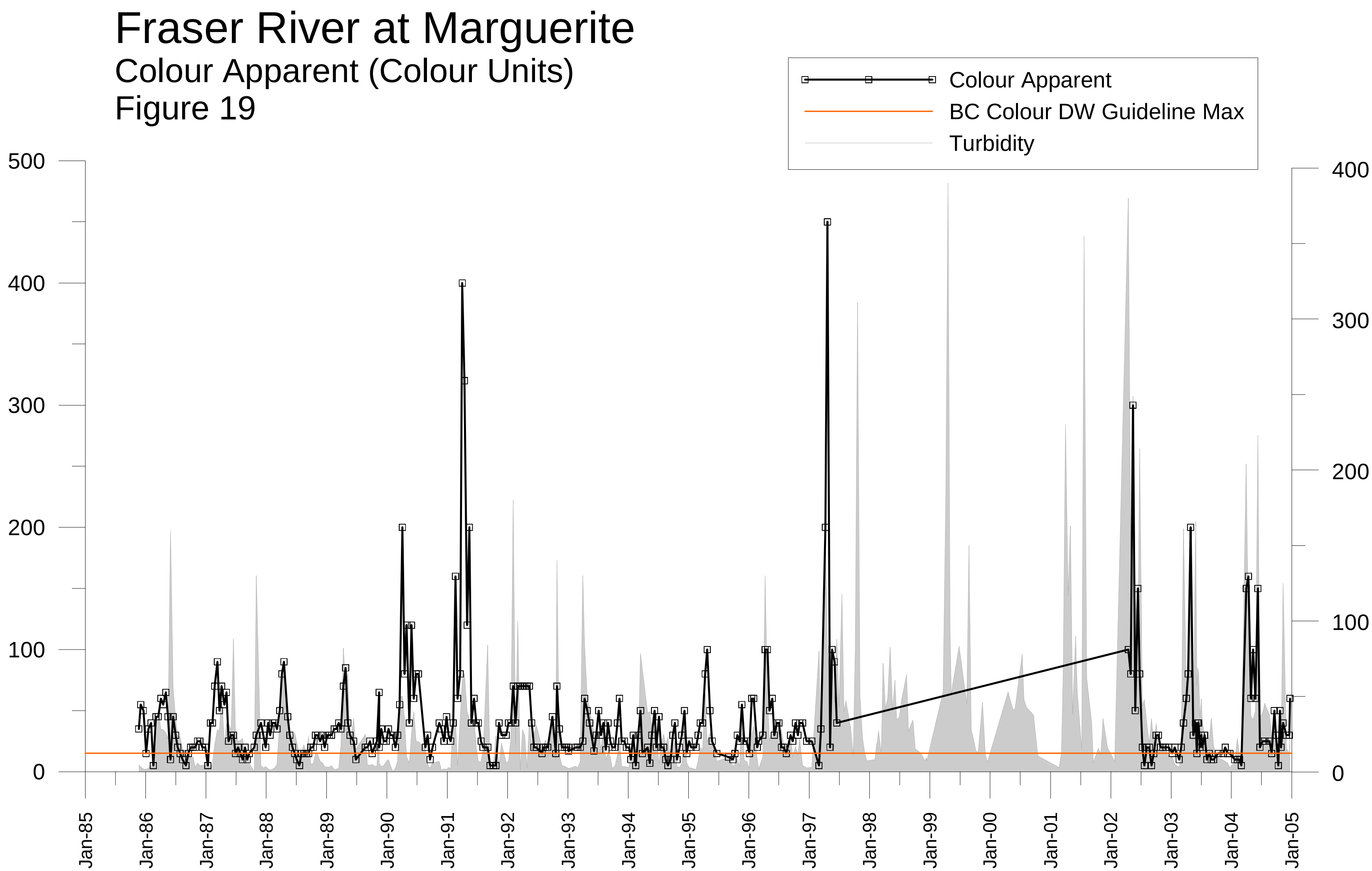


Fraser River at Marguerite
Chloride Dissolved (mg/L)
Figure 16
Cl Dissolved
Conductivity (uS/cm)
Outlier removed at 9/27/04 - 595 ug/L
12
8
4
0
280
240
200
160
120
80
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

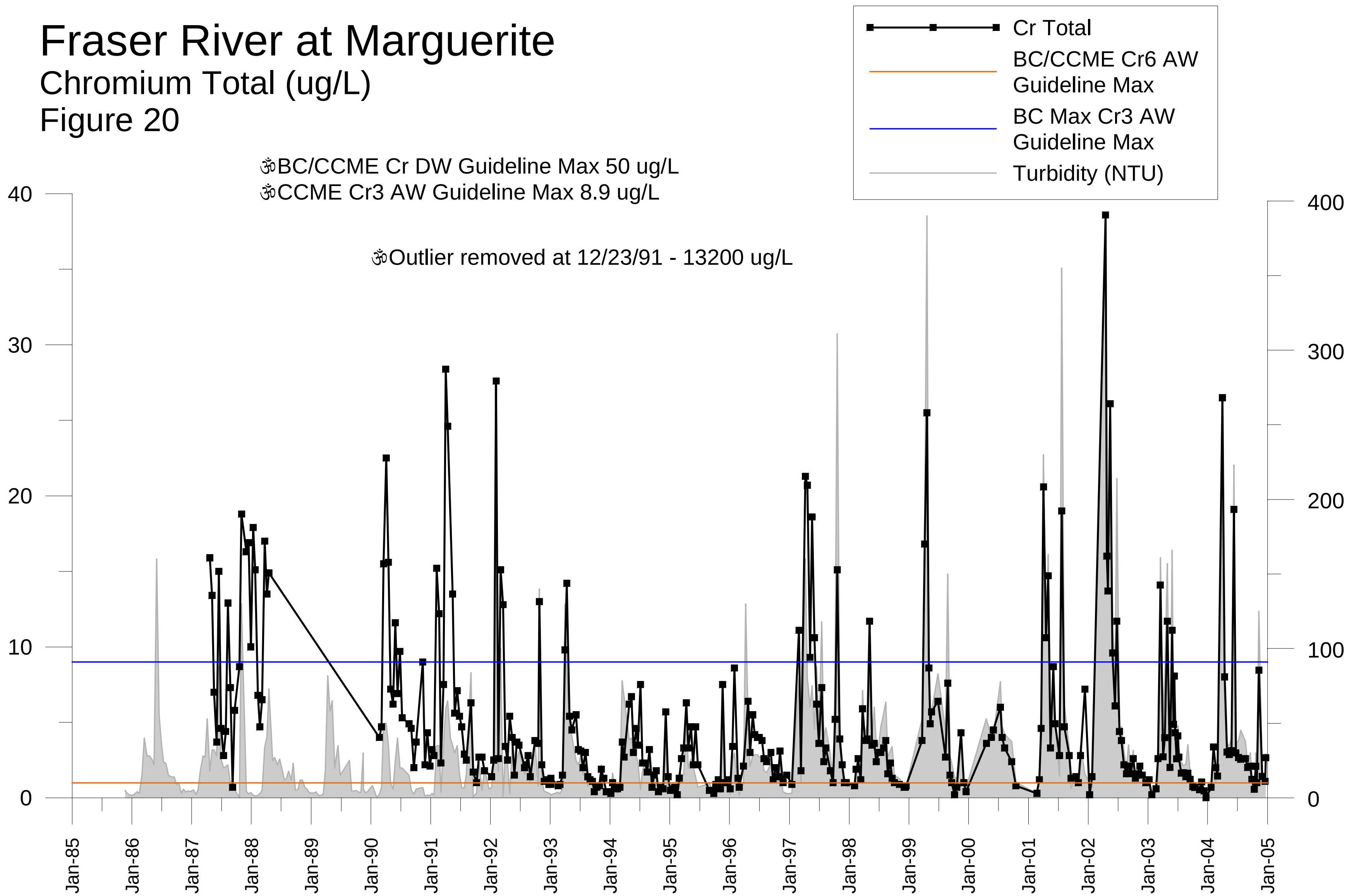

Fraser River at Marguerite
Cobalt Total (ug/L)
Figure 17
Co Total
BC Co AW 30 Day Guideline
Turbidity (NTU)
ॐBC Co AW Guideline Max 110 ug/L
16
12
8
4
0
400
300
200
100
0
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

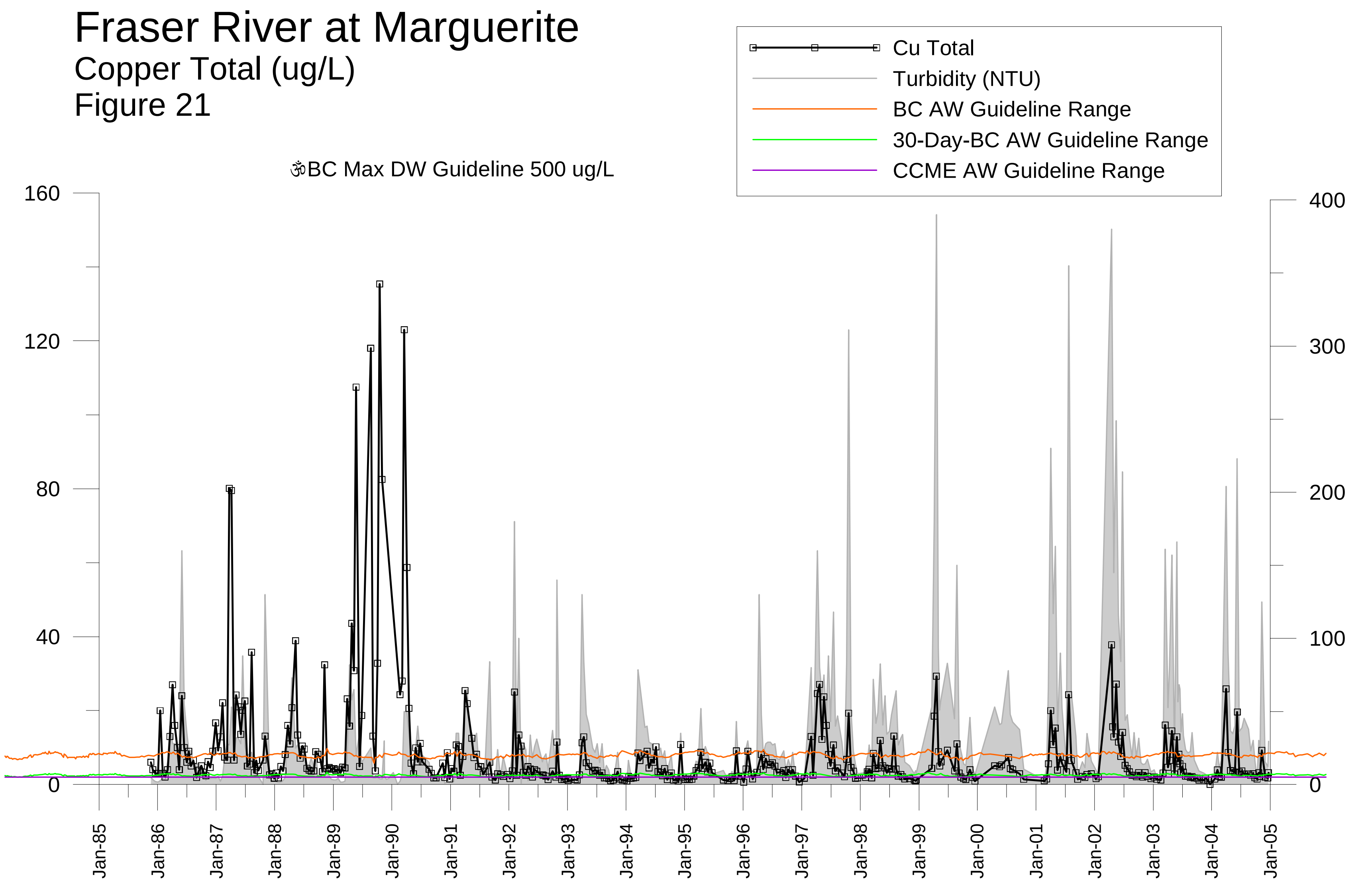
Fraser River at Marguerite
Colour Total Absorbance and Colour True (Colour Units)
Figure 18





Fraser River at Marguerite
Colour Apparent (Colour Units)
Figure 19
Colour Apparent
BC Colour DW Guideline Max
Turbidity
500
400
300
200
100
0
400
300
200
100
0
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

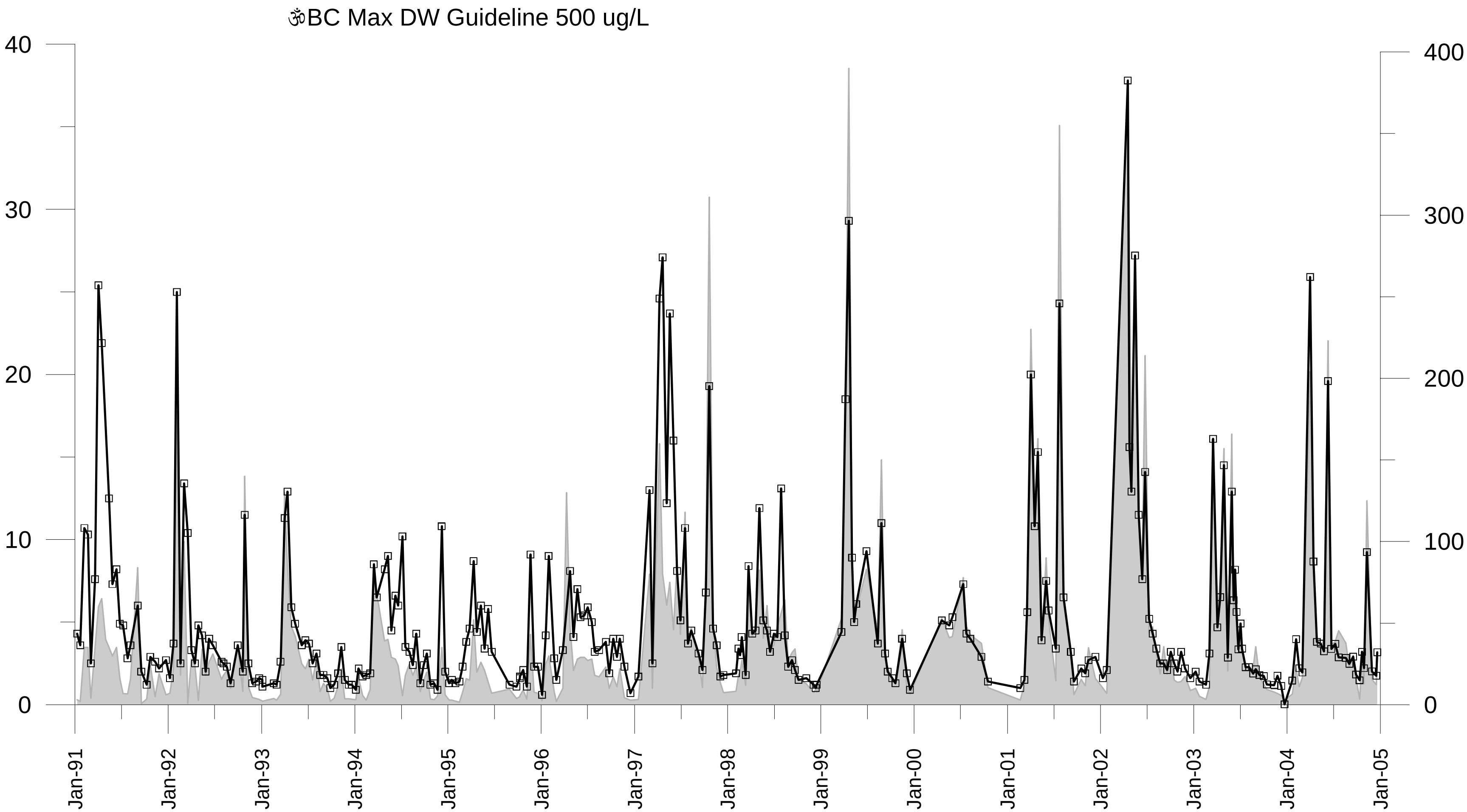

Fraser River at Marguerite
Chromium Total (ug/L)
Figure 20
Cr Total
BC/CCME Cr6 AW Guideline Max
BC Max Cr3 AW Guideline Max
Turbidity (NTU)
ॐBC/CCME Cr DW Guideline Max 50 ug/L
ॐCCME Cr3 AW Guideline Max 8.9 ug/L
ॐOutlier removed at 12/23/91 - 13200 ug/L
0
10
20
30
40
0
100
200
300
400
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

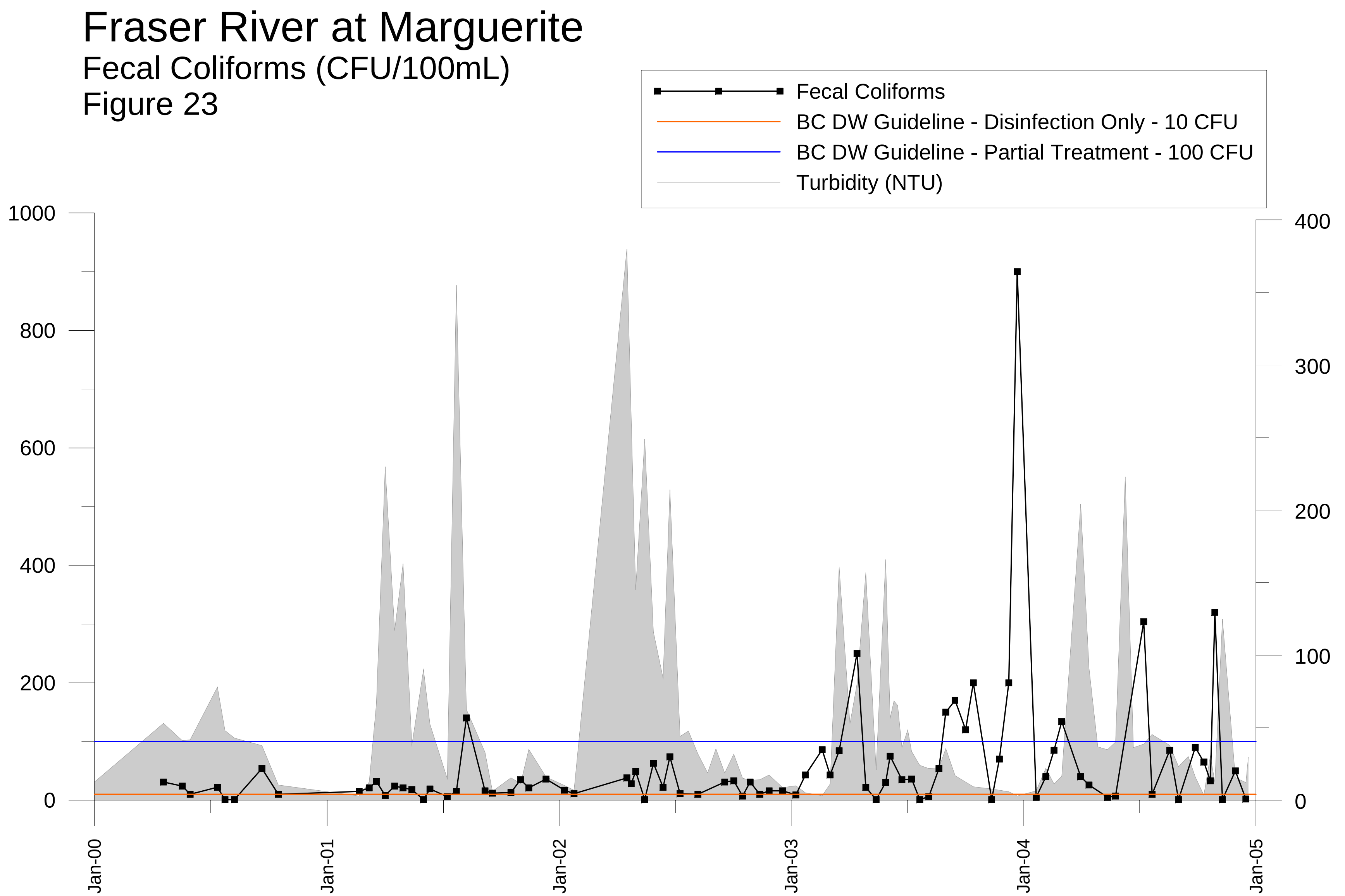

Fraser River at Marguerite
Copper Total (ug/L)
Figure 21
Cu Total
Turbidity (NTU)
BC AW Guideline Range
30-Day-BC AW Guideline Range
CCME AW Guideline Range
BC Max DW Guideline 500 ug/L
160
120
80
40
0
400
300
200
100
0
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

