3

STATE OF ALASKA

FRANK H. MURKOWSKI, GOVERNOR

1300 COLLEGE ROAD
FAIRBANKS, ALASKA 99709-1551
PHONE: (907) 459-7289
FAX: (907) 456-3091

DEPARTMENT OF NATURAL RESOURCES

OFFICE OF HABITAT MANAGEMENT & PERMITTING

May 27, 2005

Mr. Jim Kulas, Environmental Manager
Cominco Alaska, Inc.
P.O. Box 1230
Kotzebue, AK 99752

Dear Mr. Kulas:

RE: Biomonitoring Report, Red Dog Mine

Enclosed are three copies of our report titled "Aquatic Biomonitoring at Red Dog Mine, 2004 National Pollution Discharge Elimination System Permit No. AK-003865-2." Our report contains results of biomonitoring studies conducted during summer 2004. The report is being submitted to satisfy the requirements of the Environmental Protection Agency's NPDES permit and the Alaska Department of Environmental Conservation's Certificate of Reasonable Assurance. If there are any questions regarding the report, please contact either Al Ott or me at 907-459-7289.

Sincerely,

for

Robert F. McLean, Habitat Biologist IV
Office of Habitat Management and Permitting
Department of Natural Resources

Enclosure

"Develop, Conserve, and Enhance Natural Resources for Present and Future Alaskans."

cc: w/enclosure

Rose Barr, NANA, Anchorage
Keith Cohon, EPA, Seattle
Walter Sampson, NANA, Kotzebue
Ed Fogels, ADNR, Anchorage
Larry Hartig, Hartig, Rhodes, Anchorage
Cam Leonard, ADL, Fairbanks
Steve McGroarty, ADNR, Fairbanks
Victor Ross, ACOE, Anchorage
Jim Vohden, ADNR, Fairbanks

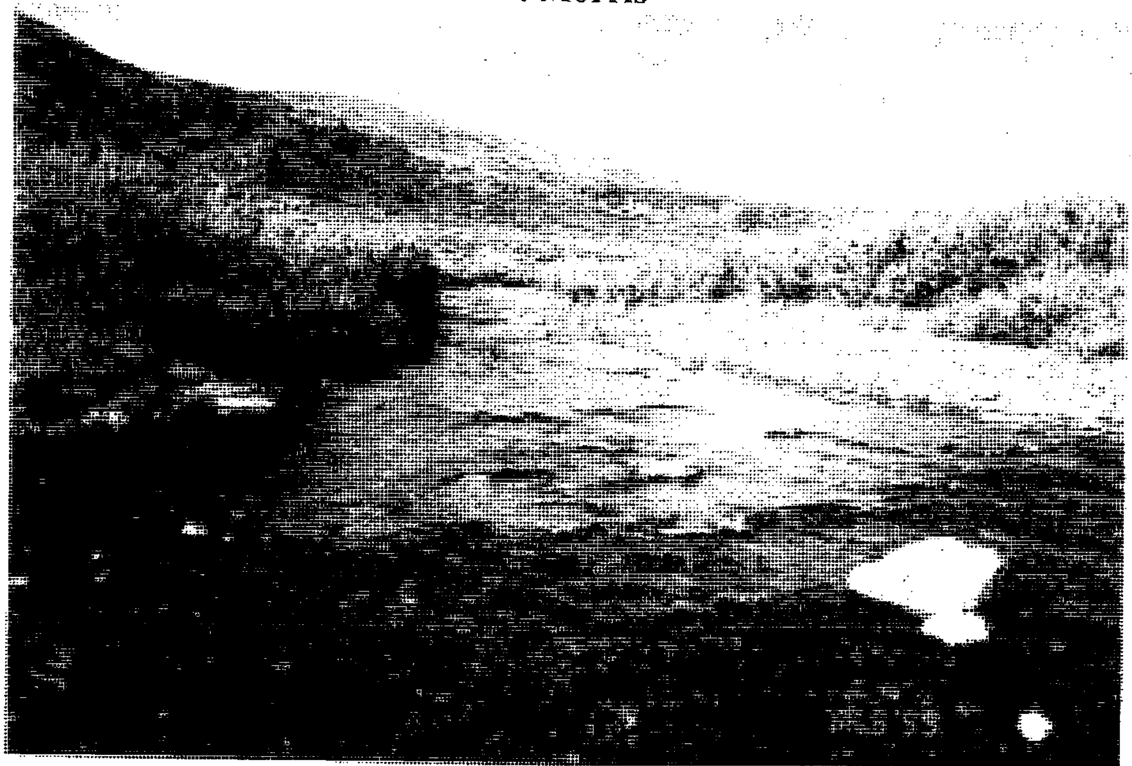
Eva Chun, EPA, Seattle
Phil Driver, Anchorage
Jim Dau, ADF&G, Kotzebue
Jeanne Hanson, NMFS, Anchorage
Colleen Koenig, Kivalina IRA Council
Pete McGee, ADEC, Fairbanks
NPS, Kotzebue
Enoch Shiedt, Maniilaq, Kotzebue
John Wood, AIDEA, Anchorage

RFM/ago

Technical Report No. 05-03

Aquatic Biomonitoring at Red Dog Mine, 2004
National Pollution Discharge Elimination System Permit No. AK-003865-2

by Alvin G. Ott and William A. Morris



Mainstem Red Dog Creek, Station 151
Photograph by Al Townsend 1999

May 2005

Alaska Department of Natural Resources
Office of Habitat Management and Permitting

The Alaska Department of Natural Resources administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to DNR, 1300 College Road, Fairbanks, Alaska 99701; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203; or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-269-8549 or (TDD) 907-269-8411.