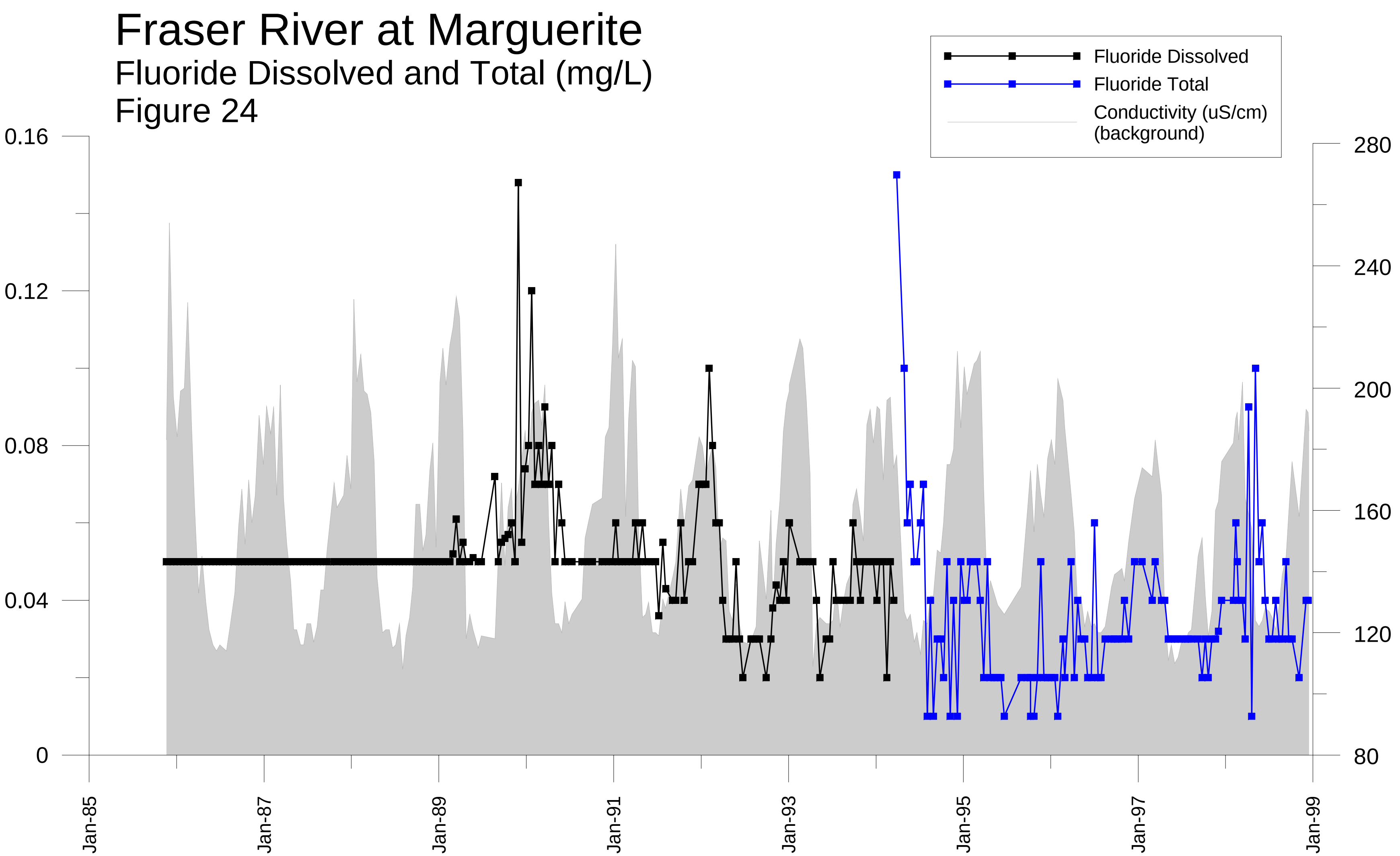
Fraser River at Marguerite

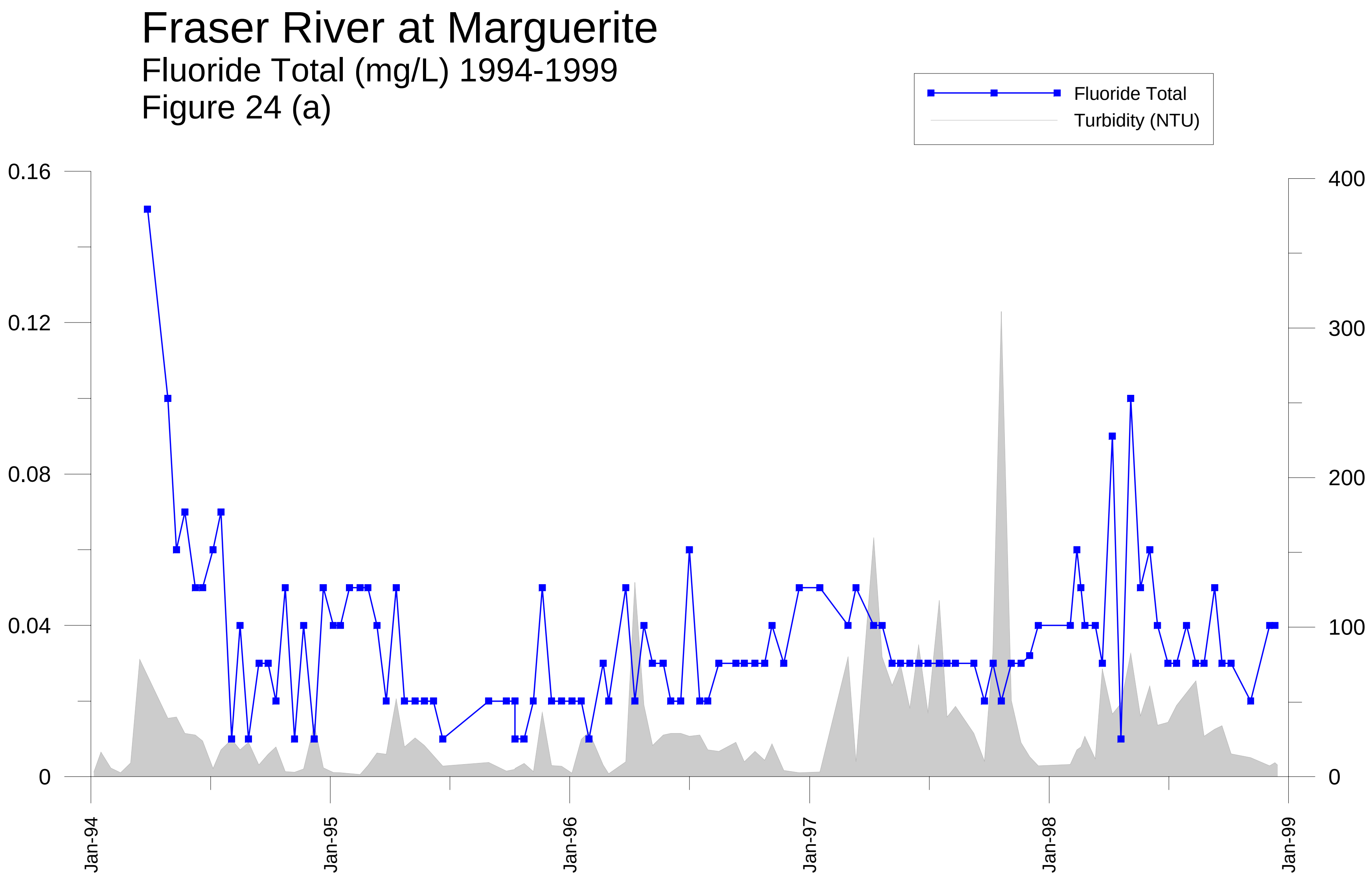
Copper Total (ug/L) 1991-2005

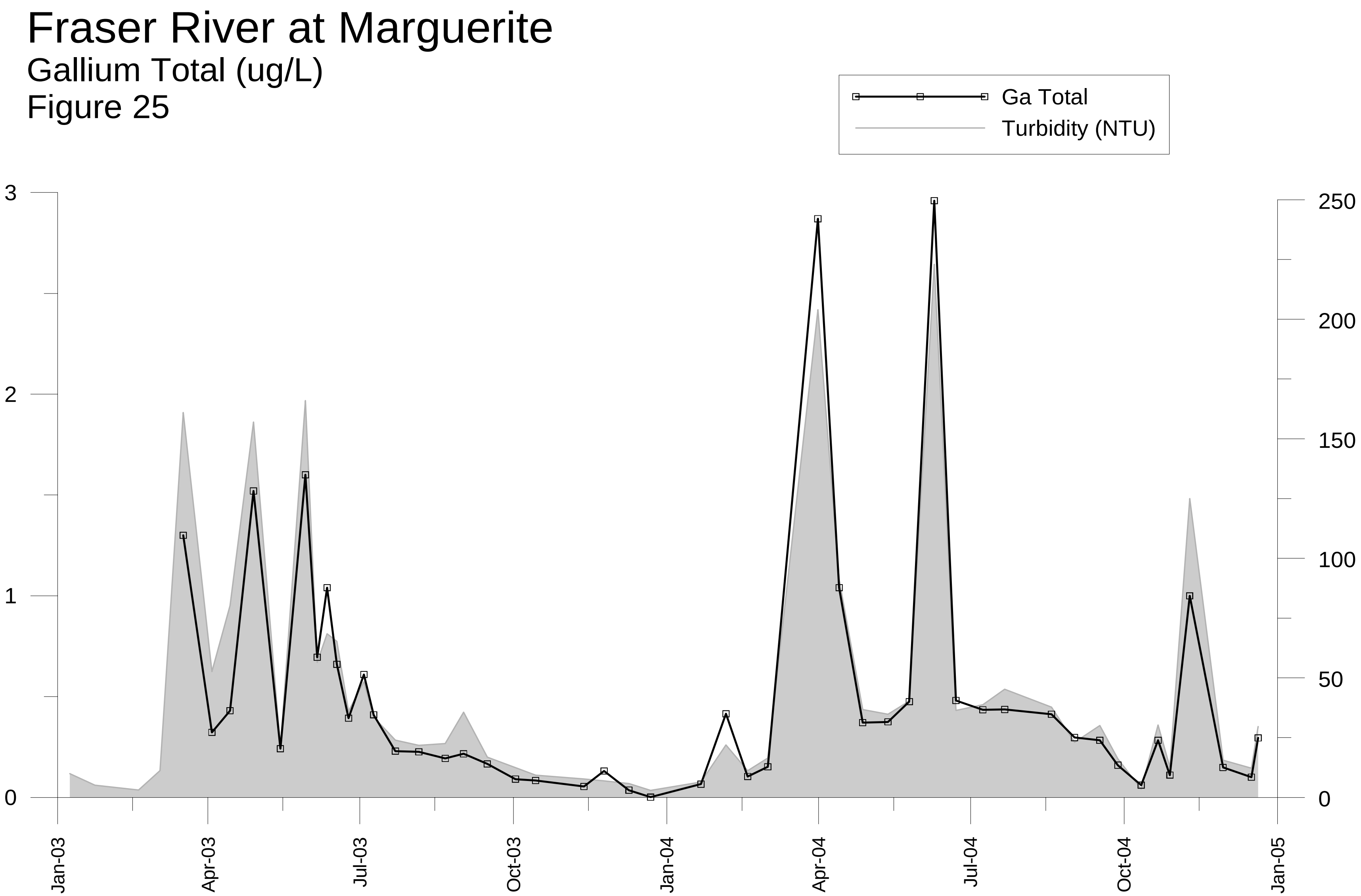
Figure 22



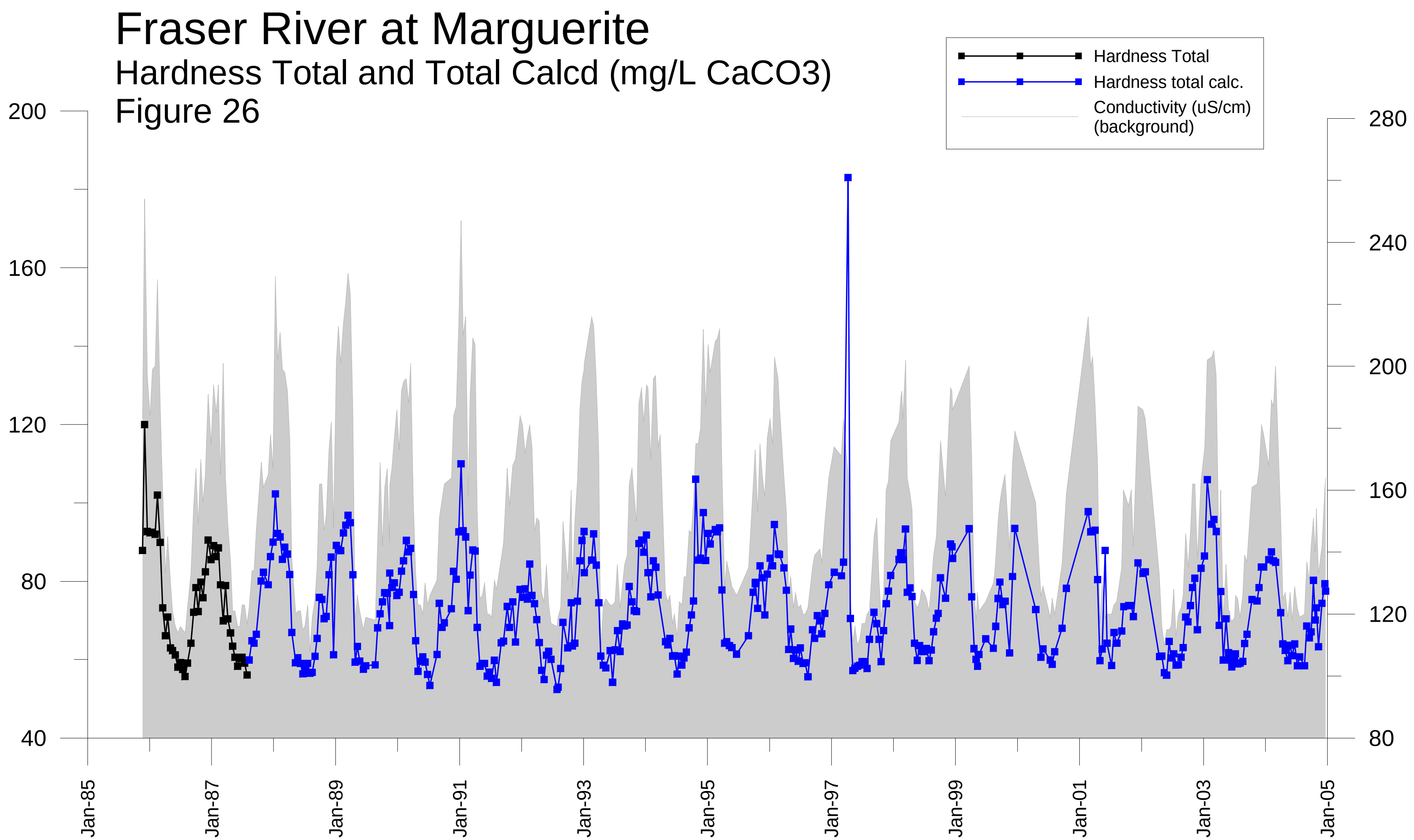

Fraser River at Marguerite
Fecal Coliforms (CFU/100mL)
Figure 23
Fecal Coliforms
BC DW Guideline - Disinfection Only - 10 CFU
BC DW Guideline - Partial Treatment - 100 CFU
Turbidity (NTU)
1000
800
600
400
200
0
400
300
200
100
0
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

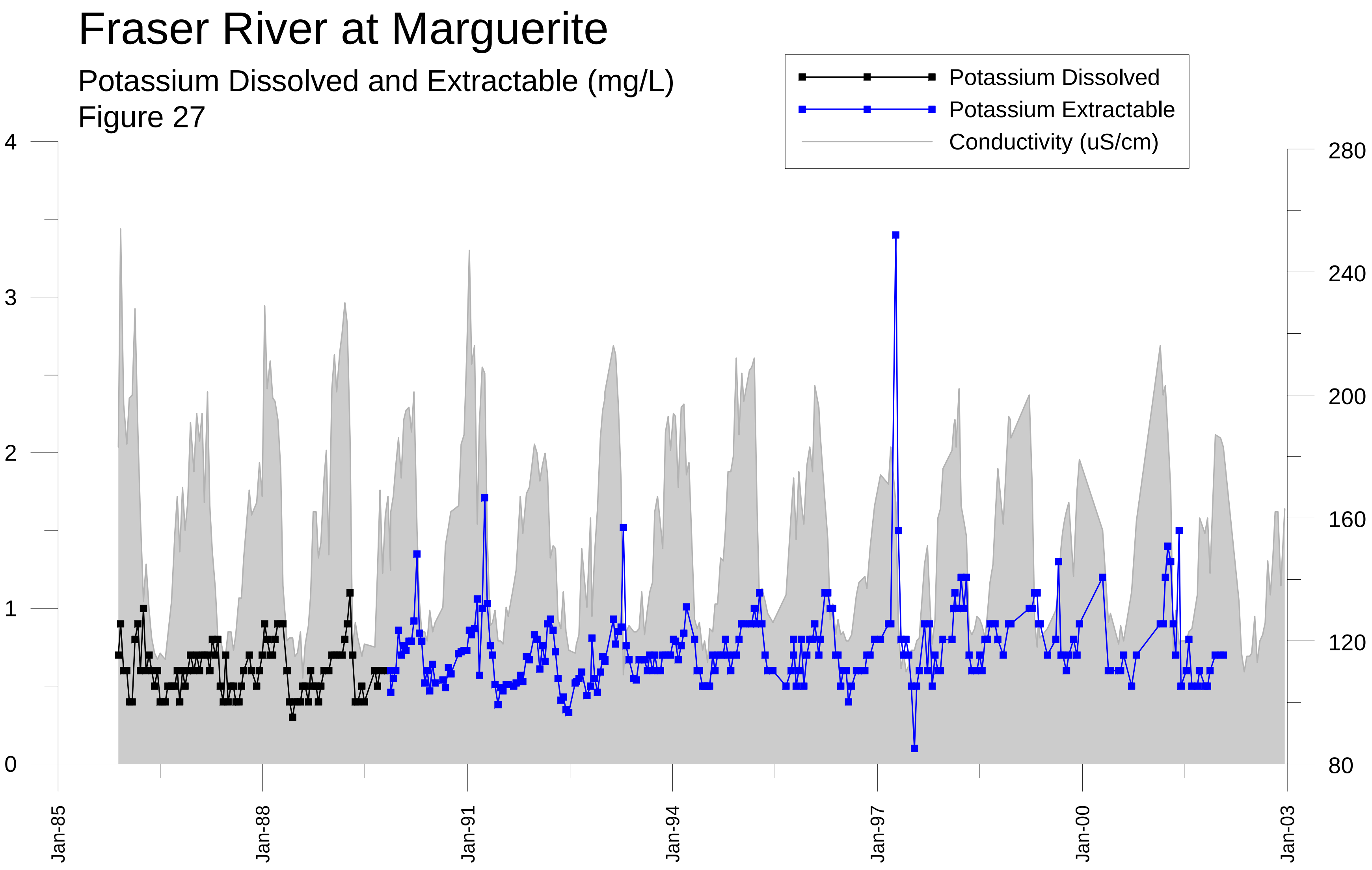

Fraser River at Marguerite
Fluoride Dissolved and Total (mg/L)
Figure 24
Fluoride Dissolved
Fluoride Total
Conductivity (uS/cm) (background)
0.16
0.12
0.08
0.04
0
280
240
200
160
120
80
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99


Fraser River at Marguerite
Fluoride Total (mg/L) 1994-1999
Figure 24 (a)
Fluoride Total
Turbidity (NTU)
0.16
0.12
0.08
0.04
0
400
300
200
100
0
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99

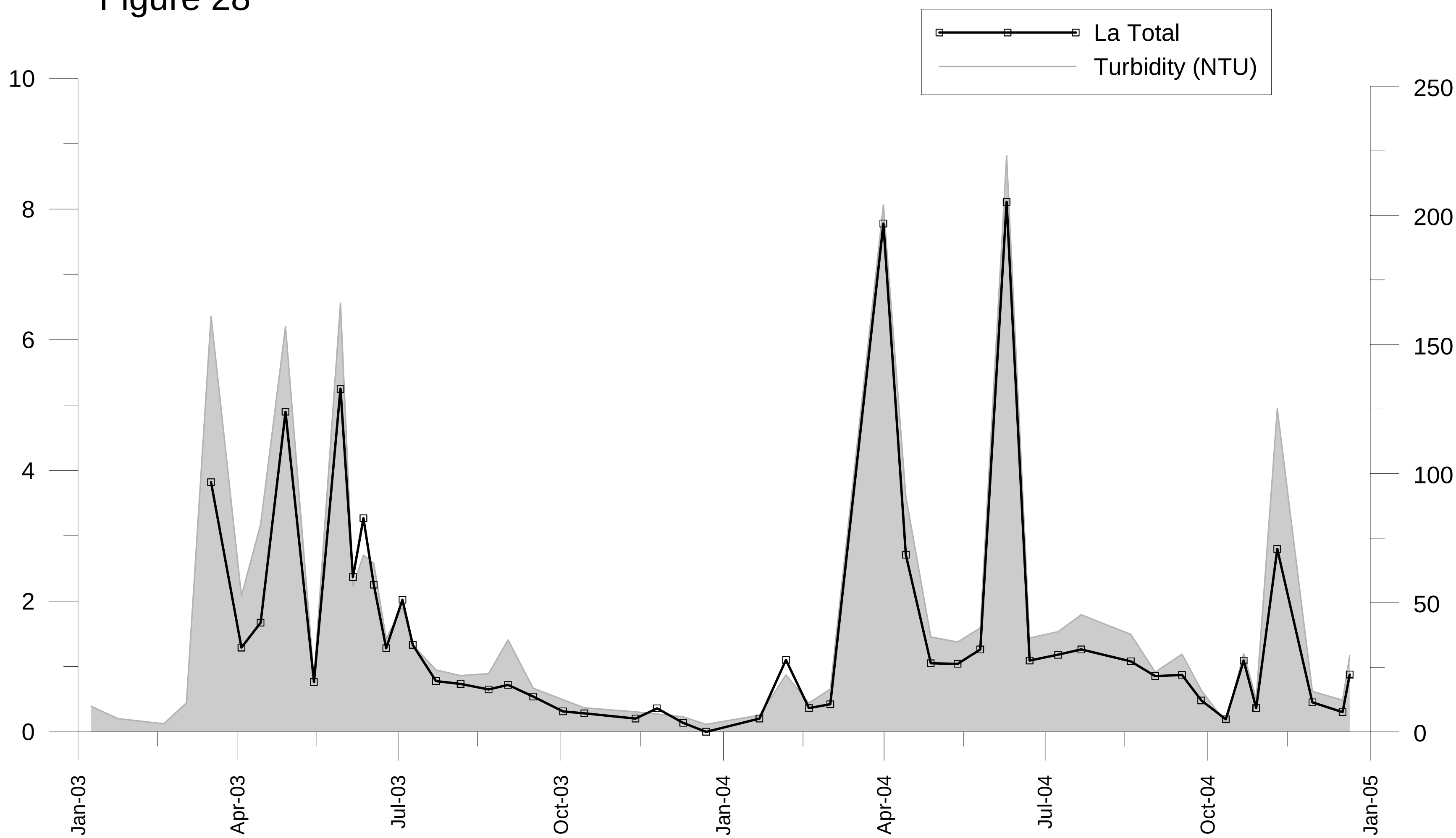


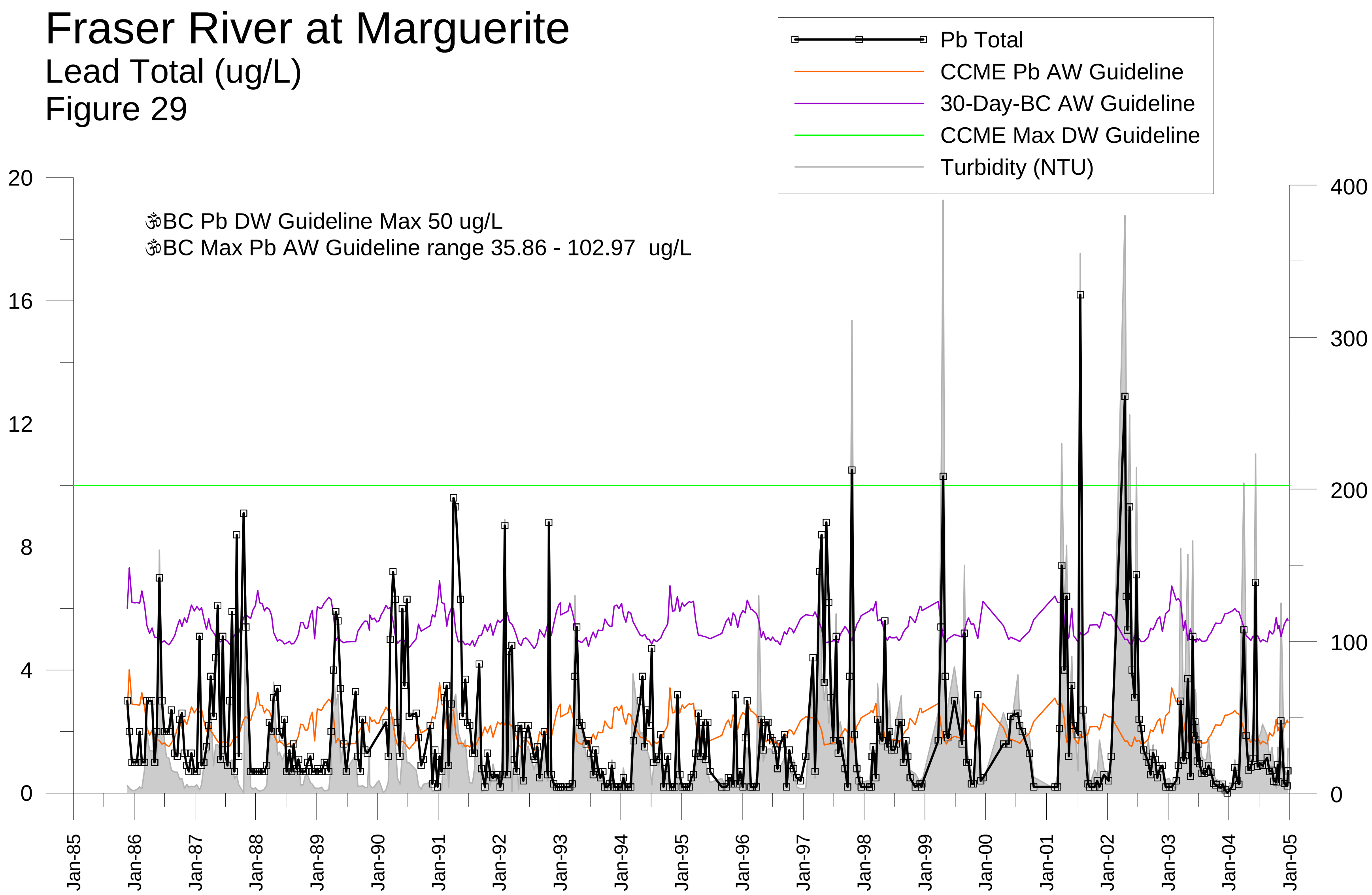
Fraser River at Marguerite
Gallium Total (ug/L)
Figure 25
Ga Total
Turbidity (NTU)
0
1
2
3
0
50
100
150
200
250
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05

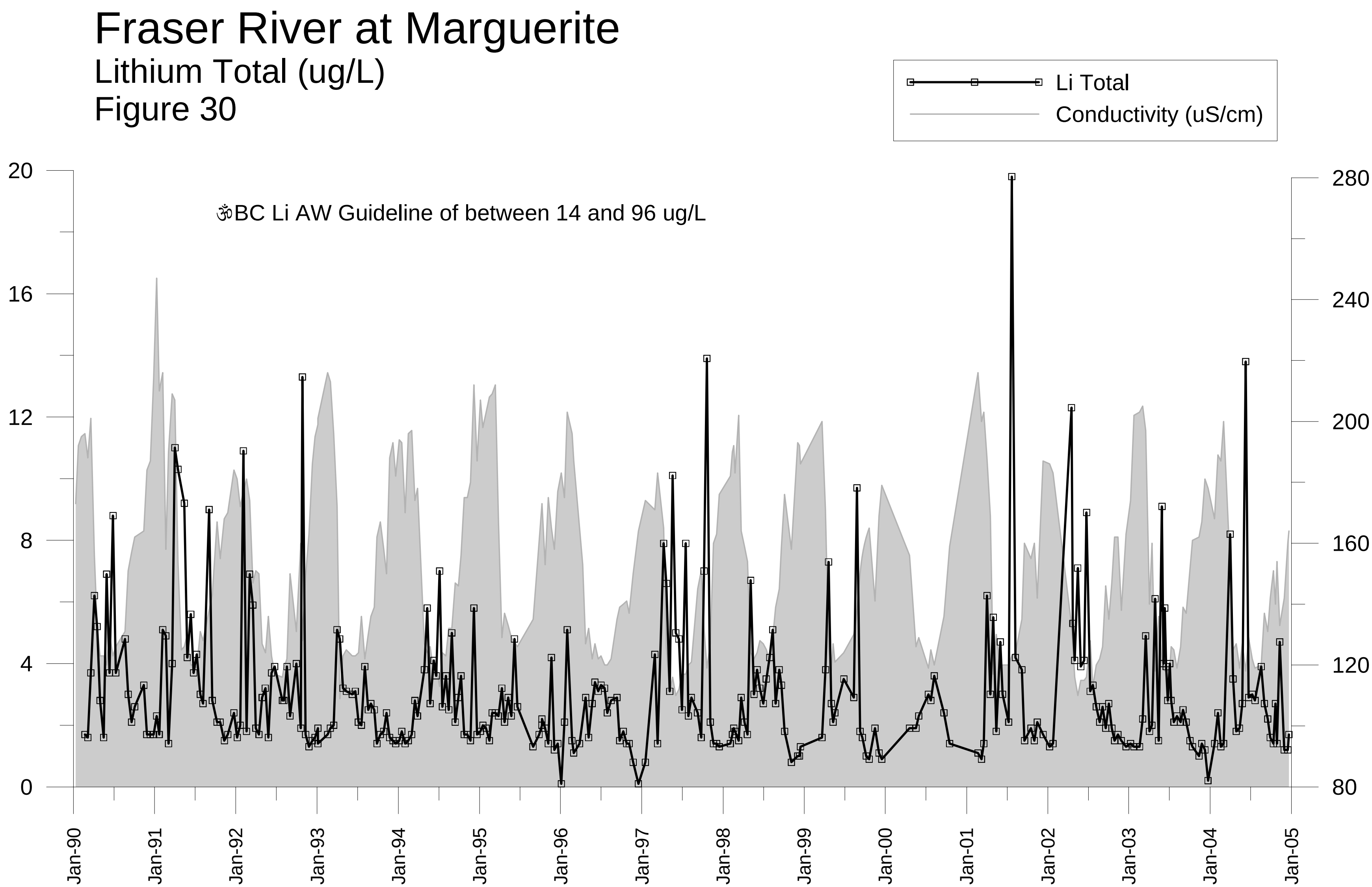

Fraser River at Marguerite
Hardness Total and Total Calcd (mg/L CaCO3)
Figure 26
Hardness Total
Hardness total calc.
Conductivity (uS/cm) (background)
200
160
120
80
40
280
240
200
160
120
80
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05

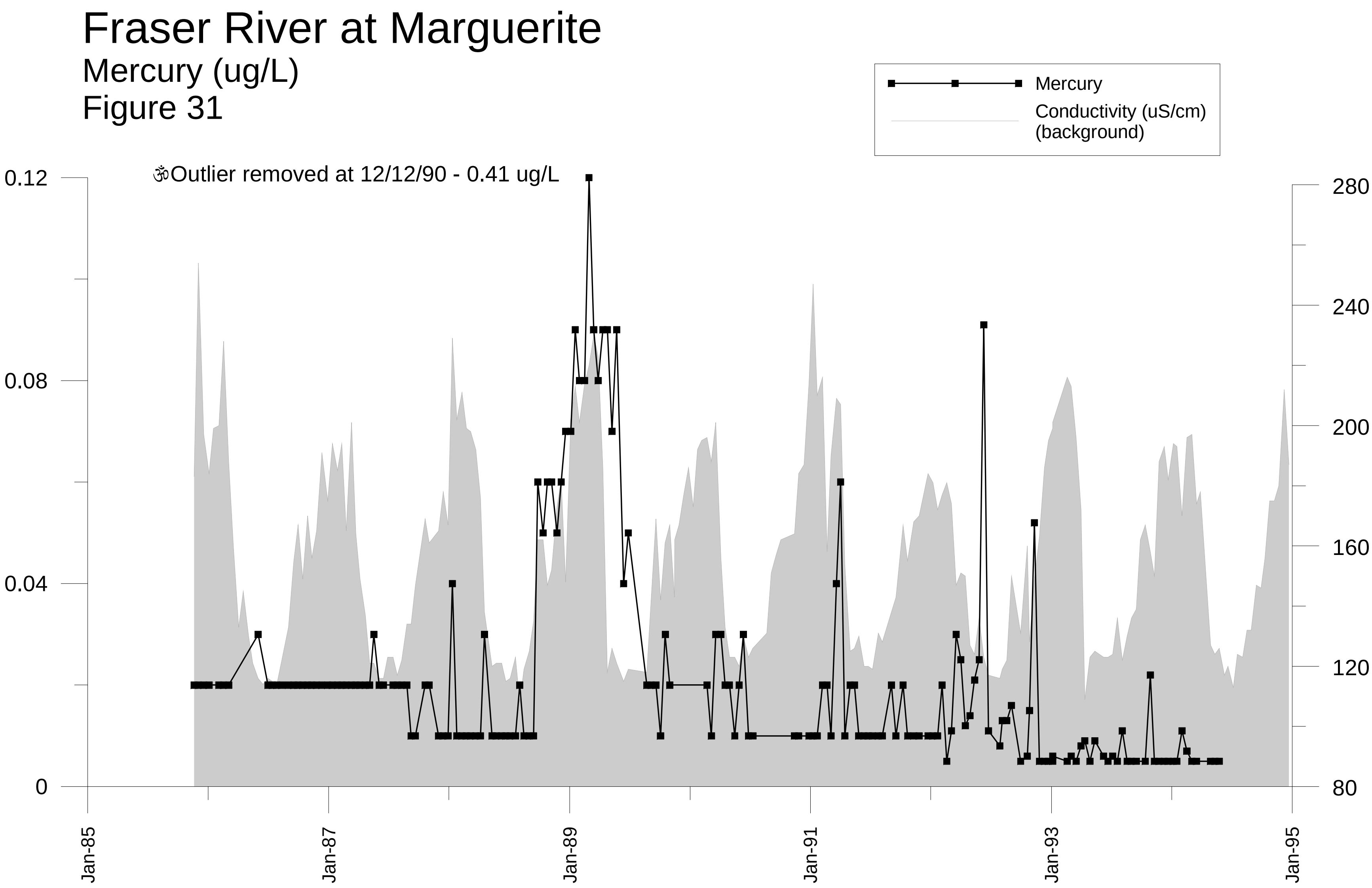

Fraser River at Marguerite
Potassium Dissolved and Extractable (mg/L)
Figure 27
Potassium Dissolved
Potassium Extractable
Conductivity (uS/cm)
0
1
2
3
4
80
120
160
200
240
280
Jan-85
Jan-88
Jan-91
Jan-94
Jan-97
Jan-00
Jan-03

Fraser River at Marguerite
Lanthanum Total (ug/L)
Figure 28




Fraser River at Marguerite
Lead Total (ug/L)
Figure 29
Pb Total
CCME Pb AW Guideline
30-Day-BC AW Guideline
CCME Max DW Guideline
Turbidity (NTU)
ॐBC Pb DW Guideline Max 50 ug/L
ॐBC Max Pb AW Guideline range 35.86 - 102.97 ug/L
20
16
12
8
4
0
400
300
200
100
0
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

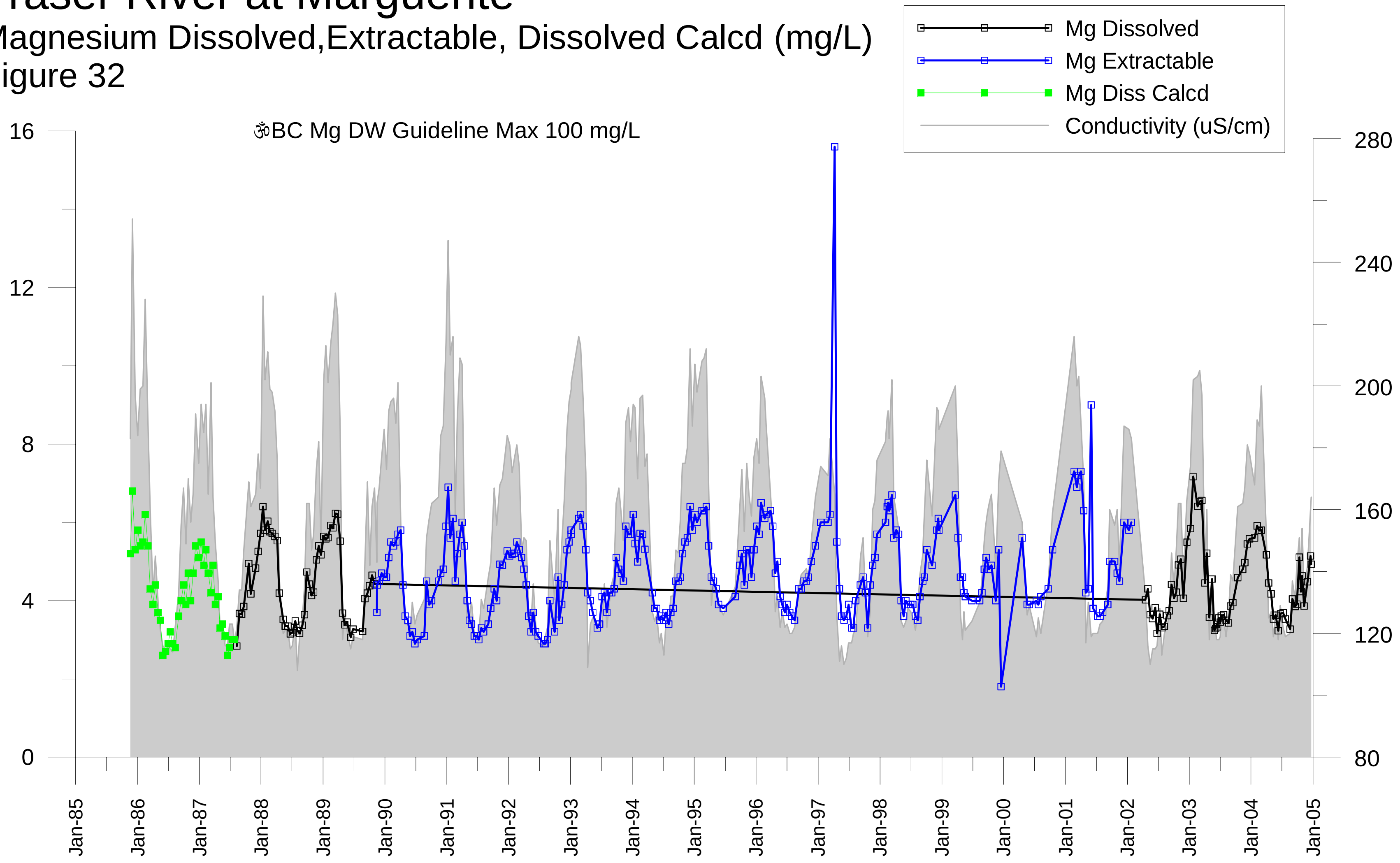

Fraser River at Marguerite
Lithium Total (ug/L)
Figure 30
Li Total
Conductivity (uS/cm)
ॐBC Li AW Guideline of between 14 and 96 ug/L
20
16
12
8
4
0
280
240
200
160
120
80
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Mercury (ug/L)
Figure 31
Mercury
Conductivity (uS/cm) (background)
ॐOutlier removed at 12/12/90 - 0.41 ug/L
0.12
0.08
0.04
0
280
240
200
160
120
80
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95

Fraser River at Marguerite

Magnesium Dissolved,Extractable, Dissolved Calcd (mg/L)

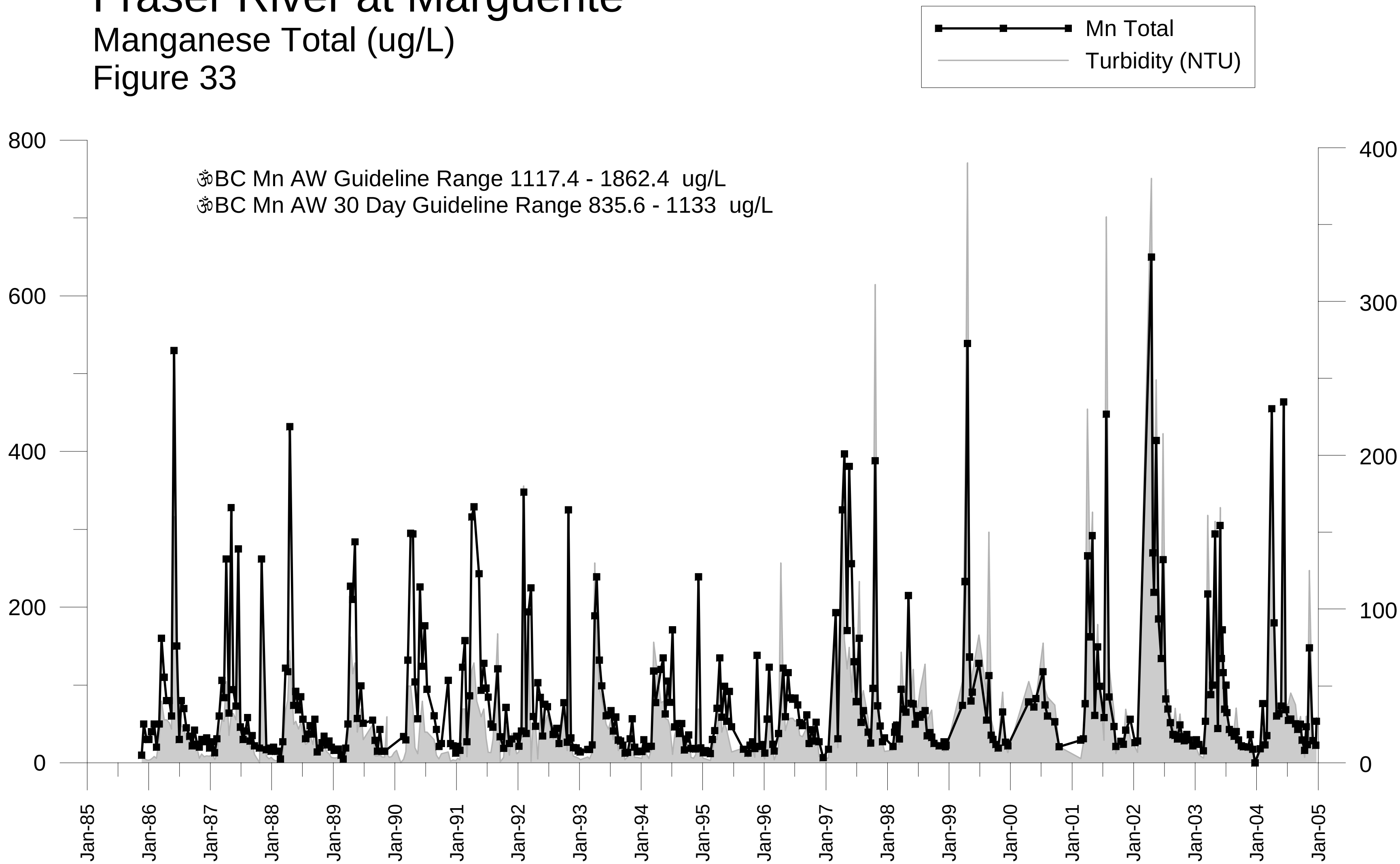
Figure 32

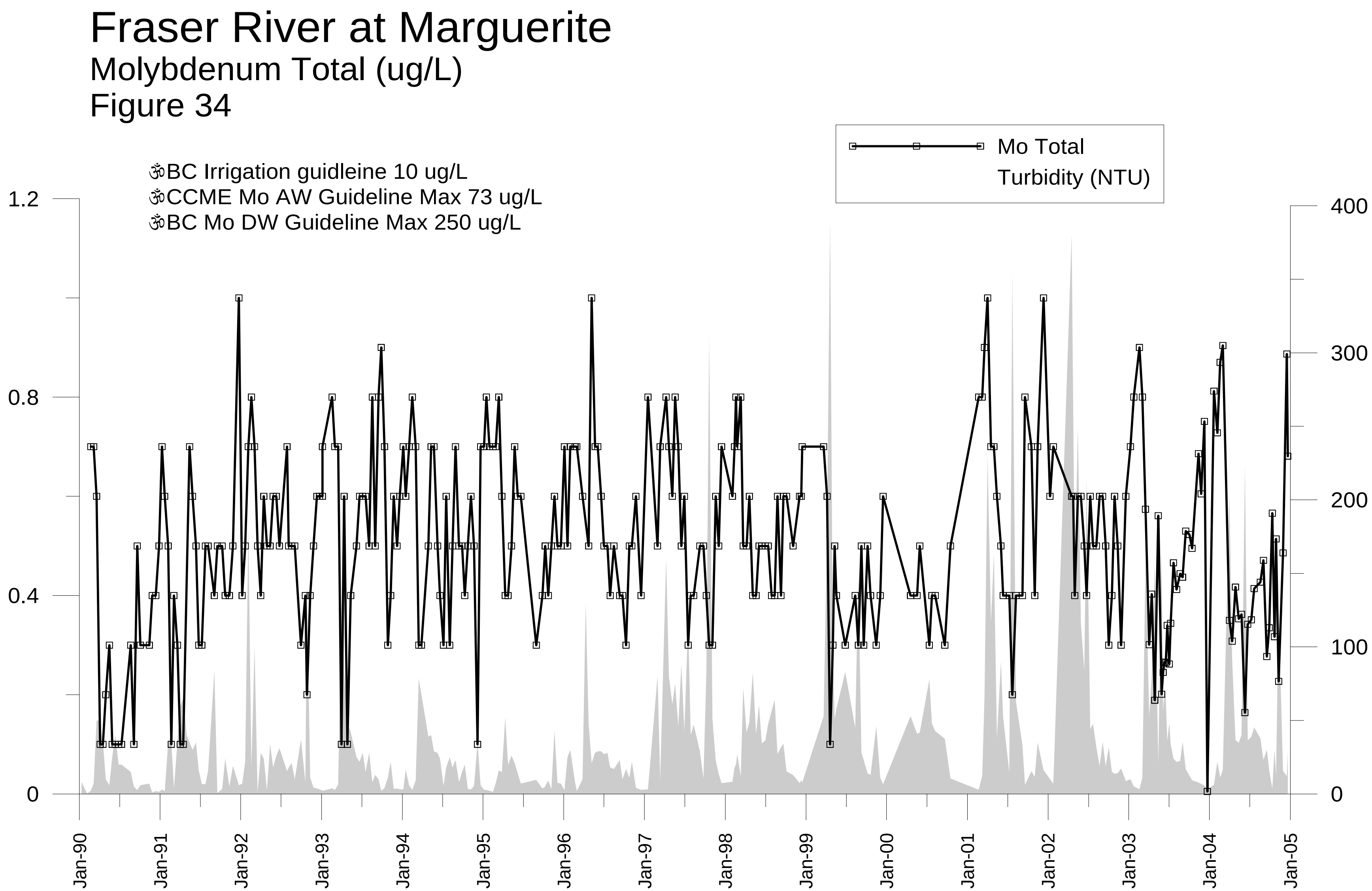


Fraser River at Marguerite

Manganese Total (ug/L)