Aquatic Biomonitoring at Red Dog Mine, 2004
National Pollution Discharge Elimination System
Permit No. AK-003865-2

Technical Report No. 05-03

By

Alvin G. Ott and William A. Morris

Kerry M. Howard
Executive Director
Office of Habitat Management and Permitting
Alaska Department of Natural Resources

Table of Contents

Table of Contents i
List of Tables iv
List of Figures v
Acknowledgements xii
Executive Summary xiii
Station 9, Ikalukrok Creek upstream of Mainstem Red Dog Creek xiii
Station 8, Ikalukrok Creek downstream of Mainstem Red Dog Creek xiii
Ikalukrok Creek upstream of Dudd Creek xiv
Station 7, Ikalukrok Creek downstream of Dudd Creek xiv
Station 10, Mainstem Red Dog Creek xiv
Station 20, Middle Fork Red Dog Creek xv
Station 12, North Fork Red Dog Creek xv
Station 140, Middle Fork Red Dog Creek xv
Wulik River, Metals Concentrations in Dolly Varden Tissues xv
Fish Resources in Wulik River drainage xvi
Dolly Varden Adults xvi
Chum Salmon xvi
Dolly Varden Juveniles xvi
Arctic Grayling xvi
Slimy Sculpin xvii
Introduction 1
Structure of Report 3
Location of Sample Sites 3
Description of Streams 5
Methods Used for NPDES Biomonitoring 7
Results and Discussion 8
Ikalukrok Creek at Station 9 8
Site Description 8
Water Quality 8
Invertebrate Community (Abundance, Density, and Taxa Richness) 11
Community Structure 13
Periphyton Standing Crop 13
Summary of Biomonitoring, Station 9, 1999-2004 14
Ikalukrok Creek at Station 8 15
Site Description 15
Water Quality 15
Invertebrate Community (Abundance, Density, and Taxa Richness) 16
Community Structure 17
Periphyton Standing Crop 18
Summary of Biomonitoring at Station 8, 1999-2004 19

Table of Contents, continued.

Ikalukrok Creek Upstream of Dudd Creek 20
Site Description 20
Water Quality 20
Invertebrate Community (Abundance, Density, and Taxa Richness) 23
Community Structure 25
Periphyton Standing Crop 25
Summary of Biomonitoring, Ikalukrok Creek Upstream of Dudd Creek 26
Ikalukrok Creek at Station 7 27
Site Description 27
Water Quality 27
Invertebrate Community (Abundance, Density, and Taxa Richness) 31
Community Structure 32
Periphyton Standing Crop 33
Summary of Biomonitoring, Ikalukrok Creek at Station 7, 1999-2004. 34
Mainstem Red Dog Creek at Station 10 35
Site Description 35
Water Quality 35
Invertebrate Community (Abundance, Density, and Taxa Richness) 39
Community Structure 41
Periphyton Standing Crop 41
Summary of Biomonitoring, Mainstem Red Dog Creek at Station 10 42
Middle Fork Red Dog Creek at Station 20 43
Site Description 43
Water Quality 44
Invertebrate Community (Abundance, Density, and Taxa Richness) 47
Community Structure 48
Periphyton Standing Crop 49
Summary of Biomonitoring, Middle Fork Red Dog Creek at Station 20 50
North Fork Red Dog Creek at Station 12 51
Site Description 51
Water Quality 51
Invertebrate Community (Abundance, Density, and Taxa Richness) 54
Community Structure 56
Periphyton Standing Crop 56
Summary of Biomonitoring, North Fork Red Dog Creek at Station 12 57
Middle Fork Red Dog Creek at Station 140 58
Site Description 58
Metals Concentrations in Adult Dolly Varden, Wulik River 60
Aluminum 64
Cadmium 64
Copper 65
Lead 66

Table of Contents, concluded.

Selenium 66
Zinc 67
Mercury 68
Distribution of Fish in the Wulik River Drainage 69
Overwintering Dolly Varden 69
Chum Salmon Surveys 70
Juvenile Dolly Varden 72
Arctic Grayling 77
Slimy Sculpin 83
Literature Cited 84
Appendix 1. A Summary of Mine Development and Operations 87
Appendix 2. Dolly Varden Aerial Surveys 96
Appendix 3. Adult Dolly Varden and Chum Salmon Survey Areas 97
Appendix 4. Juvenile Dolly Varden Sampling Sites 98
Appendix 5. Juvenile Dolly Varden Catches at NPDES Sample Sites 99
Appendix 6. Length-Frequency Distribution of Juvenile Dolly Varden 100
Appendix 7. Length-Frequency Distribution of Arctic Grayling 103
Appendix 8. Arctic Grayling, Mainstem Red Dog Creek 105

List of Tables

1. Location of sample sites for NPDES biomonitoring. 3

2. Locations and components of studies required by NPDES Permit.............................. 5

3. Locations and components of supplemental biomonitoring studies in 2004................ 6

4. Summary of biomonitoring, Ikalukrok Creek at Station 9, 1999 to 2004. 14

5. Summary of biomonitoring, Ikalukrok Creek at Station 8, 1999 to 2004. 19

6. Summary of biomonitoring, Ikalukrok Creek upstream of Dudd Creek 26

7. Summary of biomonitoring, Ikalukrok Creek at Station 7, 1999 to 2004. 34

8. Summary of biomonitoring, Mainstem Red Dog Creek at Station 10......................... 42

9. Summary of biomonitoring, Middle Fork Red Dog Creek at Station 20..................... 50

10. Summary of biomonitoring, North Fork Red Dog Creek at Station 12..................... 57

11. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek. 71

12. Locations of juvenile Dolly Varden fish trap sites. 72

13. Arctic grayling spawning in Mainstem Red Dog Creek, 2001-2004......................... 79

14. Relative number of age 0 Arctic grayling in North Fork Red Dog Creek................ 81

List of Figures

1. Location of the Red Dog Mine in northwestern Alaska 2
2. Location of sites in the Red Dog Creek drainage for aquatic sampling. 4
3. Ikalukrok Creek upstream of Mainstem Red Dog Creek, Station 9. 8
4. Median, maximum, and minimum concentrations of Al at Station 9. 9
5. Median, maximum, and minimum concentrations of Cd at Station 9. 9
6. Median, maximum, and minimum concentrations of Fe at Station 9. 10
7. Median, maximum, and minimum concentrations of Ni at Station 9. 10
8. Median, maximum, and minimum concentrations of Pb at Station 9. 10
9. Median, maximum, and minimum concentrations of Se at Station 9. 11
10. Median, maximum, and minimum concentrations of Zn at Station 9. 11
11. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 9. 12
12. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 9 12
13. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 9. 12
14. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 9 13
15. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 9. 13
16. Ikalukrok Creek downstream of Mainstem Red Dog Creek, Station 8. 15
17. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 8. 16
18. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 8 16
19. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 8. 17

List of Figures, continued.

20. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 8. 17

21. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 8. 18

22. Ikalukrok Creek upstream of Dudd Creek. 20

23. Median, maximum, and minimum concentrations of Al at Station 73. 21

24. Median, maximum, and minimum concentrations of Cd at Station 73. 21

25. Median, maximum, and minimum concentrations of Fe at Station 73. 22

26. Median, maximum, and minimum concentrations of Ni at Station 73. 22

27. Median, maximum, and minimum concentrations of Pb at Station 73. 22

28. Median, maximum, and minimum concentrations of Se at Station 73. 23

29. Median, maximum, and minimum concentrations of Zn at Station 73. 23

30. Abundance of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek. 24

31. Density of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek. 24

32. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek. 24

33. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek upstream of Dudd Creek. 25

34. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek upstream of Dudd Creek. 26

35. Ikalukrok Creek downstream of Dudd Creek, Station 7. 27

36. TDS concentrations in Ikalukrok Creek at Station 160. 28

37. Median, maximum, and minimum concentrations of Al at Station 160. 29

List of Figures, continued.

38. Median, maximum, and minimum concentrations of Cd at Station 160. 29

39. Median, maximum, and minimum concentrations of Fe at Station 160. 29

40. Median, maximum, and minimum concentrations of Ni at Station 160. 30

41. Median, maximum, and minimum concentrations of Pb at Station 160 30

42. Median, maximum, and minimum concentrations of Se at Station 160. 30

43. Median, maximum, and minimum concentrations of Zn at Station 160. 31

44. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 7......... 31

45. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 7.............. 32

46. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 7..... 32

47. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 7. 33

48. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 7. 33

49. Mainstem Red Dog Creek, Station 10 35

50. Seasonal variation in TDS concentrations in Mainstem Red Dog Creek 36

51. Median, maximum, and minimum pH values in Mainstem Red Dog Creek............ 36

52. Median, maximum, and minimum concentrations of Al at Station 10...................... 37

53. Median, maximum, and minimum concentrations of Cd at Station 10. 37

54. Median, maximum, and minimum concentrations of Fe at Station 10...................... 38

55. Median, maximum, and minimum concentrations of Ni at Station 10...................... 38

56. Median, maximum, and minimum concentrations of Pb at Station 10...................... 38

57. Median, maximum, and minimum concentrations of Se at Station 10...................... 39

List of Figures, continued.

58. Median, maximum, and minimum concentrations of Zn at Station 10. 39

59. Abundance of aquatic invertebrates collected in Mainstem Red Dog Creek 40

60. Density of aquatic invertebrates collected in Mainstem Red Dog Creek 40

61. Taxa richness of aquatic invertebrates collected in Mainstem Red Dog Creek 40

62. Proportions of EPT and Chironomidae larvae in invertebrate samples in Mainstem Red Dog Creek at Station 10. 41

63. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Mainstem Red Dog Creek at Station 10. 41

64. Middle Fork Red Dog Creek, Station 20 43

65. Median, maximum, and minimum pH values in Middle Fork Red Dog Creek at Station 20. 44

66. Median, maximum, and minimum concentrations of Al at Station 20. 45

67. Median, maximum, and minimum concentrations of Cd at Station 20. 45

68. Median, maximum, and minimum concentrations of Fe at Station 20. 45

69. Median, maximum, and minimum concentrations of Ni at Station 20. 46

70. Median, maximum, and minimum concentrations of Pb at Station 20. 46

71. Median, maximum, and minimum concentrations of Se at Station 20. 46

72. Median, maximum, and minimum concentrations of Zn at Station 20. 47

73. Abundance of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20. 47

74. Density of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20. 48

75. Taxa richness of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20. 48

List of Figures, continued.

76. Proportions of EPT and Chironomidae larvae in invertebrate samples in Middle Fork Red Dog Creek at Station 20. 49

77. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Middle Fork Red Dog Creek at Station 20. 49

78. North Fork Red Dog Creek, Station 12 51

79. Median, maximum, and minimum concentrations of Al at Station 12. 52

80. Median, maximum, and minimum concentrations of Cd at Station 12. 52

81. Median, maximum, and minimum concentrations of Fe at Station 12. 53

82. Median, maximum, and minimum concentrations of Ni at Station 12. 53

83. Median, maximum, and minimum concentrations of Pb at Station 12 53

84. Median, maximum, and minimum concentrations of Se at Station 12. 54

85. Median, maximum, and minimum concentrations of Zn at Station 12 54

86. Abundance of aquatic invertebrates collected in North Fork Red Dog Creek. 55

87. Density of aquatic invertebrates collected in North Fork Red Dog Creek. 55

88. Taxa richness of aquatic invertebrates collected in North Fork Red Dog Creek 55

89. Proportions of EPT and Chironomidae larvae in invertebrate samples in North Fork Red Dog Creek at Station 12. 56

90. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in North Fork Red Dog Creek at Station 12 56

91. Median, maximum, and minimum pH values in Middle Fork Red Dog Creek 58

92. Median, maximum, and minimum concentrations of Cd at Station 140. 59

93. Median, maximum, and minimum concentrations of Pb at Station 140 59

94. Median, maximum, and minimum concentrations of Zn at Station 140. 59

List of Figures, continued.