Figure 33

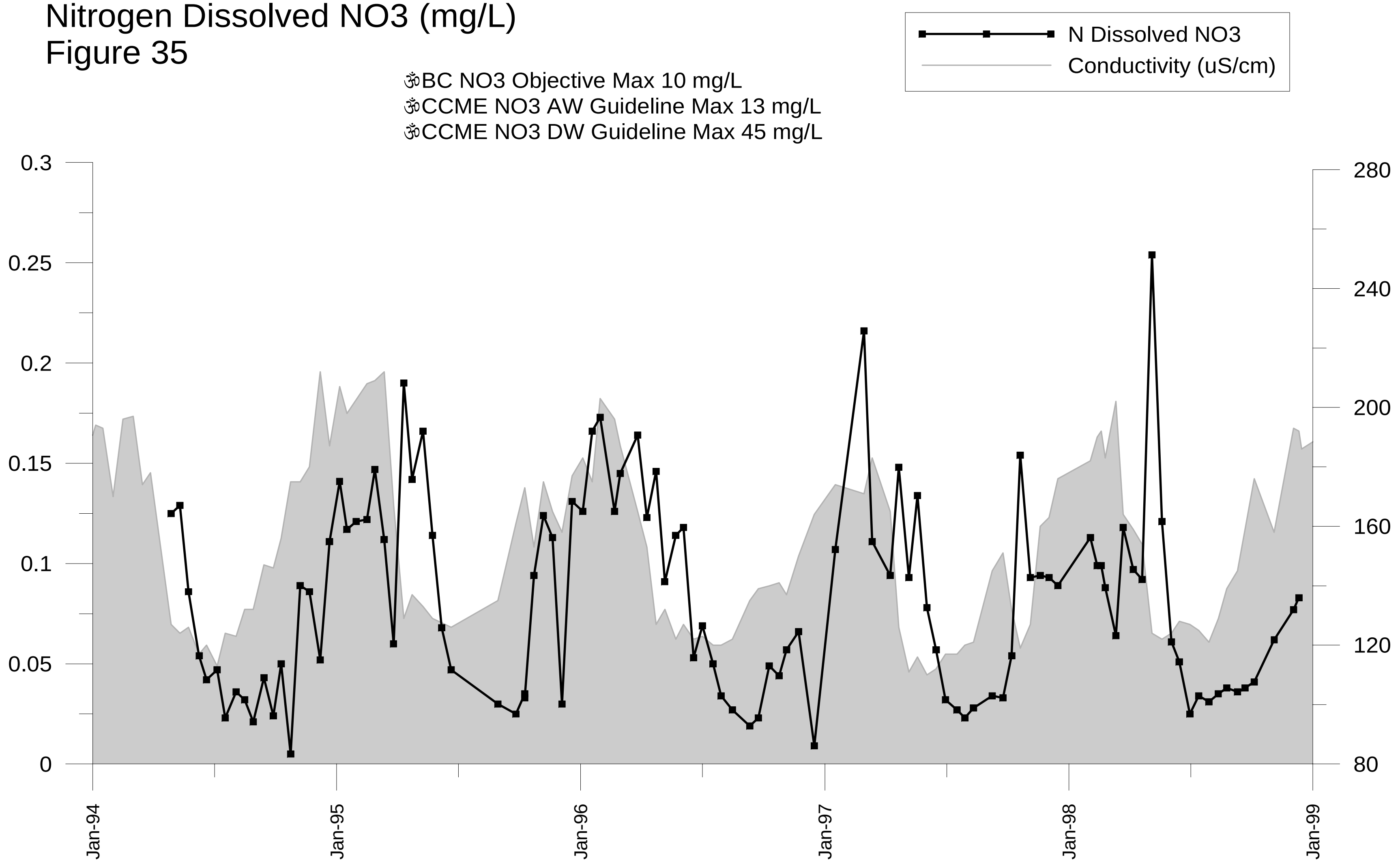



Fraser River at Marguerite
Molybdenum Total (ug/L)
Figure 34
ॐBC Irrigation guidleine 10 ug/L
ॐCCME Mo AW Guideline Max 73 ug/L
ॐBC Mo DW Guideline Max 250 ug/L
Mo Total
Turbidity (NTU)
1.2
0.8
0.4
0
400
300
200
100
0
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

Fraser River at Marguerite

Nitrogen Dissolved NO3 (mg/L)

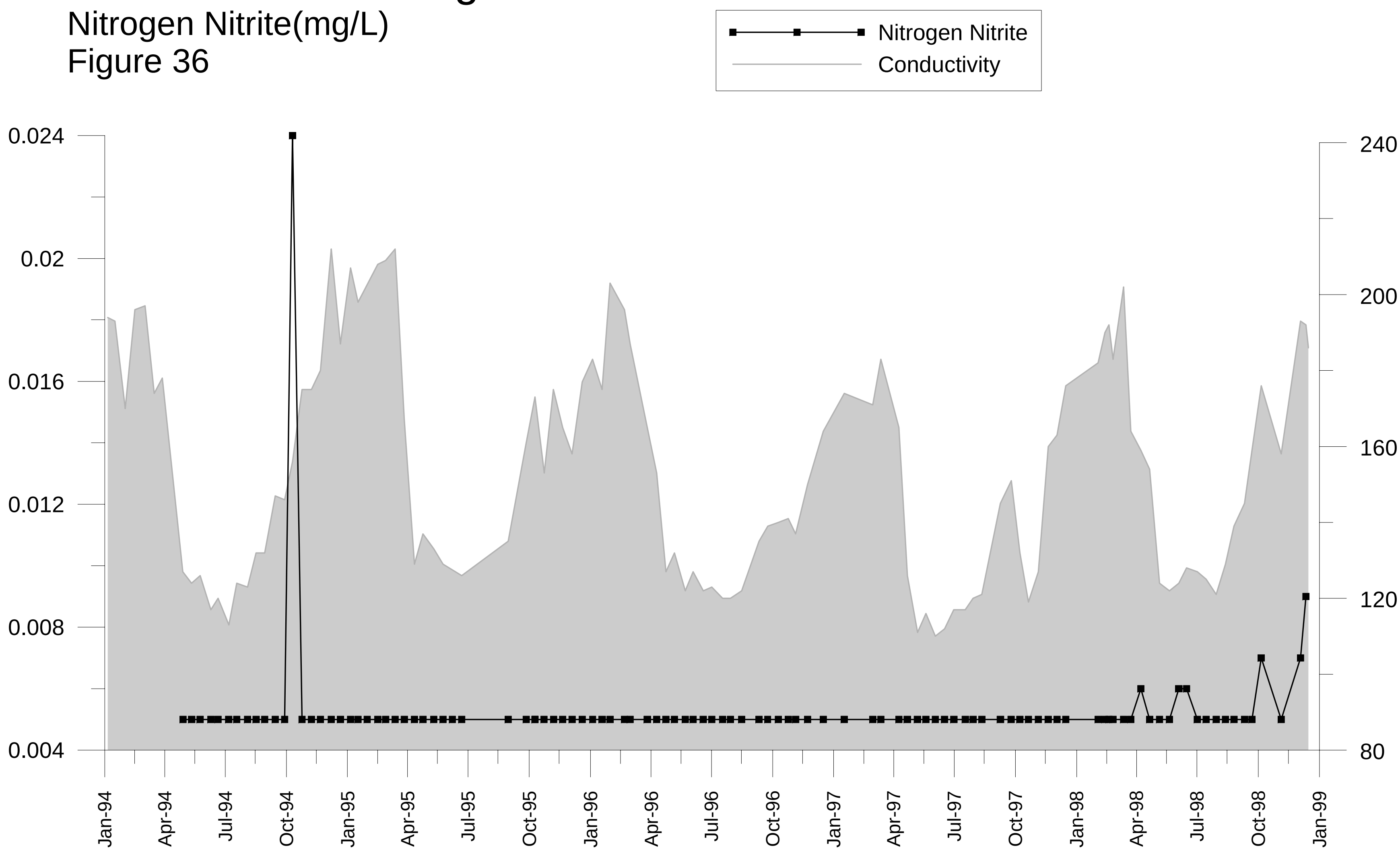
Figure 35



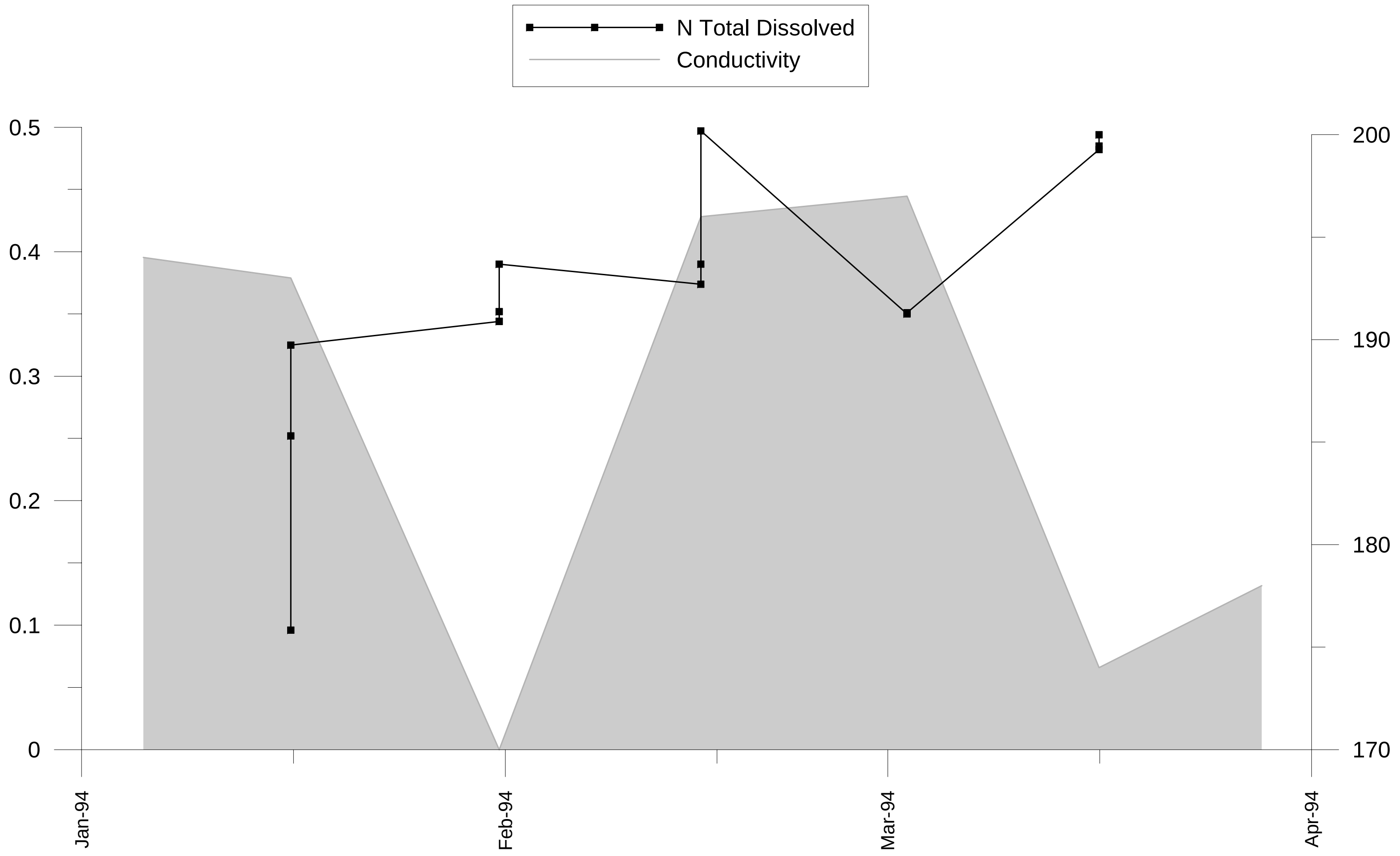
Fraser River at Marguerite

Nitrogen Nitrite(mg/L)

Figure 36



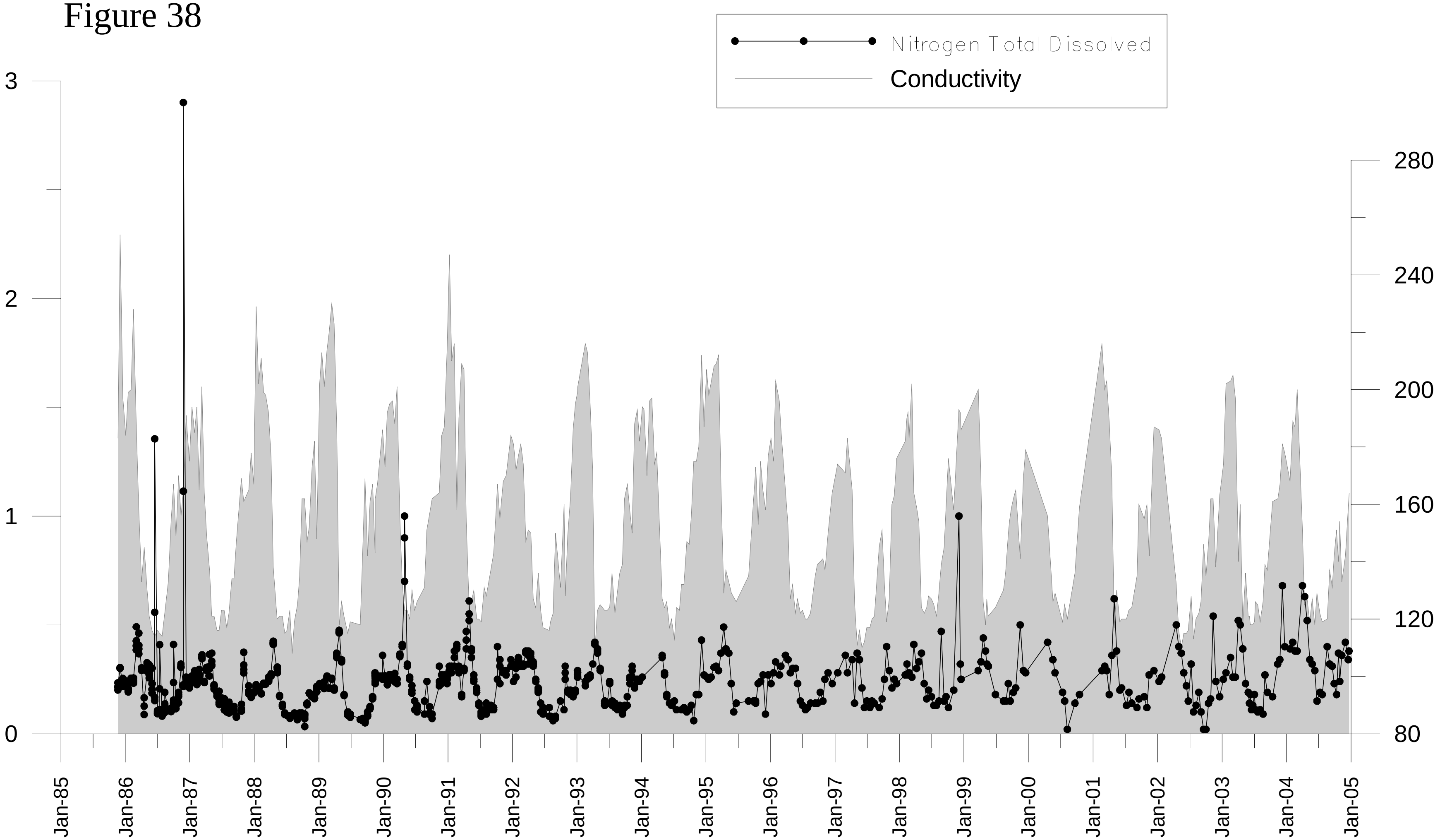
Fraser River at Marguerite
Nitrogen Total (mg/L)
Figure 37

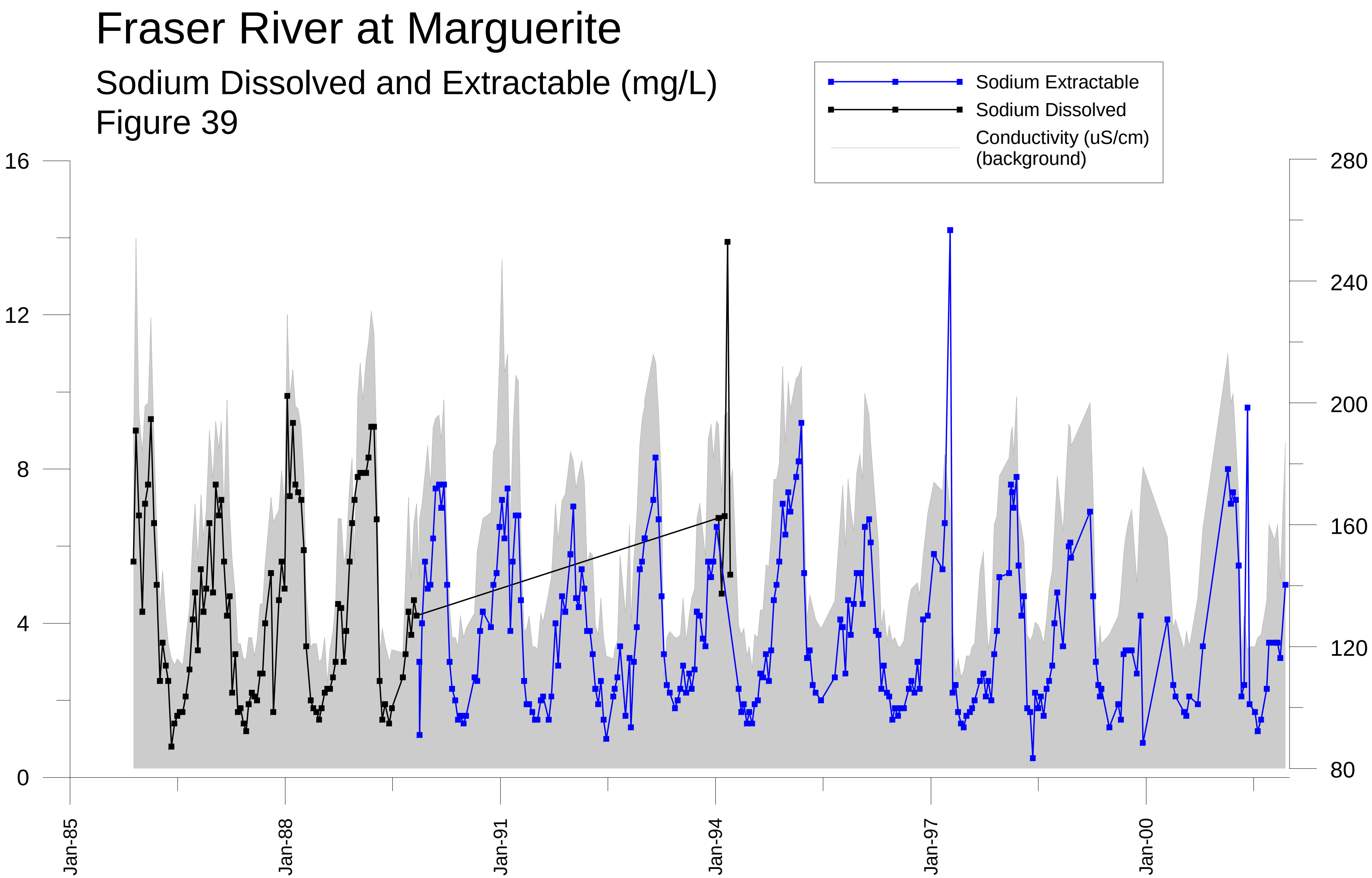


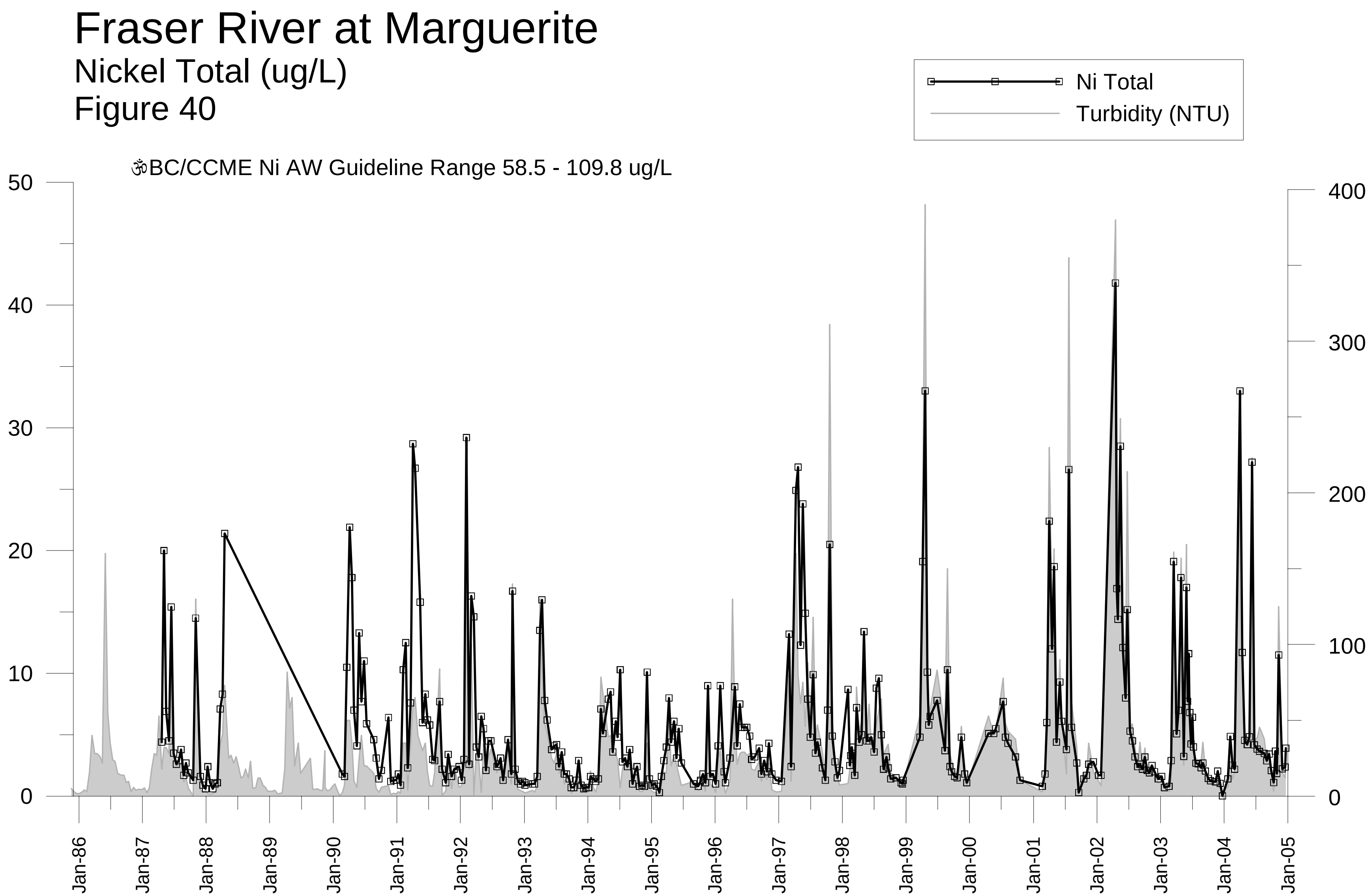
Fraser River at Marguerite

Nitrogen Total Dissolved (mg/L)

Figure 38



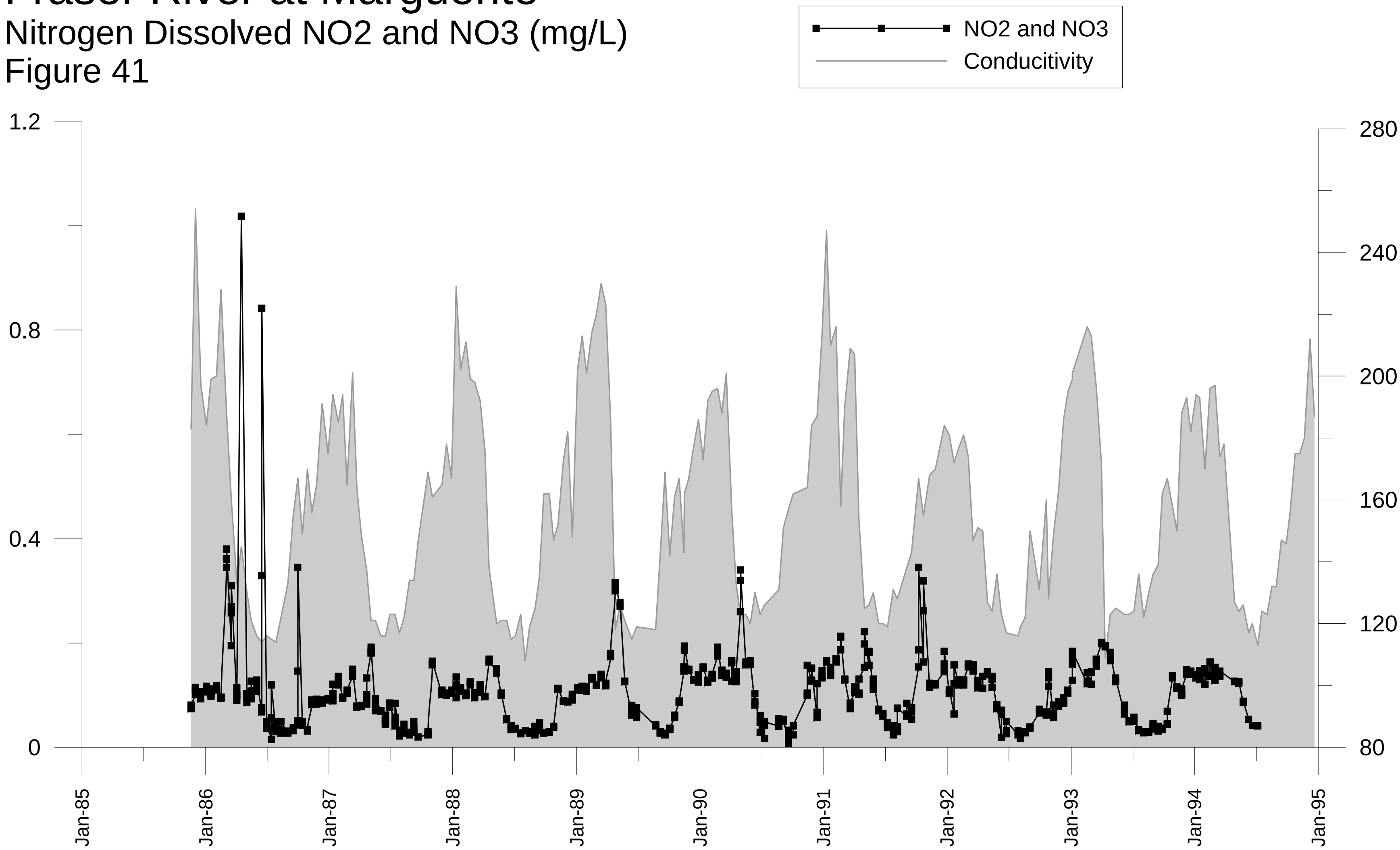

Fraser River at Marguerite
Sodium Dissolved and Extractable (mg/L)
Figure 39
Sodium Extractable
Sodium Dissolved
Conductivity (uS/cm) (background)
0
4
8
12
16
80
120
160
200
240
280
Jan-85
Jan-88
Jan-91
Jan-94
Jan-97
Jan-00

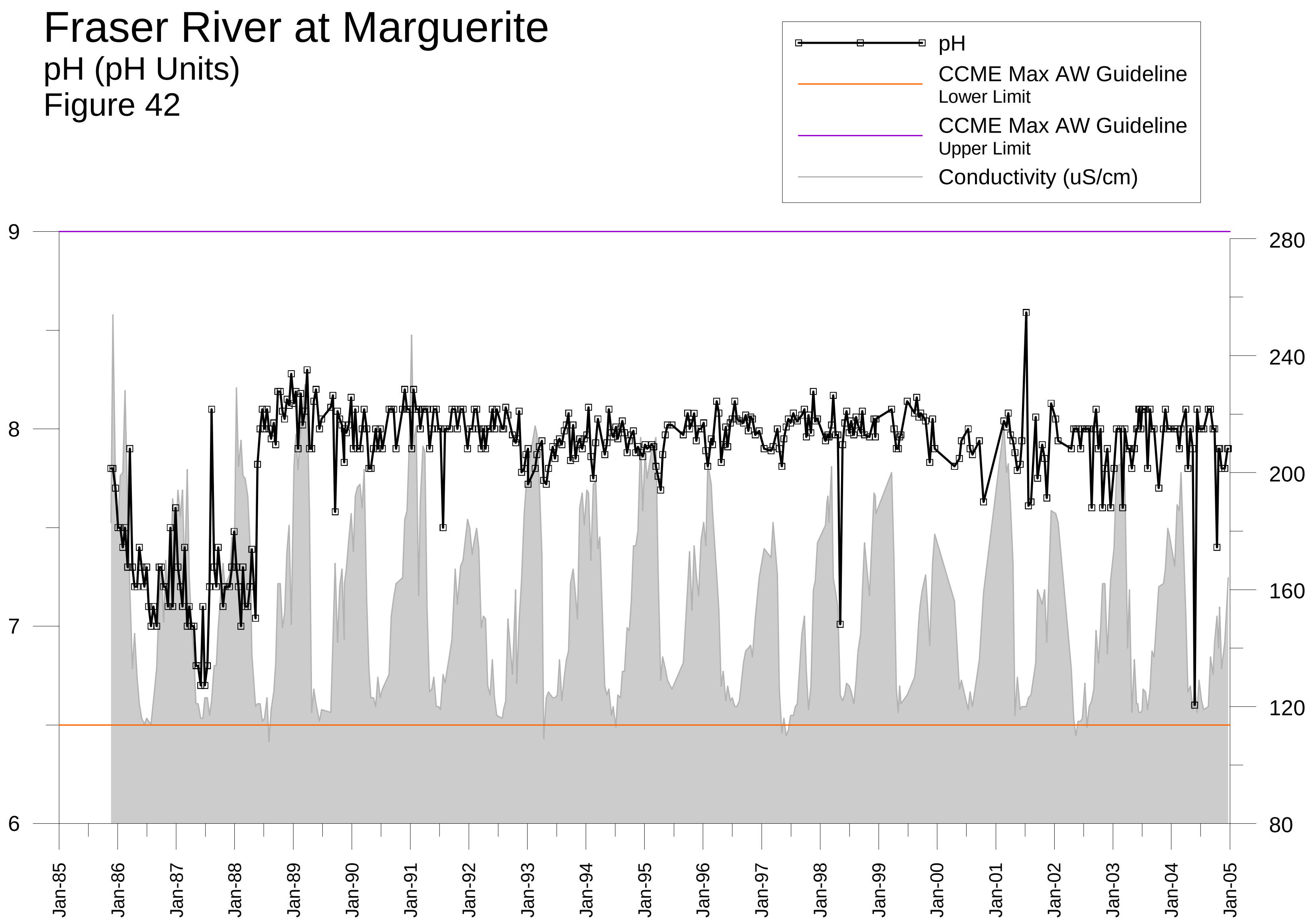

Fraser River at Marguerite
Nickel Total (ug/L)
Figure 40
Ni Total
Turbidity (NTU)
BC/CCME Ni AW Guideline Range 58.5 - 109.8 ug/L
50
40
30
20
10
0
400
300
200
100
0
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

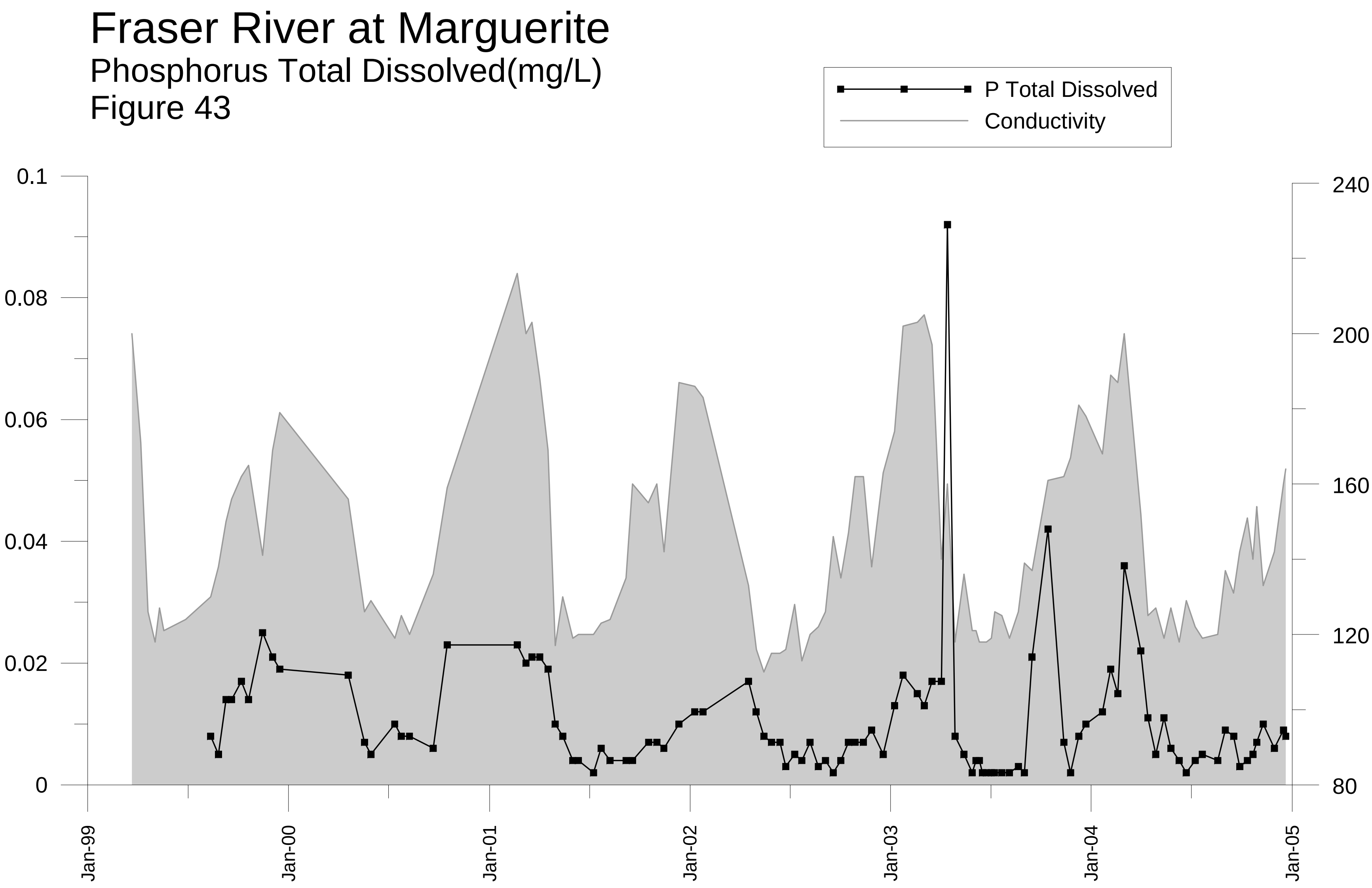
Fraser River at Marguerite

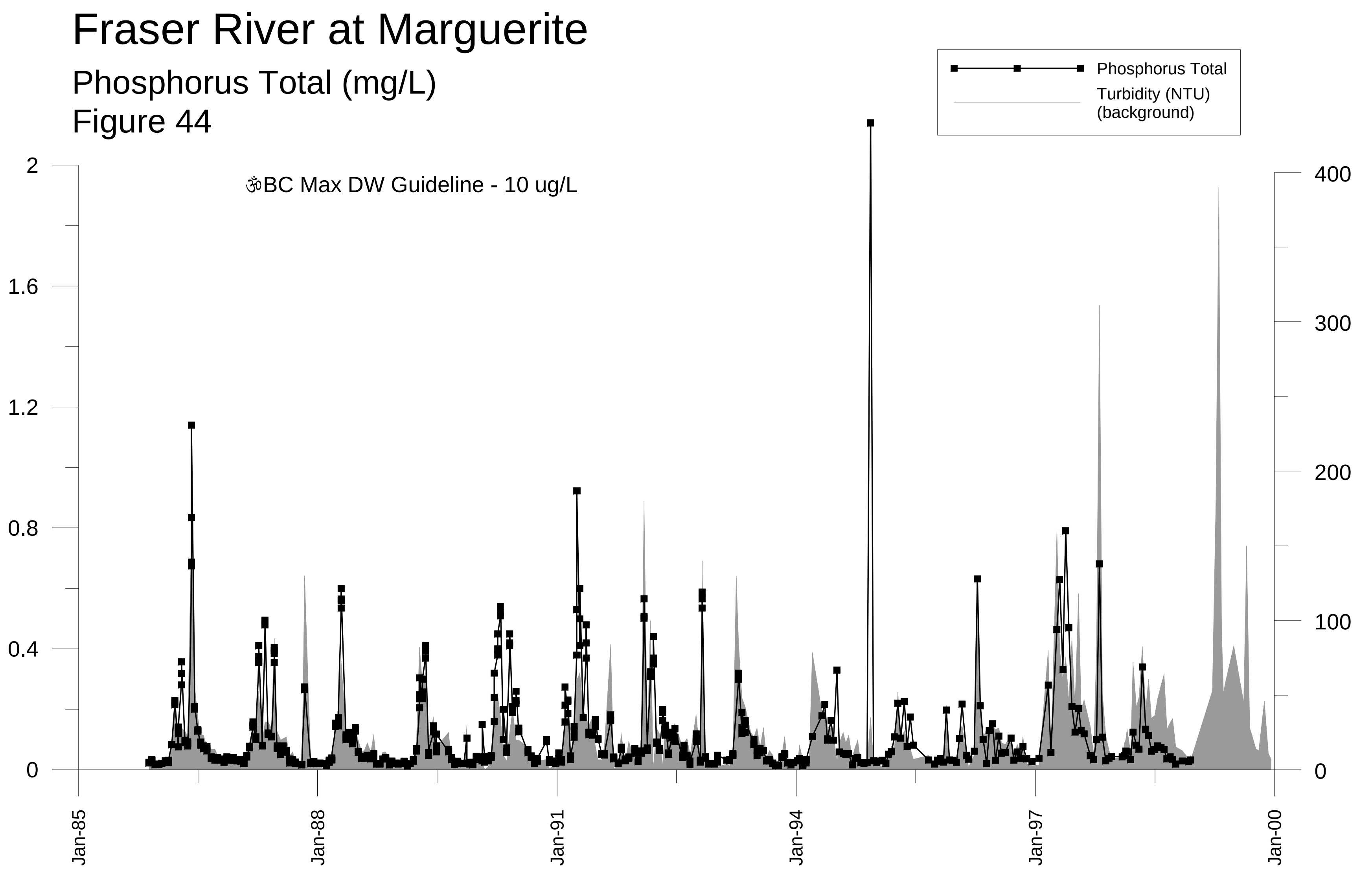
Nitrogen Dissolved NO2 and NO3 (mg/L)

Figure 41

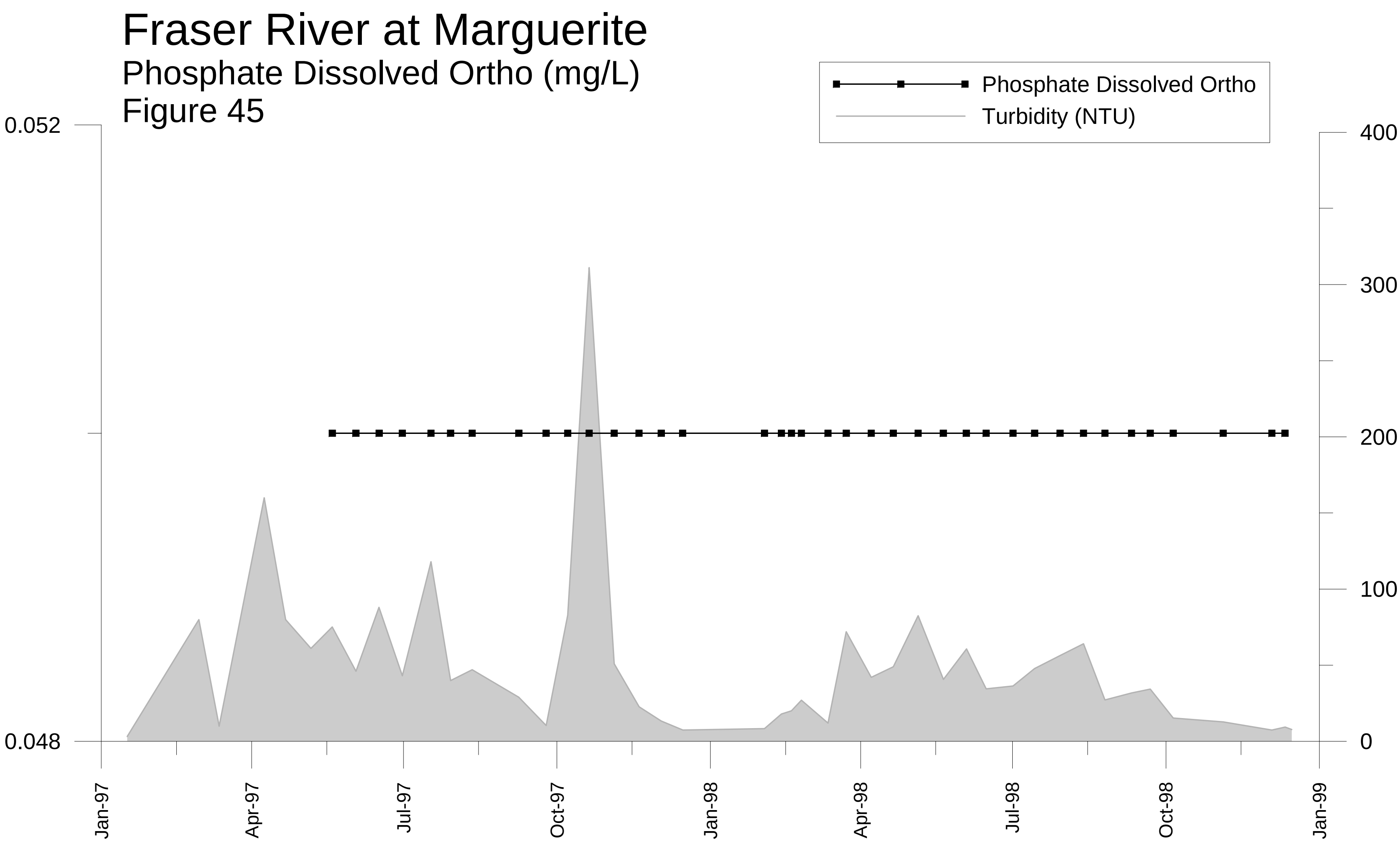


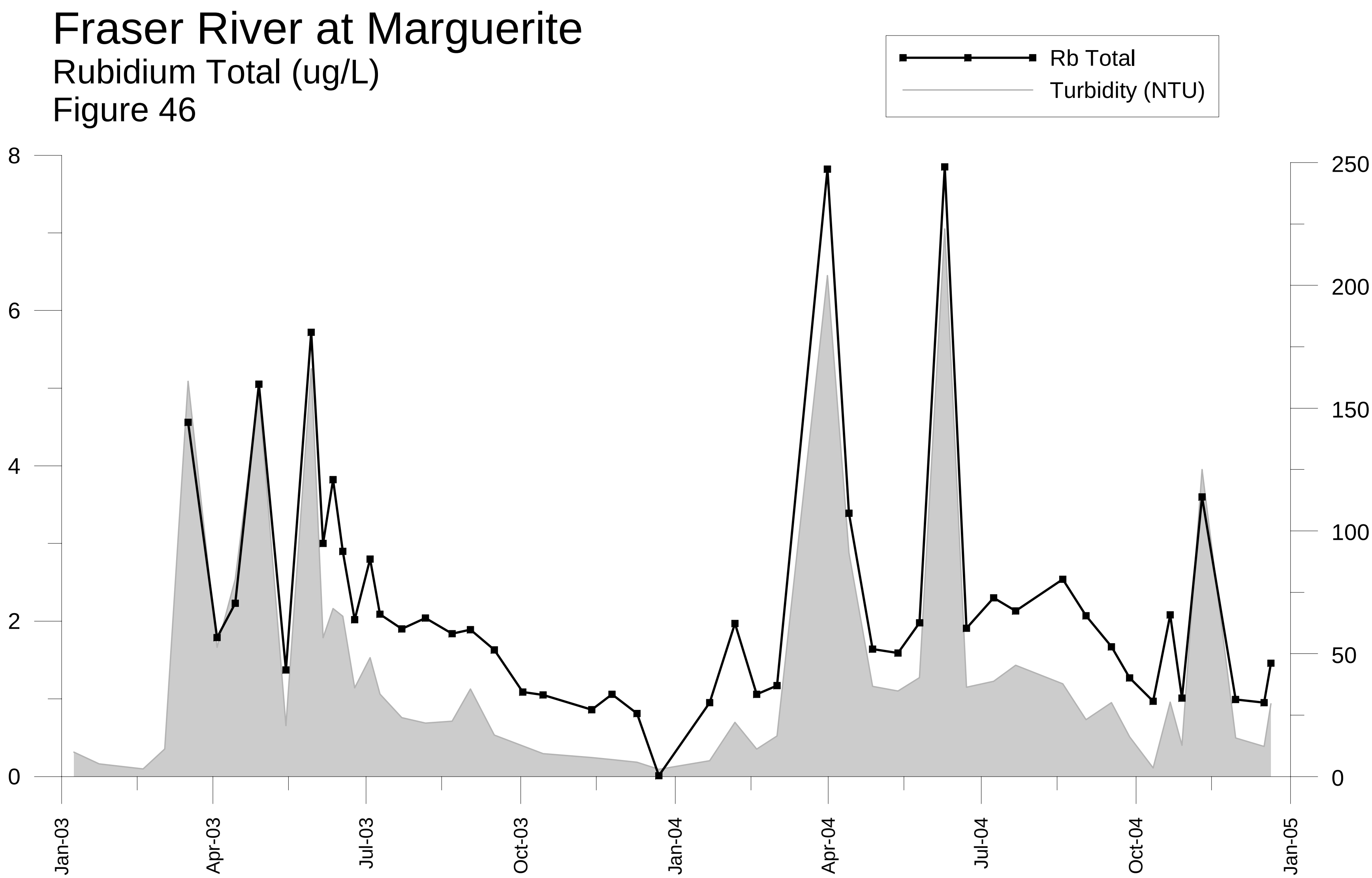

Fraser River at Marguerite
pH (pH Units)
Figure 42
pH
CCME Max AW Guideline
Lower Limit
CCME Max AW Guideline
Upper Limit
Conductivity (uS/cm)
9
8
7
6
280
240
200
160
120
80
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Phosphorus Total Dissolved(mg/L)
Figure 43
P Total Dissolved
Conductivity
0.1
0.08
0.06
0.04
0.02
0
240
200
160
120
80
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05