95. Al concentrations (two graphs with identical data, but different scales) are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation 61

96. Cd concentrations are the average of all fish collected during the NPDES 61

97. Cu concentrations are the average of all fish collected during the NPDES 62

98. Pb concentrations are the average of all fish collected during the NPDES. 62

99. Se concentrations are the average of all fish collected during the NPDES. 62

100. Zn concentrations are the average of all fish collected during the NPDES 63

101. Hg concentrations are the average of all fish collected during the NPDES 63

102. Median, maximum, and minimum concentrations of Al (dry weight) 64

103. Median, maximum, and minimum concentrations of Cd (dry weight) 65

104. Median, maximum, and minimum concentrations of Cu (dry weight) 65

105. Median, maximum, and minimum concentrations of Pb (dry weight) 66

106. Median, maximum, and minimum concentrations of Se (dry weight) 67

107. Median, maximum, and minimum concentrations of Zn (dry weight) 67

108. Median, maximum, and minimum concentrations of Hg (dry weight) 68

109. The number of Dolly Varden counted in aerial surveys in the Wulik 69

110. Catches of juvenile Dolly Varden in Anxiety Ridge (ANX) and Upper Mainstem Red Dog Creeks (UMS), 1997-2004. 73

111. Catches of juvenile Dolly Varden in Buddy (BUD) and Upper Mainstem Red Dog Creeks (UMS), 1997-2004. 74

112. Length-frequency of juvenile Dolly Varden caught in fall 2004 75

113. Dolly Varden caught in fyke nets in North Fork Red Dog Creek in June 2000. 75

List of Figures, concluded.

14. Dolly Varden caught in fyke nets in North Fork Red Dog Creek in July 2000....... 76

15. Length (maximum, average, and minimum) of Dolly Varden caught in spring with fyke-nets in North Fork Red Dog and Mainstem Red Dog creeks. 76

16. Water temperatures (°C) in Mainstem Red Dog Creek in spring 2004. 78

17. Length-frequency distribution of Arctic grayling caught in spring 2004 79

18. Slimy sculpin collected in Ikalukrok, Red Dog, Buddy, and Anxiety Ridge creeks, 1996-2004. 83

Acknowledgements

We thank Teck Cominco Alaska Inc. (TCAK) for financial and logistical support that allowed us to continue to conduct the Red Dog biomonitoring project. We acknowledge the support of Mr. Jim Kulas, Mr. Mark Thompson, Mr. Wayne Hall, and Mr. John Martinisko. We also thank Mr. Al Townsend, Ms. Lisa Whitman, Mr. Bill Morris, Mr. Jack Winters, Ms. Leslie Conley, Laura Jacobs, and Ms. Nancy Ihlenfeldt, with the Alaska Department of Natural Resources (ADNR) who assisted with field and laboratory work. We thank Mr. Fred DeCicco and Mr. Cal Skaugstad with the Alaska Department of Fish and Game (ADF&G) for helping with the sampling of Arctic grayling and Dolly Varden. The University of Alaska Fairbanks allowed us to use their equipment for chlorophyll analyses. Special thanks to Dr. Phyllis Weber Scannell (former ADF&G employee) for providing, by contract, substantial input in the preparation of the Red Dog biomonitoring report.

We continue to work cooperatively with the ADF&G. It should be noted that previous biomonitoring for Red Dog was done by ADF&G via agreement with TCAK. The biomonitoring work, along with the funding, was transferred to the ADNR, Office of Habitat Management and Permitting in May 2003.

Executive Summary

The following summaries compare results of water quality, invertebrate communities, periphyton, and fish at Red Dog monitoring sites in 2004 with results from combined data collected from 1999 through 2003. When available, results are compared with baseline data.

Station 9, Ikalukrok Creek upstream of Mainstem Red Dog Creek

Station 9 is not affected by activities at the mine, as it is located in Ikalukrok Creek upstream of Mainstem Red Dog Creek. There has been a general trend for decreasing metals and increased chlorophyll-a concentrations at Station 9. Al, Cd, and Zn were higher at Station 9 than during baseline studies, but Cd and Zn are decreasing. The density of aquatic invertebrates has been highly variable. Decreasing metal concentrations at Station 9 probably are related to a natural seep of minerals at Cub Creek located in upper Ikalukrok Creek. Visible effects of the seep on Ikalukrok Creek have been decreasing. Although not numerous, larval Arctic grayling (age 0) have been found at Station 9 in four of the six sample years.

Station 8, Ikalukrok Creek downstream of Mainstem Red Dog Creek

Station 8 is affected by activities at the mine (e.g., wastewater discharge, clean water bypass), as it is located in Ikalukrok Creek just downstream of Mainstem Red Dog Creek. Metals data are not presented because waters are not fully mixed. The density of aquatic invertebrates has been highly variable. A trend for increasing chlorophyll-a concentrations has been seen at Station 8 since summer 2000. Only a few larval Arctic grayling (age 0) have been collected at this site in two of the six sample years.