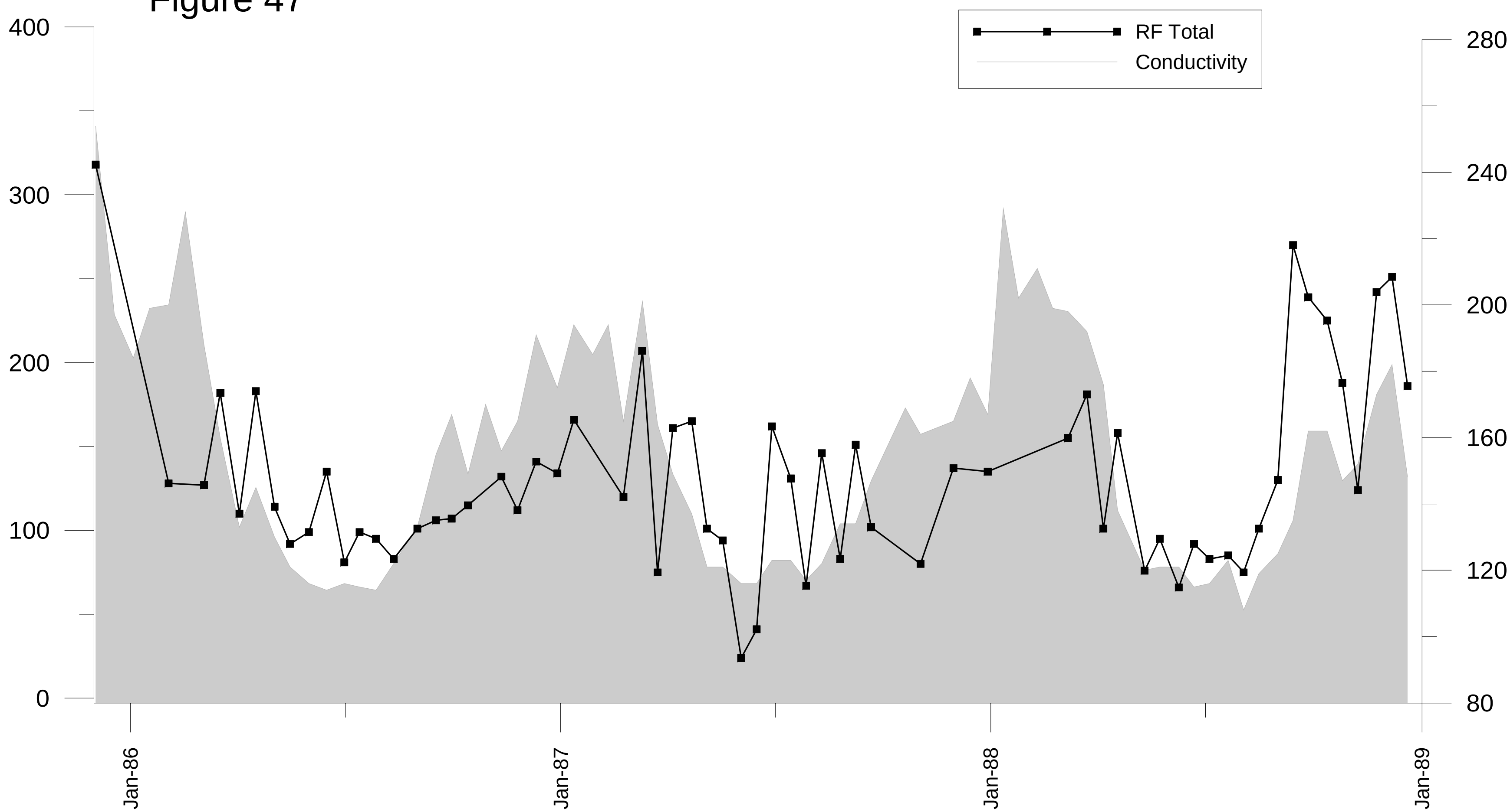
Fraser River at Marguerite
Phosphorus Total (mg/L)
Figure 44
Phosphorus Total
Turbidity (NTU) (background)
ॐBC Max DW Guideline - 10 ug/L
2
1.6
1.2
0.8
0.4
0
400
300
200
100
0
Jan-85
Jan-88
Jan-91
Jan-94
Jan-97
Jan-00

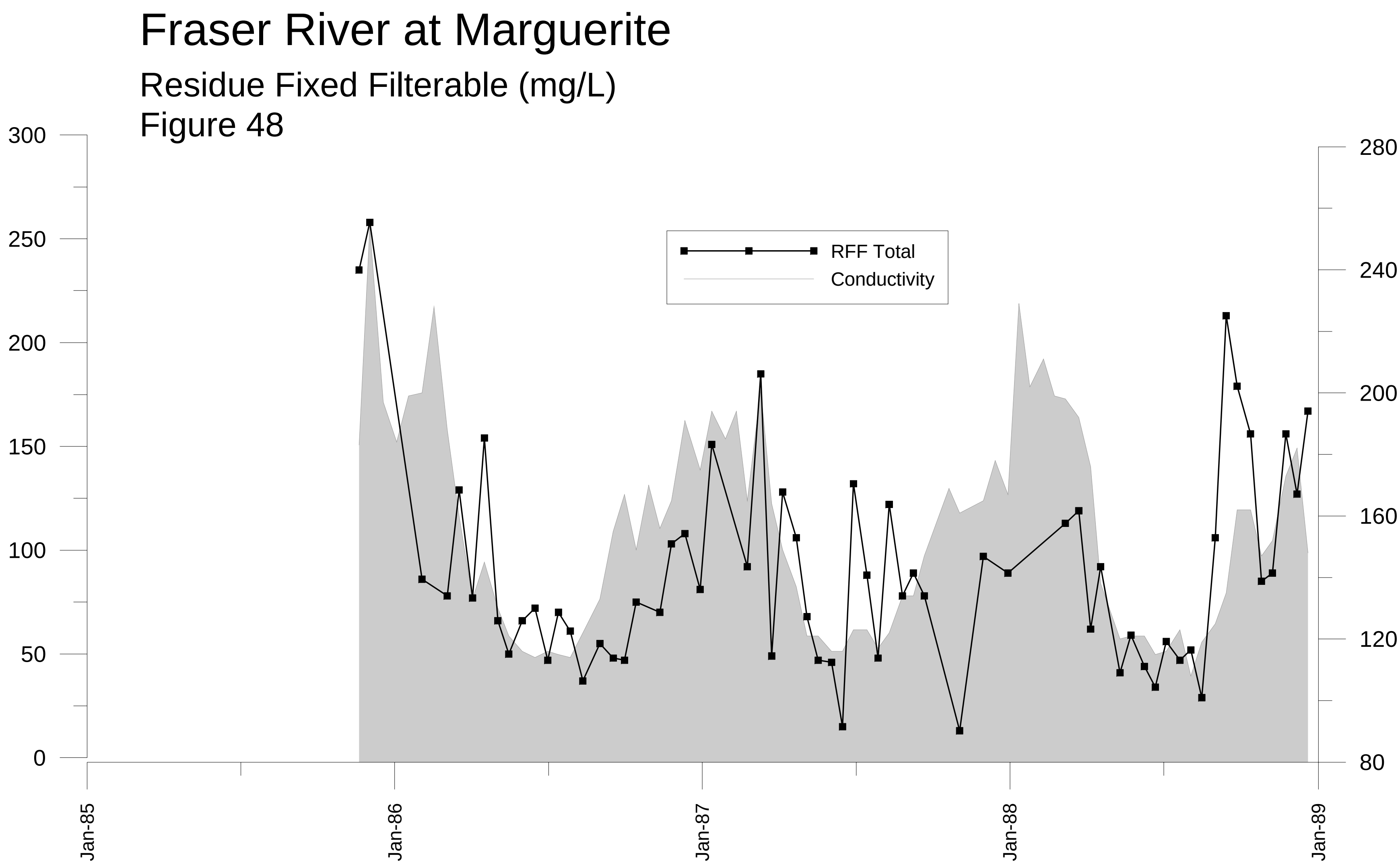

Fraser River at Marguerite
Phosphate Dissolved Ortho (mg/L)
Figure 45
Phosphate Dissolved Ortho
Turbidity (NTU)
0.052
0.048
400
300
200
100
0
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99



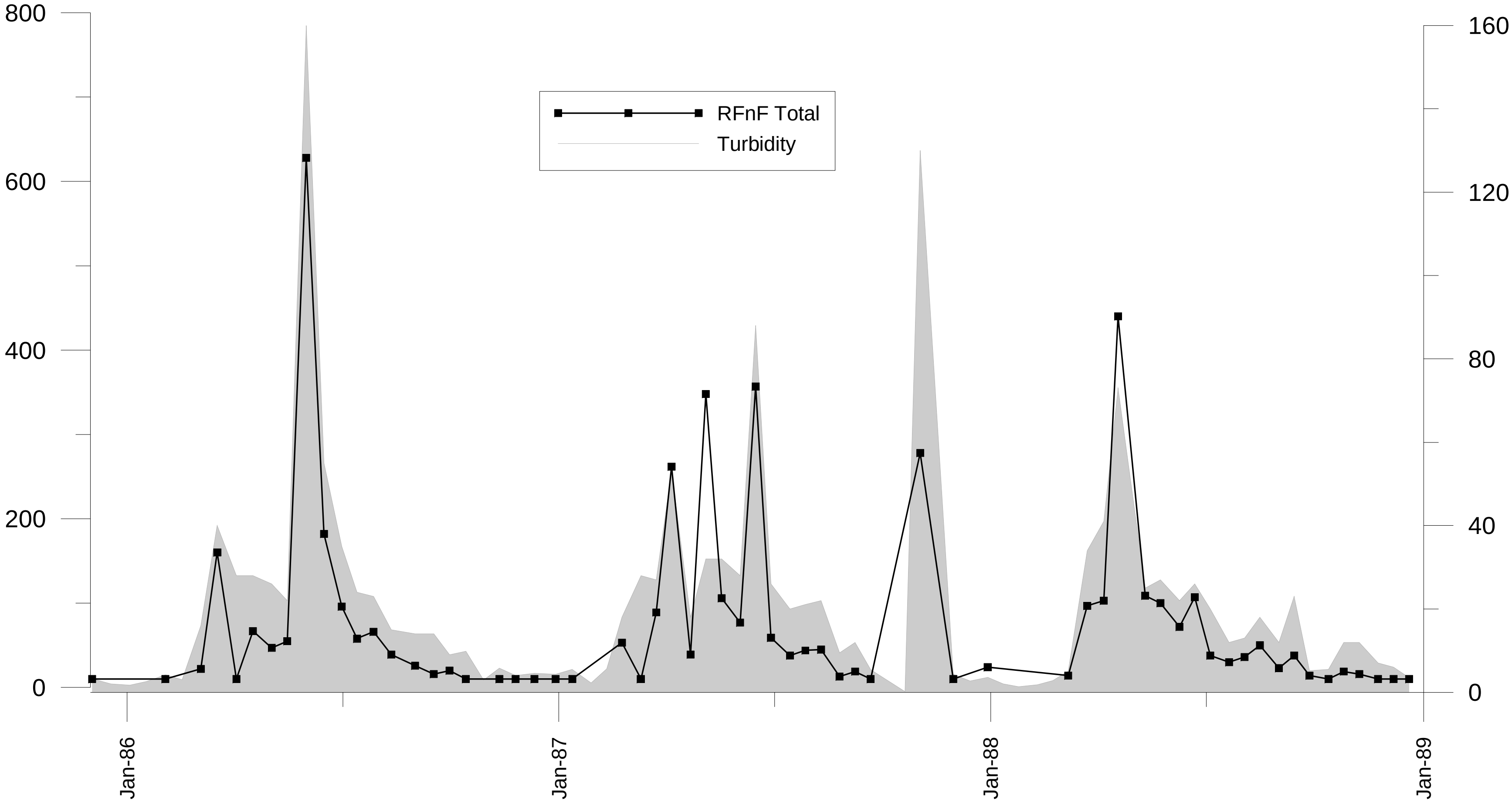
Fraser River at Marguerite
Rubidium Total (ug/L)
Figure 46
Rb Total
Turbidity (NTU)
0
2
4
6
8
0
50
100
150
200
250
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05

Fraser River at Marguerite
Residue Filterable (mg/L)
Figure 47

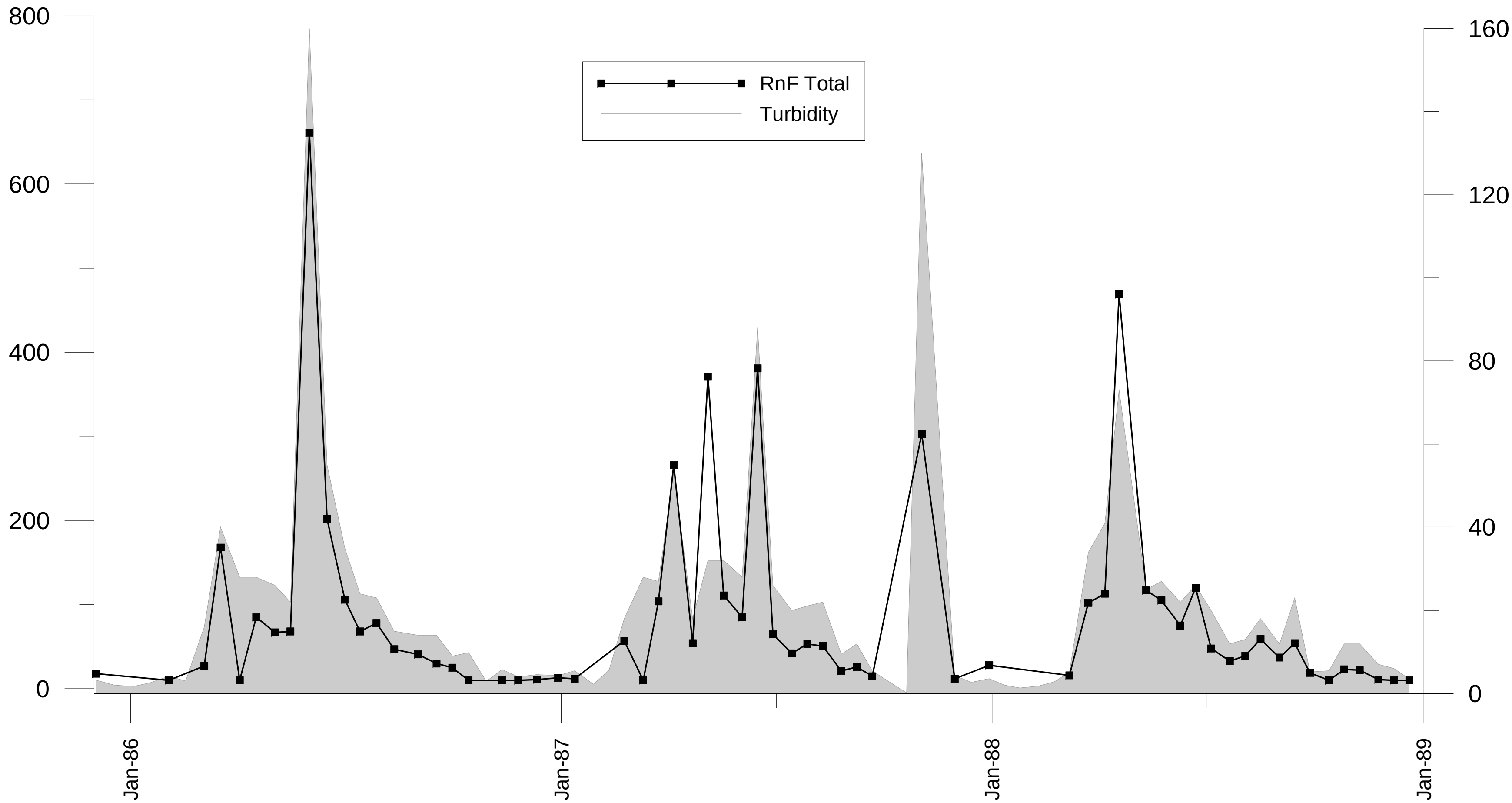



Fraser River at Marguerite
Residue Fixed Filterable (mg/L)
Figure 48
RFF Total
Conductivity
300
250
200
150
100
50
0
280
240
200
160
120
80
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89

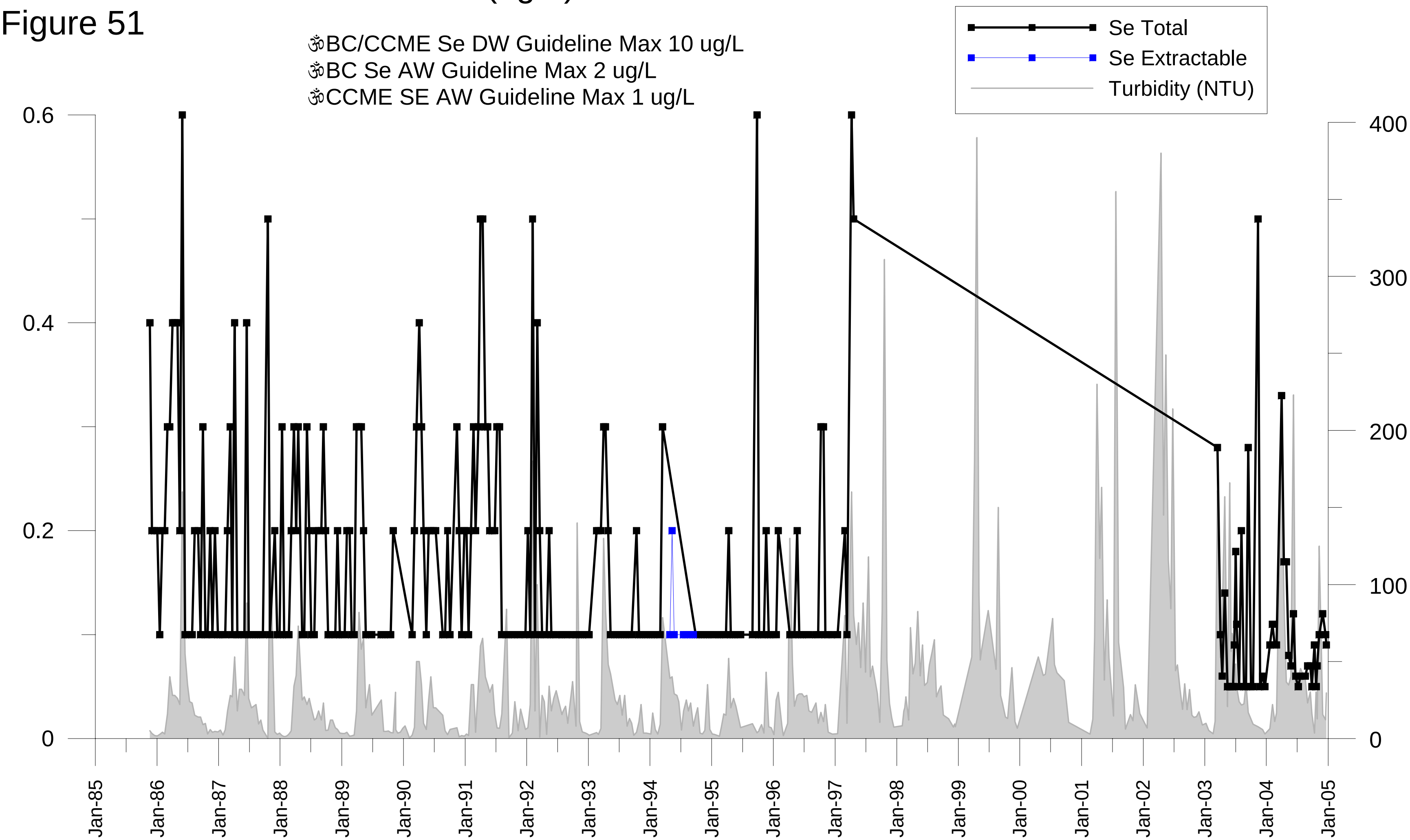
Fraser River at Marguerite
Residue Fixed non-Filterable (mg/L)
Figure 49



Fraser River at Marguerite
Residue non-filterable (mg/L)
Figure 50



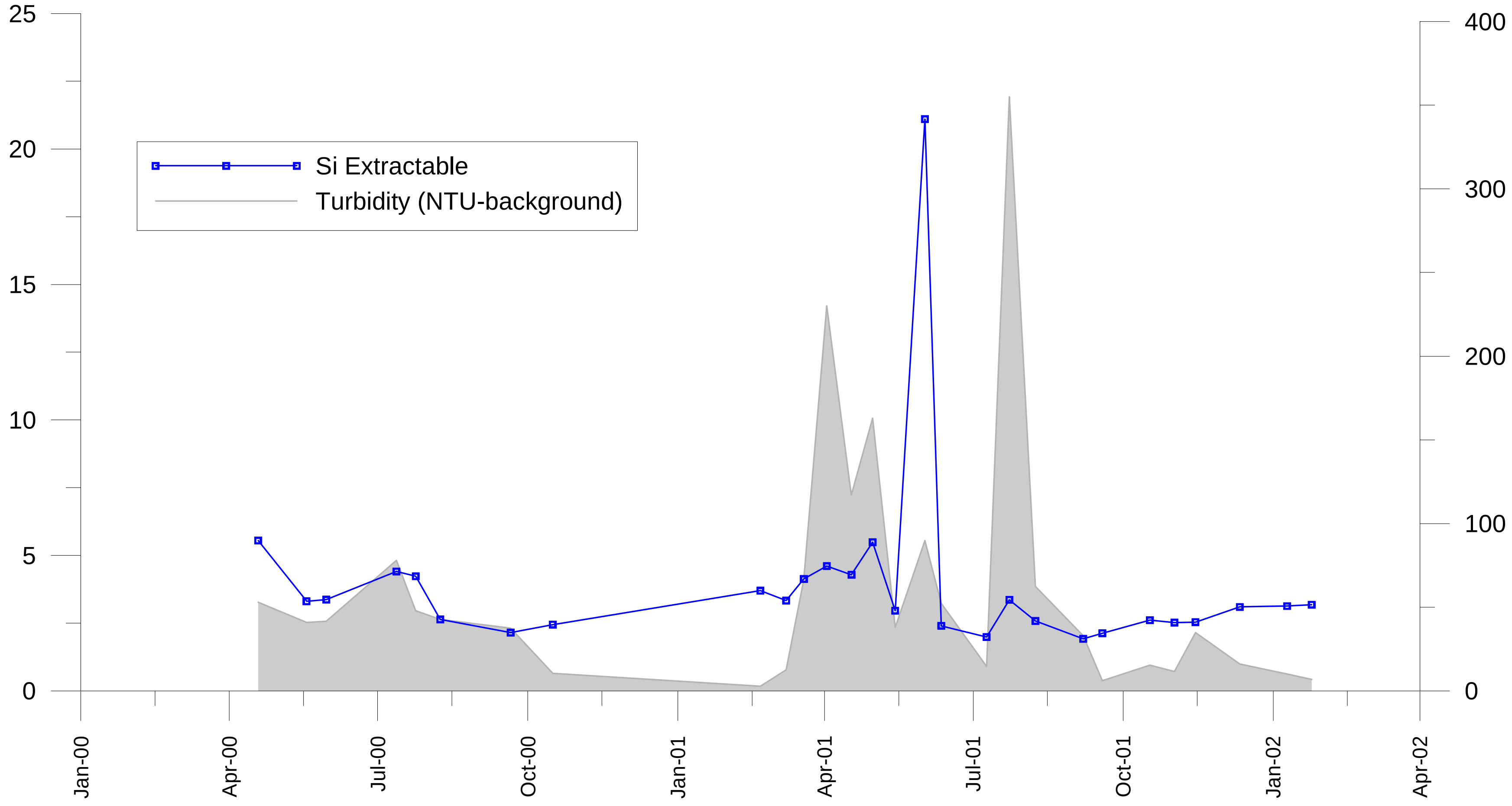
Fraser River at Marguerite
Selenium Total and Extractable (ug/L)
Figure 51

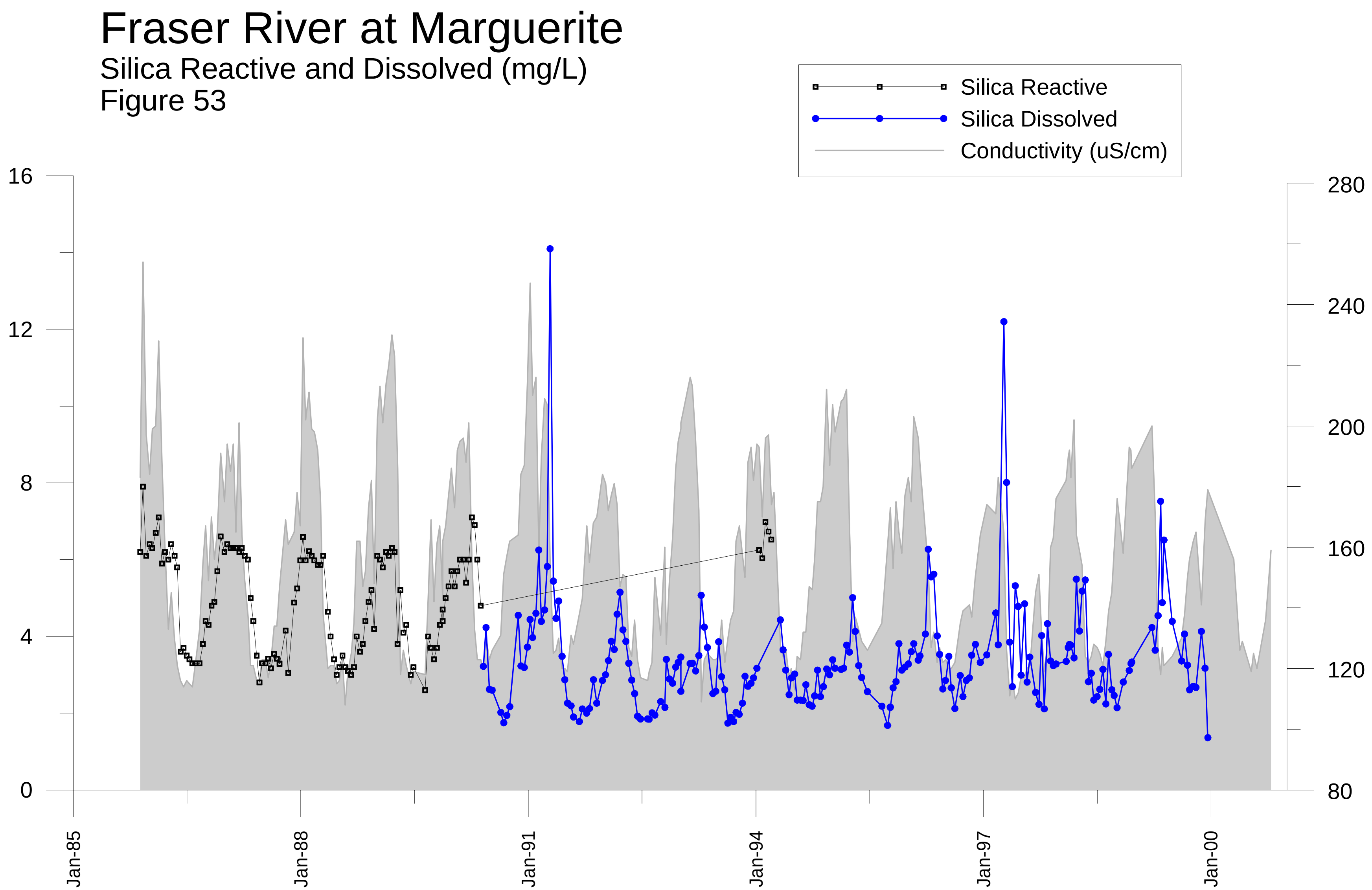


Fraser River at Marguerite

Silicon Extractable (mg/L)

Figure 52



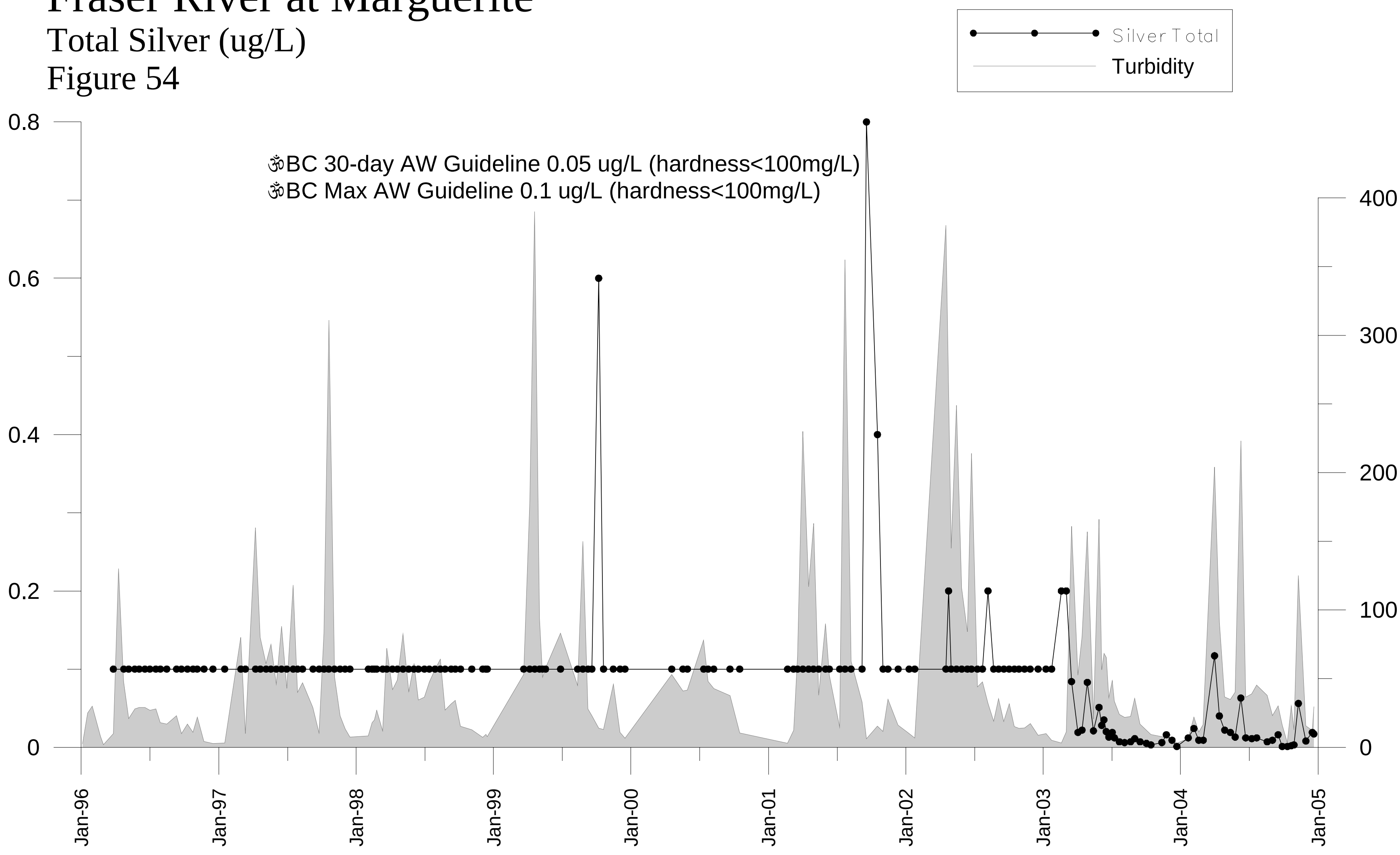


Fraser River at Marguerite
Silica Reactive and Dissolved (mg/L)
Figure 53
Silica Reactive
Silica Dissolved
Conductivity (uS/cm)
16
12
8
4
0
280
240
200
160
120
80
Jan-85
Jan-88
Jan-91
Jan-94
Jan-97
Jan-00

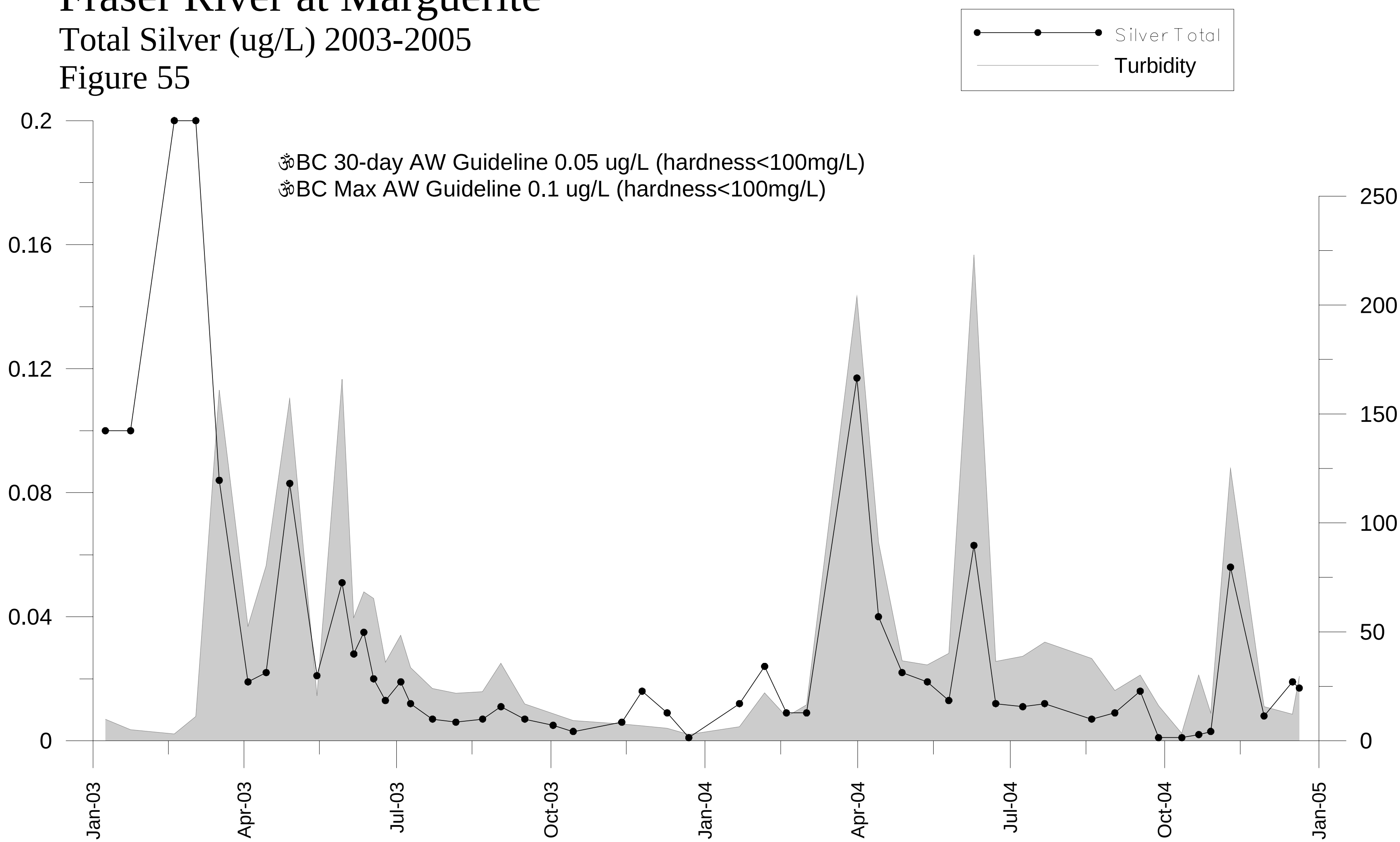
Fraser River at Marguerite

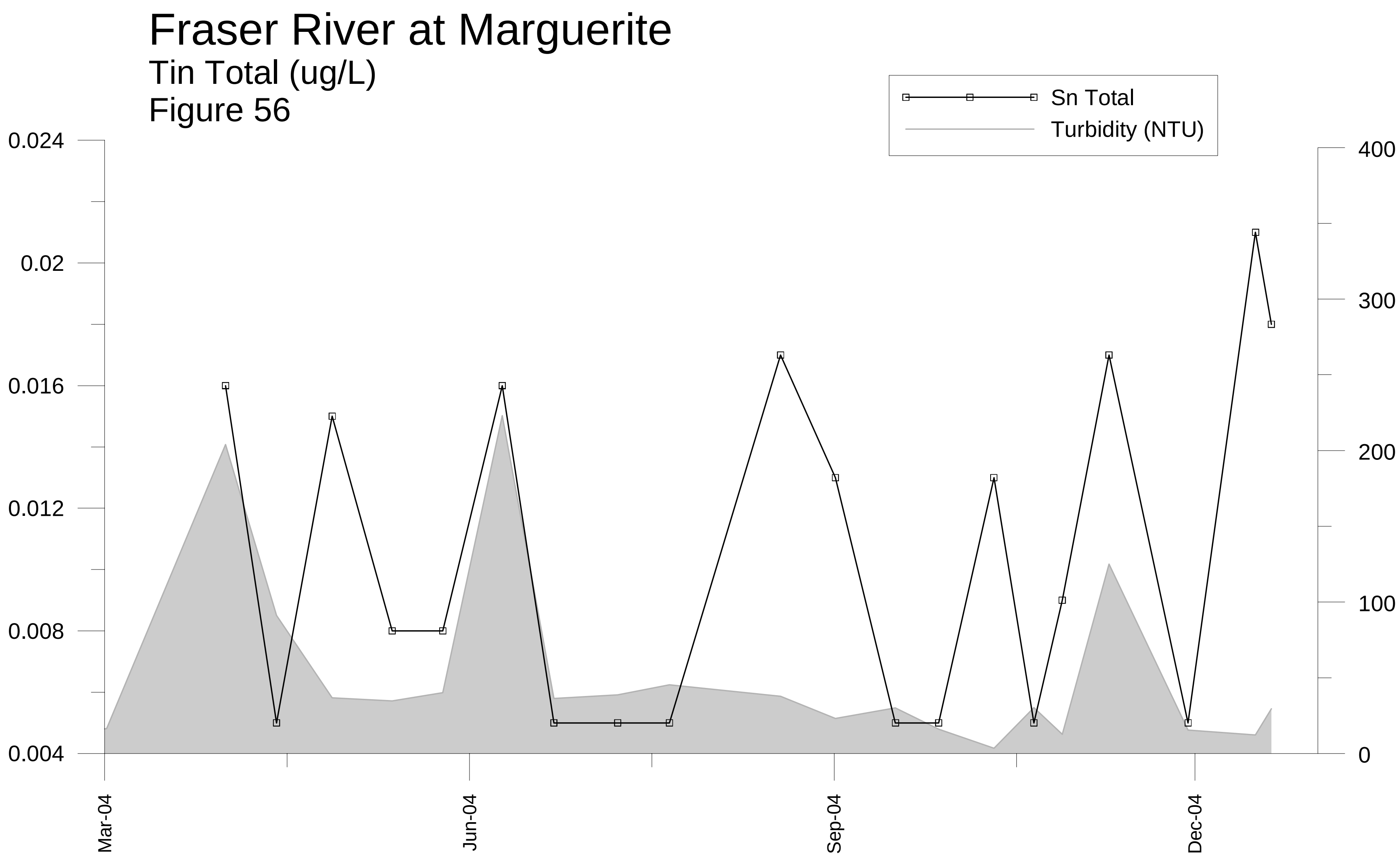
Total Silver (ug/L)

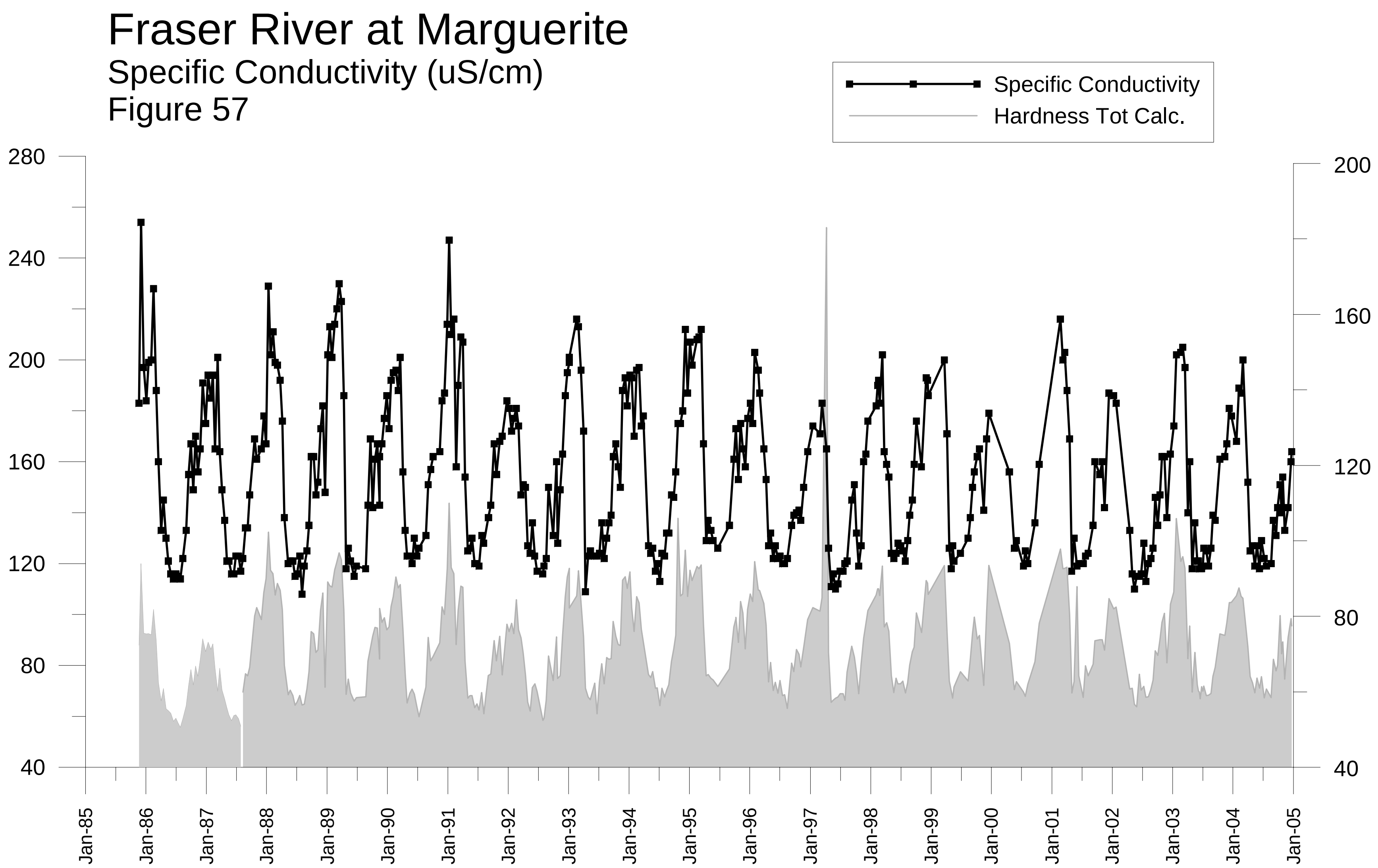
Figure 54

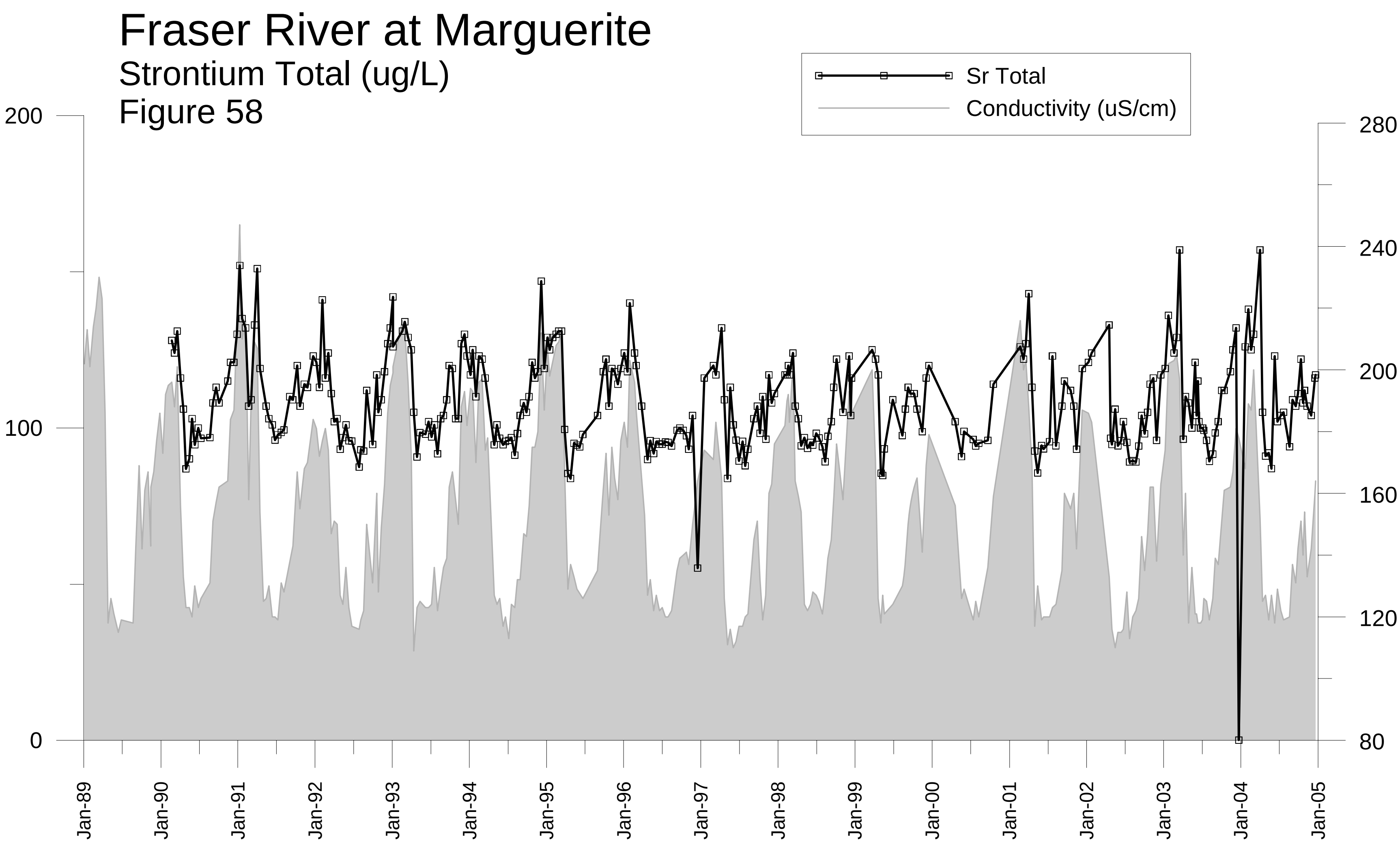


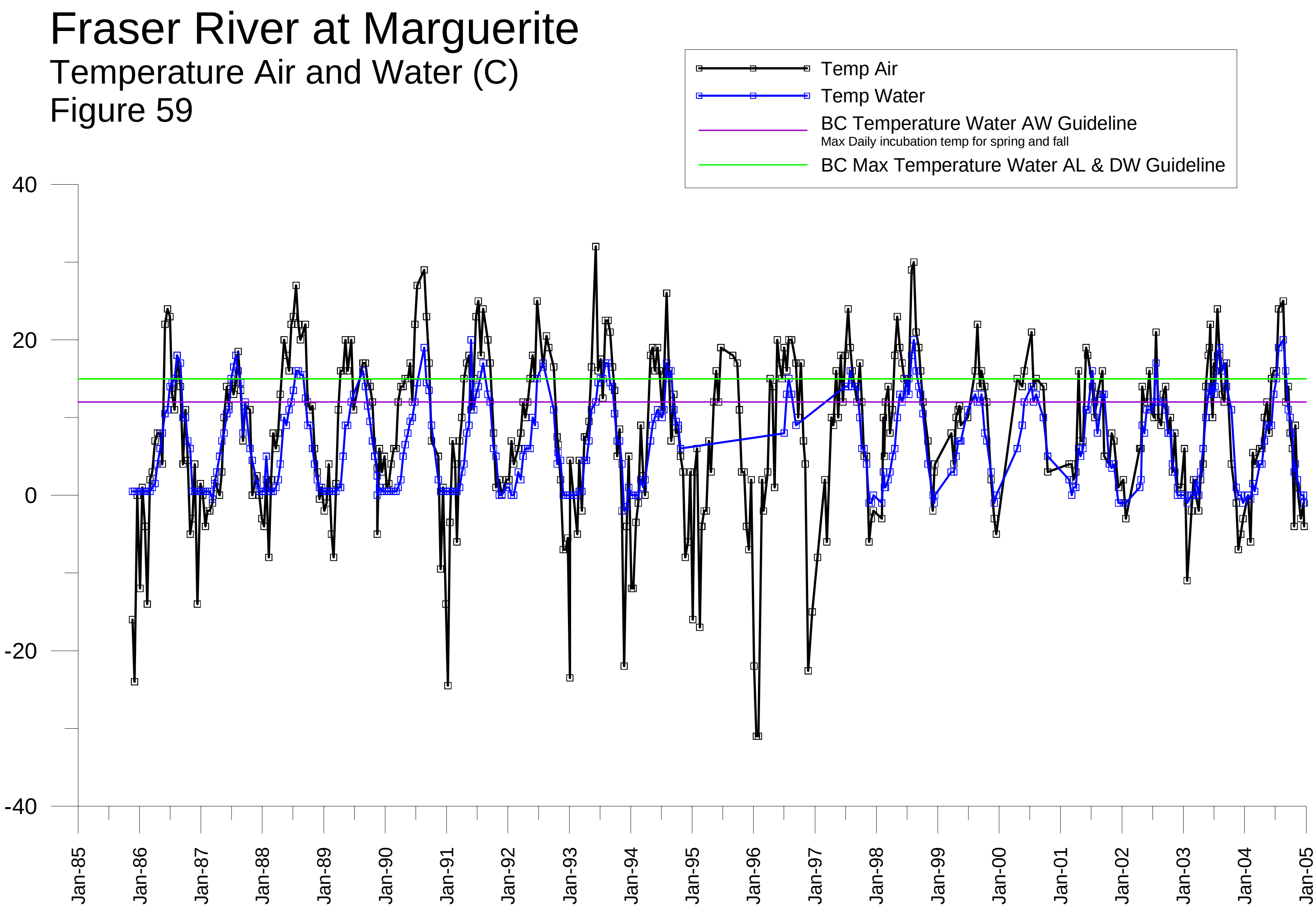
Fraser River at Marguerite
Total Silver (ug/L) 2003-2005
Figure 55