Ikalukrok Creek upstream of Dudd Creek

Ikalukrok Creek just upstream of Dudd Creek is affected by activities at the mine. There appears to be a trend of decreasing Ni and Zn concentrations. Cd and Zn concentrations also are lower than those reported from baseline studies. The density of aquatic invertebrates has been highly variable. Chlorophyll-a concentrations appear to have decreased from 2001 through 2004. Small numbers of larval Arctic grayling (age 0) have been collected at this site in three of the six sample years.

Station 7, Ikalukrok Creek downstream of Dudd Creek

Ikalukrok Creek, downstream of Dudd Creek, is affected by mine activities. Median metals concentrations were similar for all reporting years. Median Zn and Cd concentrations were lower when compared with results from baseline work. TDS concentrations were below 500 mg/L during the spawning time of Dolly Varden, and chinook and chum salmon. The density of aquatic invertebrates has been highly variable and chlorophyll-a concentrations have been similar in all reporting years. A few larval Arctic grayling (age 0) were collected at Station 7 in three of the six sample years.

Station 10, Mainstem Red Dog Creek

Mainstem Red Dog Creek is affected by mine activities. Median concentrations of Cd and Zn have been lower when compared with baseline work. TDS concentrations were below 500 mg/L at Station 10 during Arctic grayling spawning. Spawning was judged to be complete on May 31, 2004. The density of aquatic invertebrates has been highly variable. Average chlorophyll-a concentrations were substantially higher in 2004, than from 1999 through 2004. Larval Arctic grayling (age 0) were collected in four of the six sample years. The number of larval Arctic grayling caught in summer 1999 was large (about 50), as compared with an average of less than three.

Station 20, Middle Fork Red Dog Creek

Middle Fork Red Dog Creek is affected by mine activities. Median concentrations of Cd and Zn have been lower than baseline data and median concentrations of Cd and Zn have been decreasing with time. The density of aquatic invertebrates has been highly variable. Except for 2001, chlorophyll-a concentrations have been below detection. No larval Arctic grayling have been captured at Station 20.

Station 12, North Fork Red Dog Creek

North Fork Red Dog Creek is not affected by mine activities. Some of the Al and Fe concentrations in the creek are higher than at premining, whereas Cd and Pb concentrations are lower. Sediment input to North Fork Red Dog Creek from natural thermal hydraulic erosion was first seen in 2000 and has been intermittent each summer. The density of aquatic invertebrates has been relatively high, except for 2004 when densities were low. Chlorophyll-a concentrations in 2004 also were the lowest seen since 1999. Larval Arctic grayling (age 0), although not numerous, have been captured in drift nets in four of the six sample years.

Station 140, Middle Fork Red Dog Creek

Station 140 is located below the clean water bypass through the pit area, but upstream of the wastewater discharge point. Median concentrations of Cd, Pb, and Zn at Station 140 are consistently lower (1999 through 2004) than premining, indicating that the clean water bypass system is working to minimize downstream loading of metals to receiving waters.

Wulik River, Metals Concentrations in Dolly Varden Tissues

Al concentrates in gill tissue - no real pattern or trend appears to exist for Al in gill tissue, other than the fact that it is highly variable. Cd concentrates in kidney tissue – median Cd concentrations in kidney tissue were lower than those reported in baseline studies. Cu concentrates in liver tissue – median Cu concentrations in liver tissue have been consistently higher than baseline data, but virtually no change has been seen from 1999 through 2004. Pb concentrates in gill tissue – median Pb concentrations in gill tissue were higher than during baseline studies. Se concentrates in ovarian tissue – no baseline data are available. Zn concentrates in ovarian tissue – no baseline data are available and median Zn concentrations in ovarian tissue have remained fairly consistent during the sample period. None of the analytes measured appear to concentrate in muscle tissue.

Fish Resources in Wulik River drainage

Dolly Varden Adults

Dolly Varden adults continue to overwinter in the Wulik River with the majority of these fish using the Wulik River downstream of the mouth of Ikalukrok Creek. Numbers of fish estimated in the Wulik River are variable, but comparable with those found during premining surveys.

Chum Salmon

Chum salmon spawning numbers for the NPDES reporting period are comparable with those found during baseline data collection except for 1981 when the number of spawners was substantially higher.

Dolly Varden Juveniles

Dolly Varden captures continue to be highest in Buddy and Anxiety Ridge creeks. There is some indication that use of Mainstem Red Dog Creek may have decreased in 2003 and 2004.

Arctic Grayling

Arctic grayling spawning has been documented in both Mainstem Red Dog and North Fork Red Dog creeks. When temperature data for the last four years are analyzed, we found that spawning was complete after peak daily water temperatures exceeded 4°C for 5 to 9 cumulative days within the sample year.

In summers 2000 through 2002, large numbers of adult Arctic grayling were seen at the mouth of Grayling Junior Creek and/or in East Fork Ikalukrok Creek. In both 2003 and 2004, concentrations of adult Arctic grayling were not found in the Ikalukrok Creek drainage. Length-frequency distributions indicate that the larger Arctic grayling also were absent or nearly absent from the spring sample in North Fork Red Dog Creek. Recruitment appears to be strong in recent years.

Slimy Sculpin

The total catch of slimy sculpin in all nine sample areas located in the Ikalukrok Creek drainage have been steadily increasing with our highest catch occurring in summer 2004. Increased catches of slimy sculpin may be reflective of improving water quality in Ikalukrok Creek as metals from Cub Creek, located upstream of Mainstem Red Dog Creek, have been decreasing.

Introduction

The Red Dog zinc (Zn) and lead (Pb) deposit is located in northwestern Alaska, about 130 km north of Kotzebue and 75 km inland from the coast of the Chukchi Sea (Figure 1). The mine operation and facilities and the surrounding vegetation and wildlife are described in Weber Scannell and Ott (1998). A chronicle of development and operation of the Red Dog Mine is presented in Appendix 1. Aquatic resources in the Wulik River drainage are described in Weber Scannell et al. (2000).

In July 1988, the US Environmental Protection Agency (EPA) issued a draft National Pollution Discharge Elimination System Permit No. AK-003865-2 (NPDES Permit) to Teck-Cominco Alaska Inc. (TCAK) to allow discharge of up to 2.418 billion gallons of treated effluent per year. The Alaska Department of Environmental Conservation (ADEC) issued a Certificate of Reasonable Assurance and the NPDES Permit became effective August 28, 1998. The NPDES Permit was modified effective August 23, 2003, to include ADEC's authorization of two mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks.

The NPDES Permit required biomonitoring of fish, aquatic invertebrates, and periphyton in streams downstream and adjacent to the Red Dog Mine. Although the NPDES Permit expired August 28, 2003, it was administratively extended until such time as a new permit is issued. This report contains the results of biomonitoring studies conducted by the Alaska Department of Natural Resources (ADNR) in 2004.

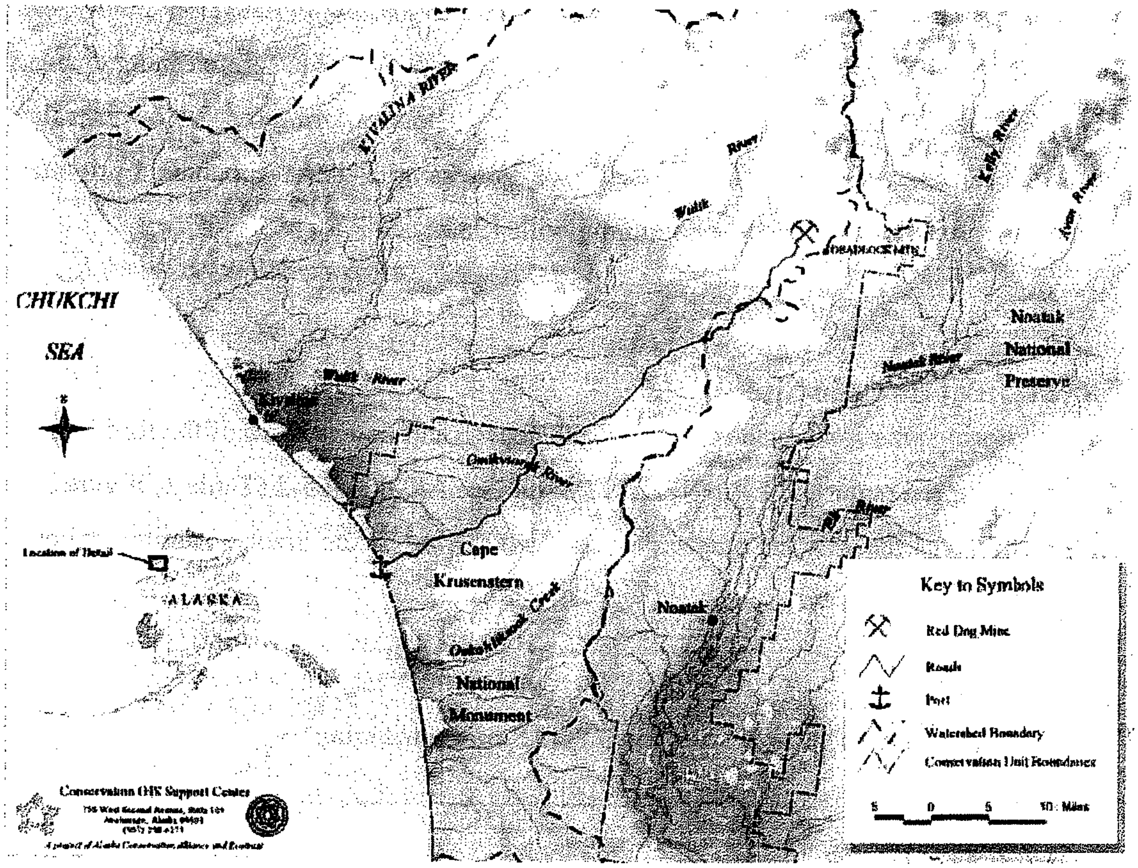


Figure 1. Location of the Red Dog Mine in northwestern Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, Alaska.

Structure of Report

Results of water quality monitoring, aquatic invertebrate sampling, and estimates of periphyton standing crop are given for each site for the years sampled (1999-2004). Following presentation of these results by individual site is a table summarizing changes in biotic communities and water quality conditions. Biomonitoring results for juvenile and adult fish are presented after discussion of these sample sites. Appendix 1 provides a chronology of substantial events beginning with 1982.

Location of Sample Sites

Biomonitoring was conducted in streams adjacent to and downstream of the Red Dog Mine as required under the EPA NPDES Permit No. AK-003865-2 (Table 1, Figure 2). A description of the sites included in this study followed by the Station Number, where available, is listed below.

Table 1. Location of sample sites for NPDES biomonitoring.