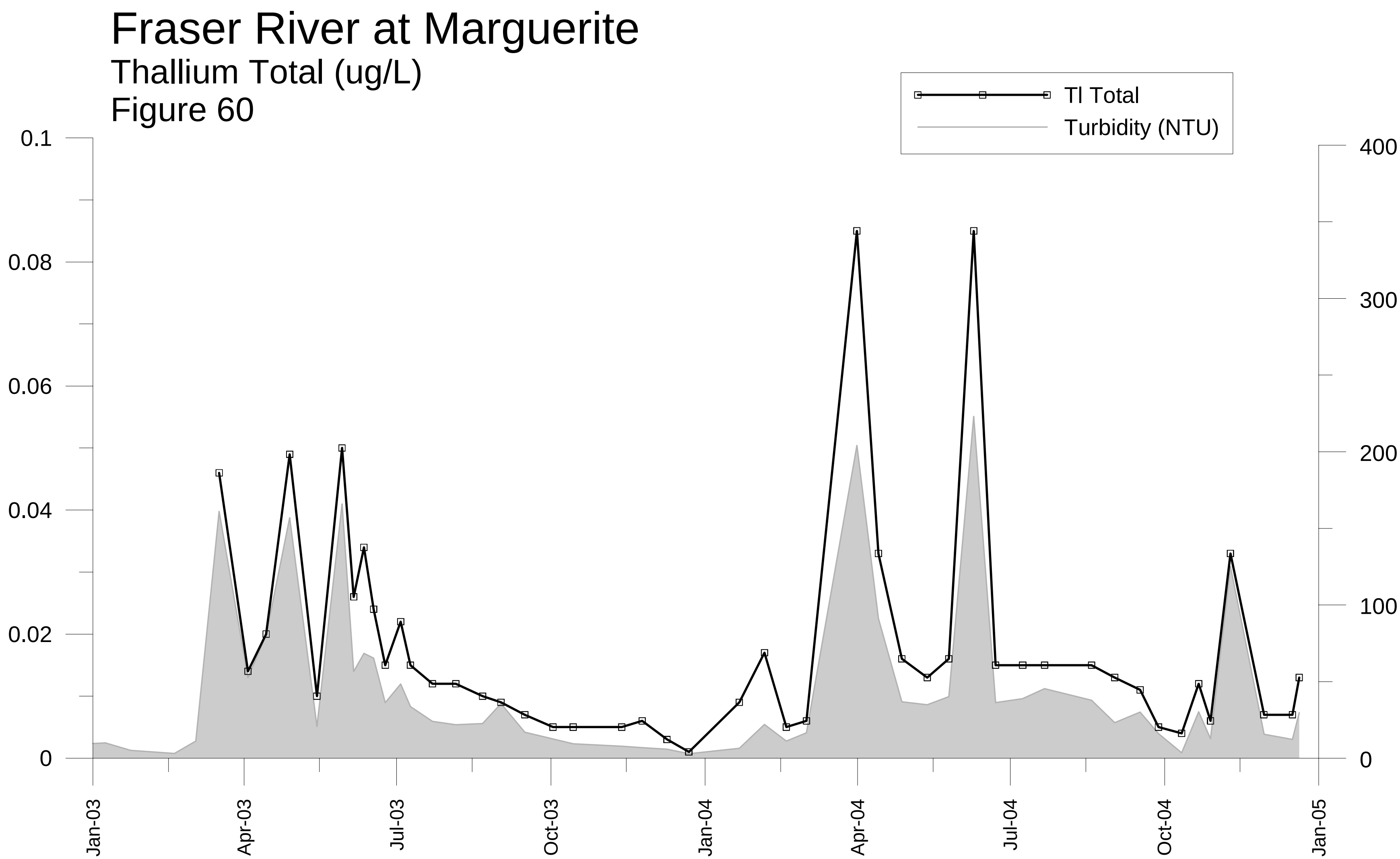



Fraser River at Marguerite
Tin Total (ug/L)
Figure 56
Sn Total
Turbidity (NTU)
0.024
0.02
0.016
0.012
0.008
0.004
400
300
200
100
0
Mar-04
Jun-04
Sep-04
Dec-04

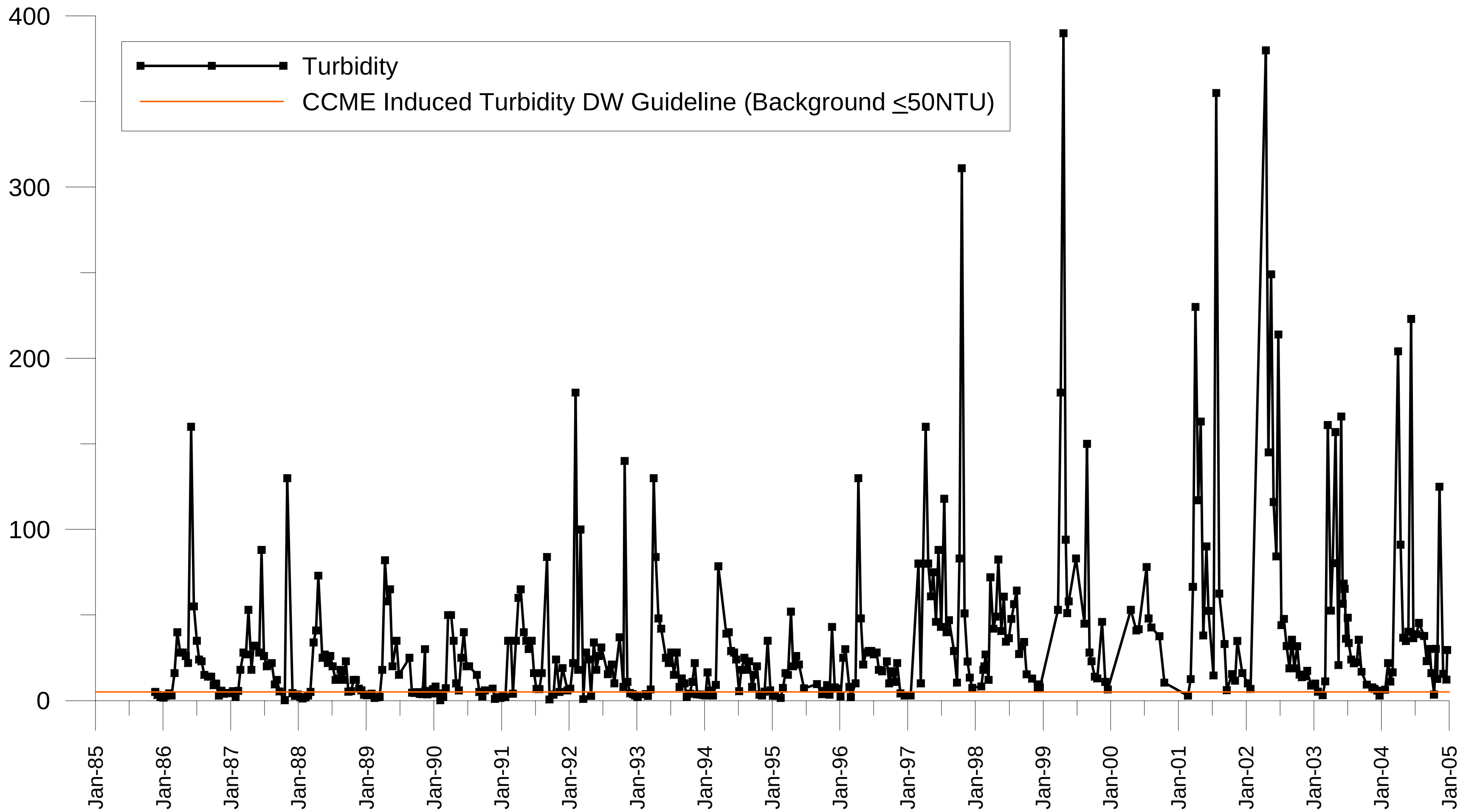

Fraser River at Marguerite
Specific Conductivity (uS/cm)
Figure 57
Specific Conductivity
Hardness Tot Calc.
280
240
200
160
120
80
40
200
160
120
80
40
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Strontium Total (ug/L)
Figure 58
Sr Total
Conductivity (uS/cm)
200
100
0
280
240
200
160
120
80
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

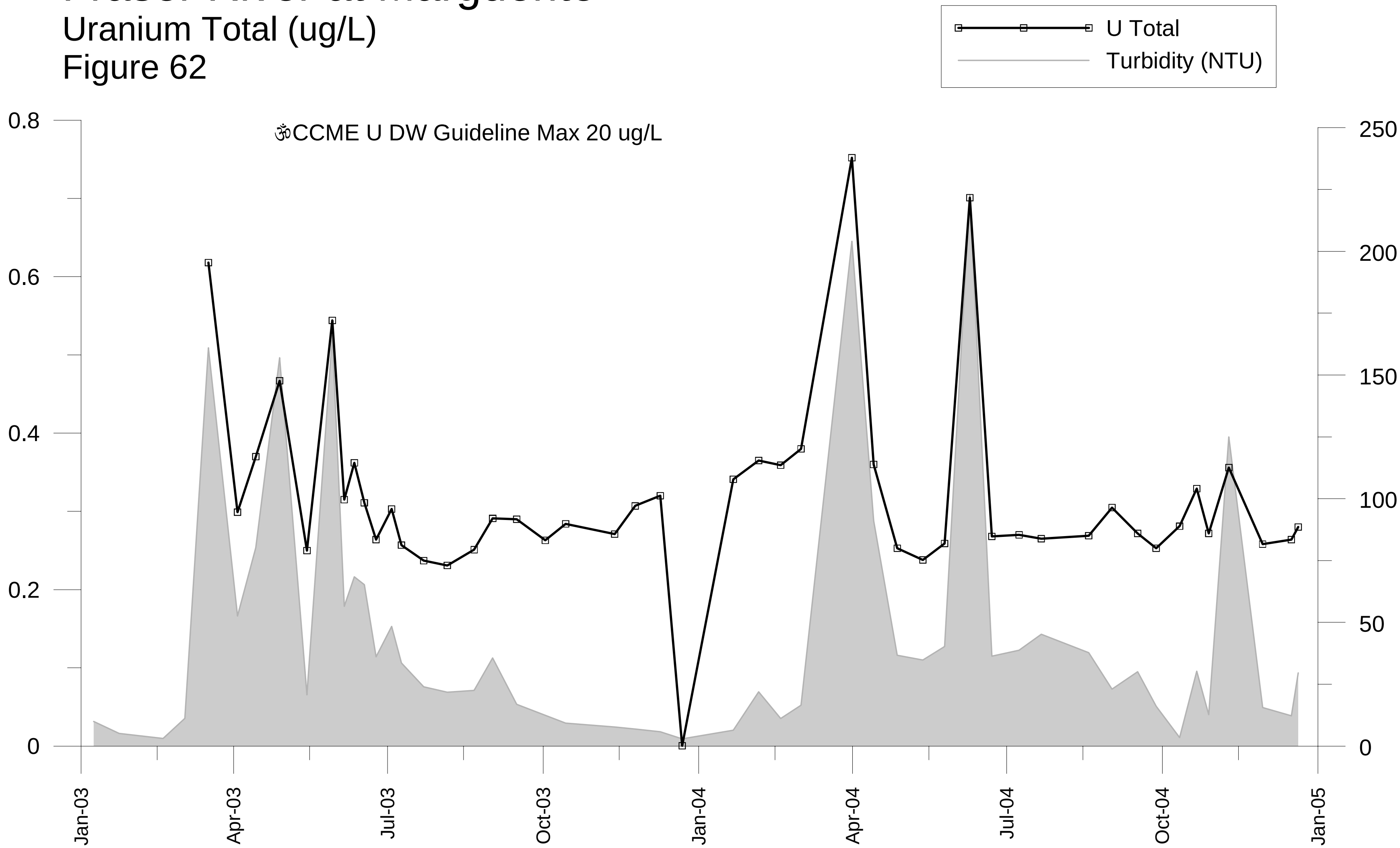

Fraser River at Marguerite
Temperature Air and Water (C)
Figure 59
Temp Air
Temp Water
BC Temperature Water AW Guideline
Max Daily incubation temp for spring and fall
BC Max Temperature Water AL & DW Guideline
40
20
0
-20
-40
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05

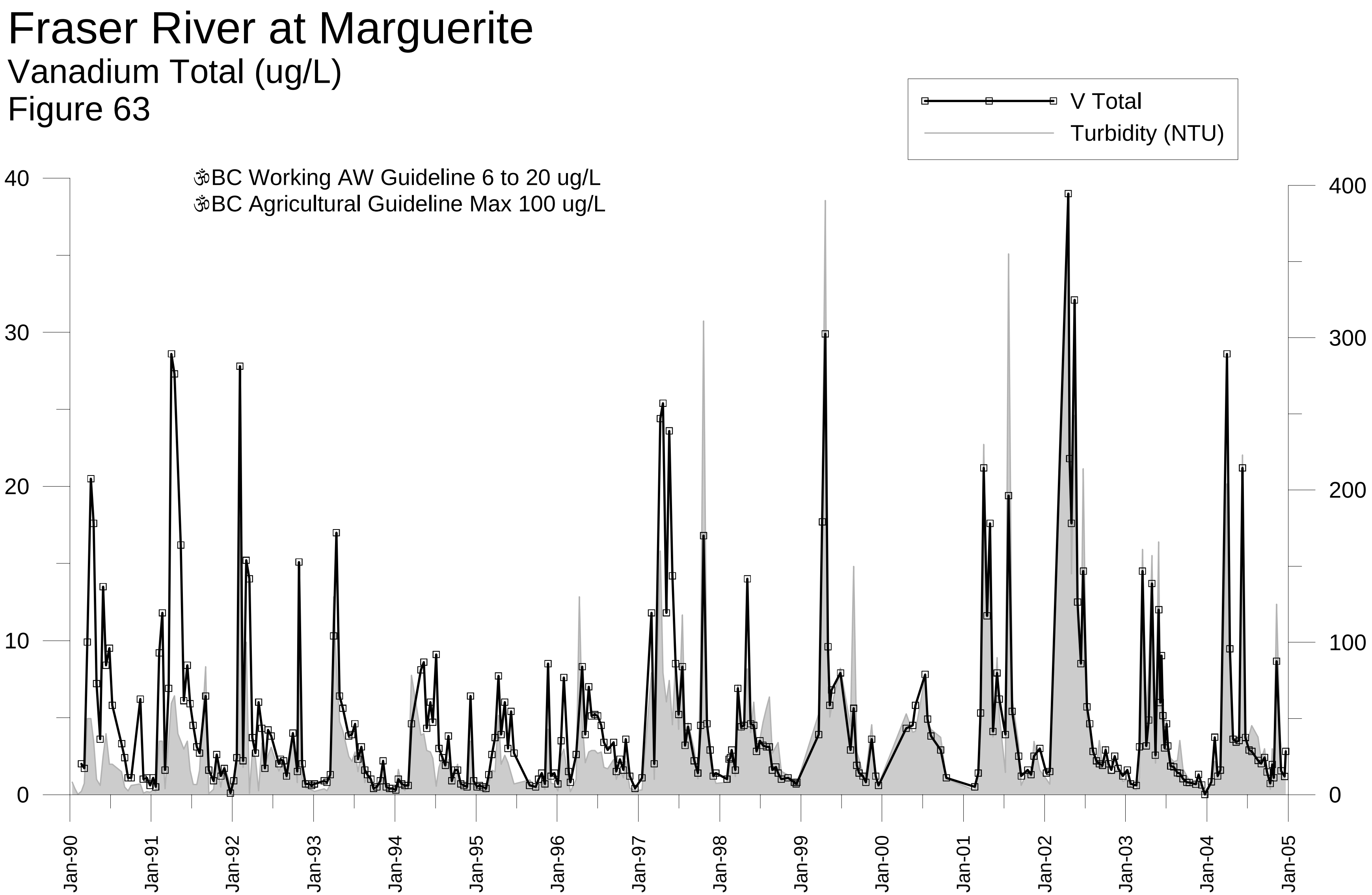

Fraser River at Marguerite
Thallium Total (ug/L)
Figure 60
Tl Total
Turbidity (NTU)
0.1
0.08
0.06
0.04
0.02
0
400
300
200
100
0
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05

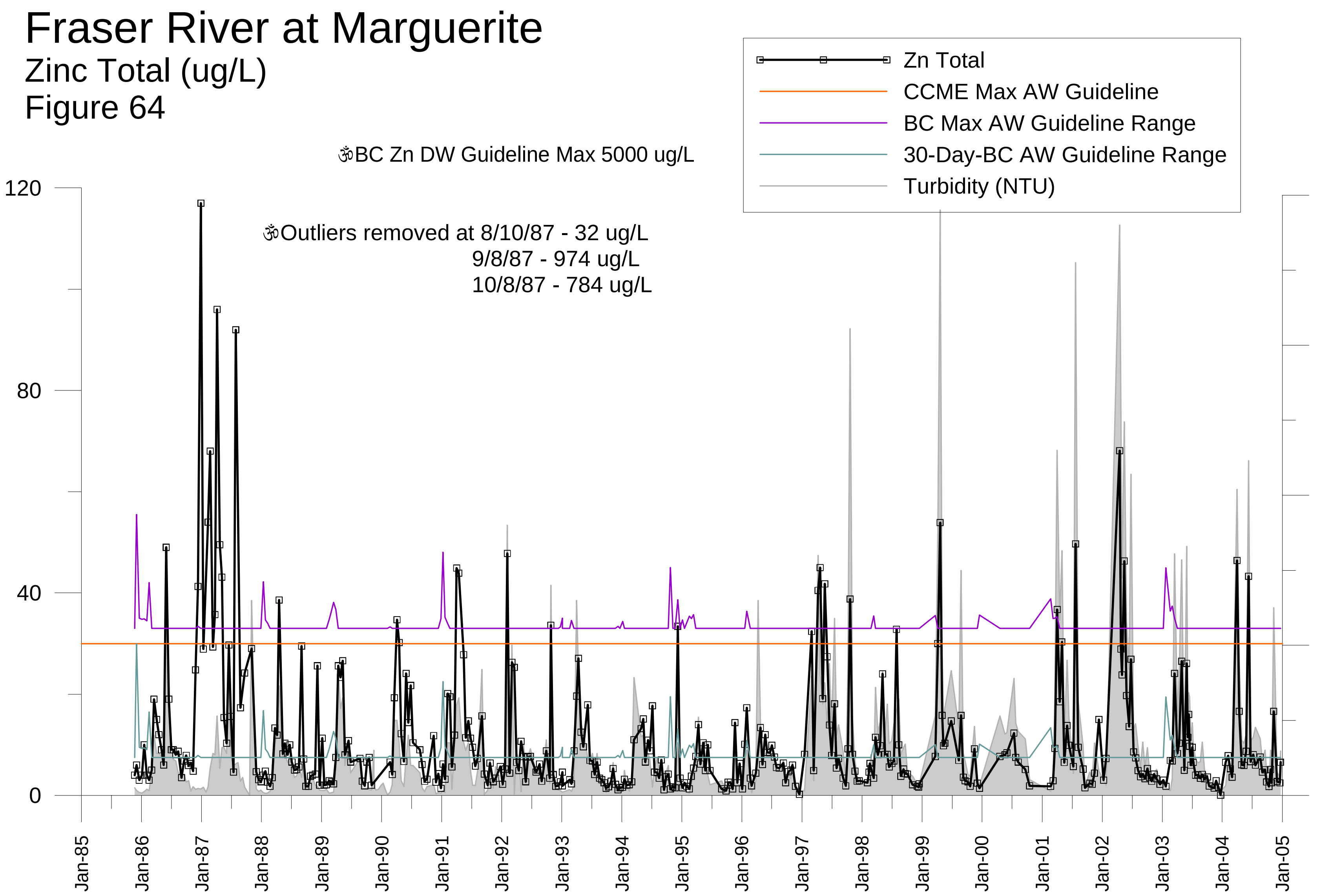
Fraser River at Marguerite
Turbidity (NTU)
Figure 61



Fraser River at Marguerite
Uranium Total (ug/L)
Figure 62




Fraser River at Marguerite
Vanadium Total (ug/L)
Figure 63
V Total
Turbidity (NTU)
ॐBC Working AW Guideline 6 to 20 ug/L
ॐBC Agricultural Guideline Max 100 ug/L
40
30
20
10
0
400
300
200
100
0
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05


Fraser River at Marguerite
Zinc Total (ug/L)
Figure 64
BC Zn DW Guideline Max 5000 ug/L
Outliers removed at 8/10/87 - 32 ug/L
9/8/87 - 974 ug/L
10/8/87 - 784 ug/L
Zn Total
CCME Max AW Guideline
BC Max AW Guideline Range
30-Day-BC AW Guideline Range
Turbidity (NTU)
120
80
40
0
400
300
200
100
0
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05