Stream or Site Name	Station Number
Ikalukrok Creek upstream of Mainstem Red Dog Creek	Station 9
Ikalukrok Creek downstream of Mainstem Red Dog Creek	Station 8
Ikalukrok Creek upstream of Dudd Creek	-----------
Ikalukrok Creek downstream of Dudd Creek	Station 7
Mainstem Red Dog Creek	Station 10
Middle Fork Red Dog Creek	Station 20
North Fork Red Dog Creek	Station 12

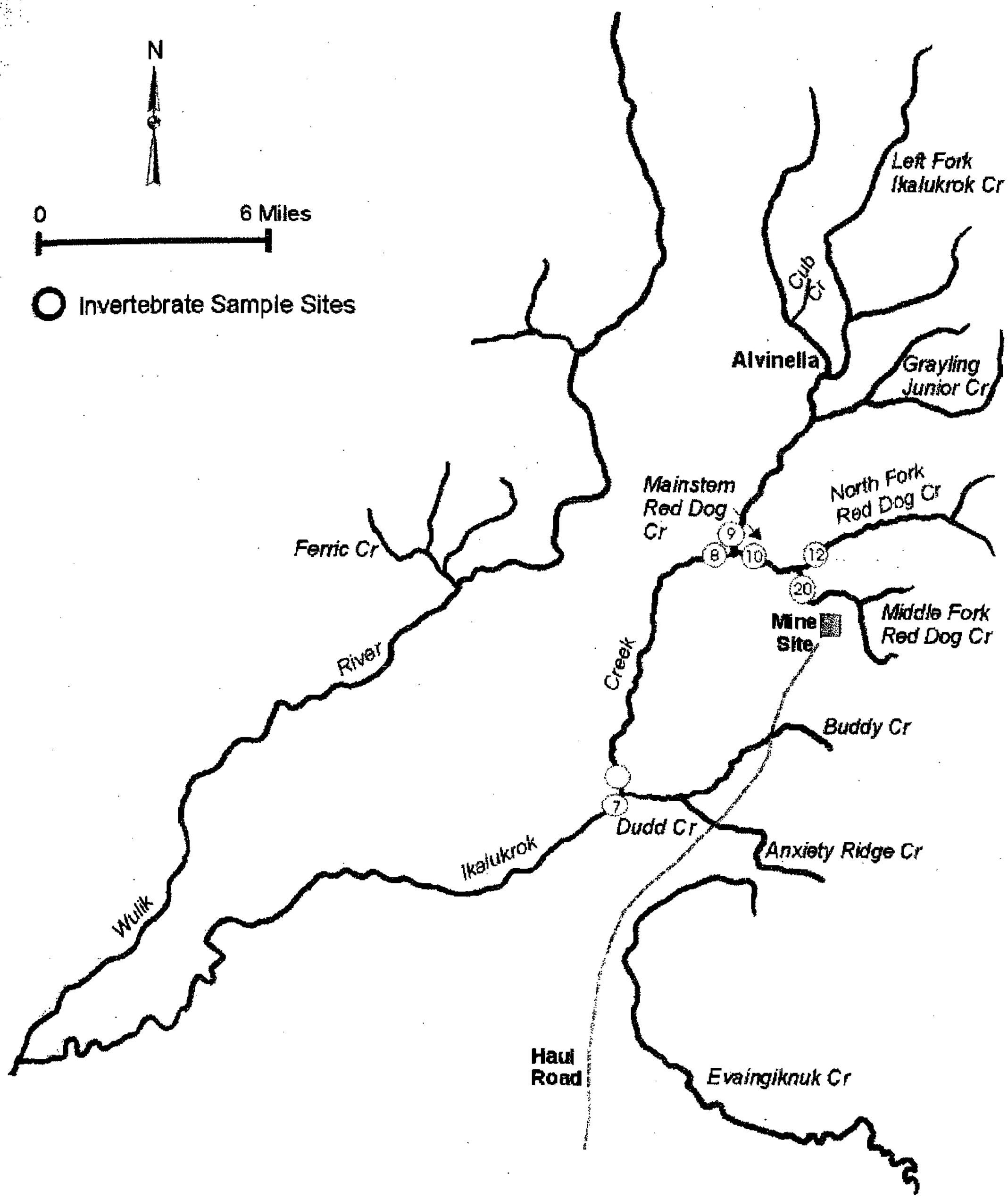


Figure 2. Location of sites in the Red Dog Creek drainage for aquatic sampling. Note, the Ikalukrok Creek site upstream of Dudd Creek does not have a numerical description.

Description of Streams

All streams in this study are in the Wulik River drainage, except for Evaingiknuk Creek which is in the Noatak River drainage. Station numbers correspond to the numbers used by Dames and Moore (1983) during baseline studies and the current water quality program being conducted by TCAK. Water quality and fisheries data collected during baseline studies (1979 to 1982) represent pre-mining conditions. Each component and location listed in Table 2 is required by NPDES Permit No. AK-003865-2. ADNR and ADEC conduct additional sampling that is supplemental to the requirements under the NPDES Permit to further our understanding of the aquatic communities (Table 3). Additional sampling is not done annually, but opportunistically based on need, time, and logistical support.

Table 2. Locations and components of studies required by NPDES Permit.

Middle Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance)
North Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use
Mainstem Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance Fish presence and use
Ikalukrok Creek Stations 8, 9, and 7; and upstream of Dudd Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance Fish presence and use
Ikalukrok Creek Wulik River	Fall aerial survey chum salmon Fall aerial survey Dolly Varden Metals concentrations in adult Dolly Varden (gill, liver, muscle, and kidney)
Anxiety Ridge Creek	Fish presence and use
Evaingiknuk Creek	Fish presence and use
Buddy Creek	Fish presence and use

Table 3. Locations and components of supplemental biomonitoring studies in 2004.

North Fork Red Dog Creek	Juvenile Dolly Varden, whole body metal analyses Fish movement Condition of Arctic grayling (spent, ripe, etc.) Mark-recapture Arctic grayling Juvenile Dolly Varden use in headwaters
Mainstem Red Dog Creek	Juvenile Dolly Varden, whole body metal analyses Fish movement Condition of Arctic grayling (spent, ripe, etc.) Mark-recapture Arctic grayling
Ikalukrok Creek (Dudd Creek upstream to headwaters)	Aerial Arctic grayling surveys
Buddy Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use Juvenile Dolly Varden, whole body metal analyses
Bons Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use
Bons Pond	Juvenile Arctic grayling whole body metal analyses Mark-recapture Arctic grayling

Methods Used for NPDES Biomonitoring

All methods used for the NPDES biomonitoring study were described by ADF&G (1998) and submitted to EPA for their approval and comment. Only minor modifications, as described by Ott and Weber Scannell (2003), have been made to the methods specified by ADF&G (1998).

The method detection limit (MDL) in 2000 for Ni, Pb, and Se was 100, 20, and 50 *u*g/L, respectively, for some of the early samples. MDL's were changed part way through the summer for Ni, Pb, and Se to 0.5, 2, and 1 *u*g/L. In the water quality figures presented for the various sample sites, the MDL for these metals is shown as a triangle and the median and minimum values are from data collected after the MDLs were changed.

Results and Discussion

Ikalukrok Creek at Station 9

Site Description

Station 9 is located in Ikalukrok Creek upstream of the confluence with Mainstem Red Dog Creek and near the US Geological Survey gauging station (Figure 3). The creek at this site, just upstream of the mouth of Mainstem Red Dog Creek, divides around a large gravel bar into two channels; the right channel (facing downstream) contains most of the flow. Periphyton and aquatic invertebrate samples were collected in the left channel.

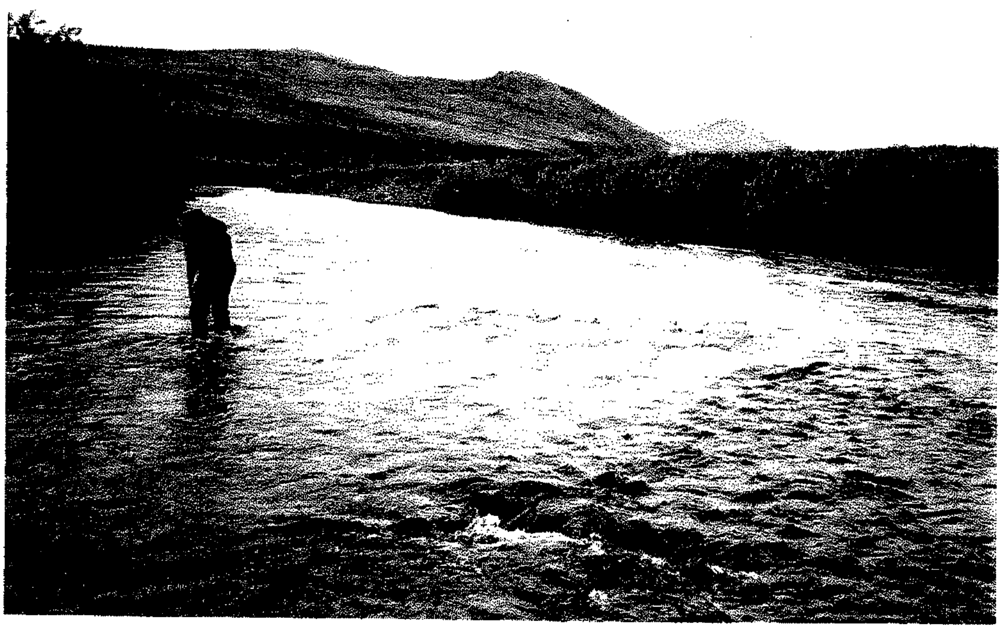


Figure 3. Ikalukrok Creek upstream of Mainstem Red Dog Creek, Station 9.

Water Quality

The water quality at Station 9 is not affected by water discharged from the Red Dog water treatment facility. Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 4 through 10 (data from TCAK), as are baseline data for Al, Cd, Pb, and Zn. There appears to be a general trend for a decrease in metals concentrations at Station 9.

These changes probably are related to a decrease in the input of metals from Cub Creek, a tributary to Ikalukrok Creek. Visual effects of Cub Creek in terms of water color and staining of rocks in Ikalukrok Creek were intense in summer 1997 and while still present, these effects have decreased over the last several years.

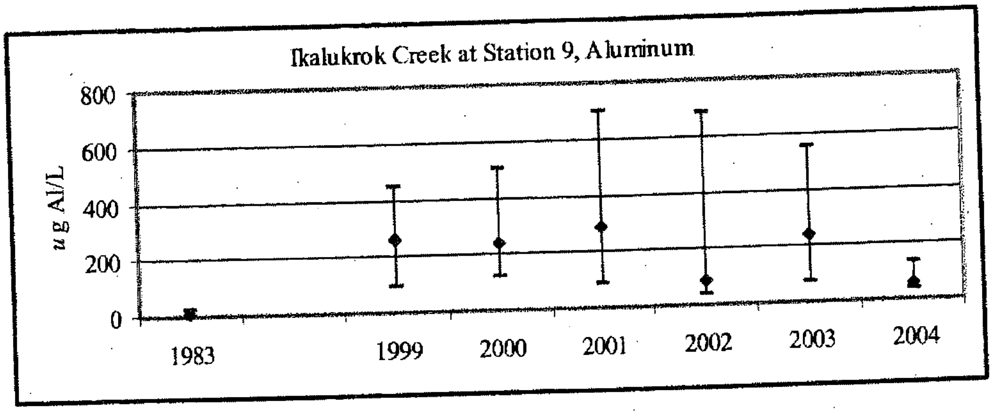


Figure 4. Median, maximum, and minimum concentrations of Al at Station 9.

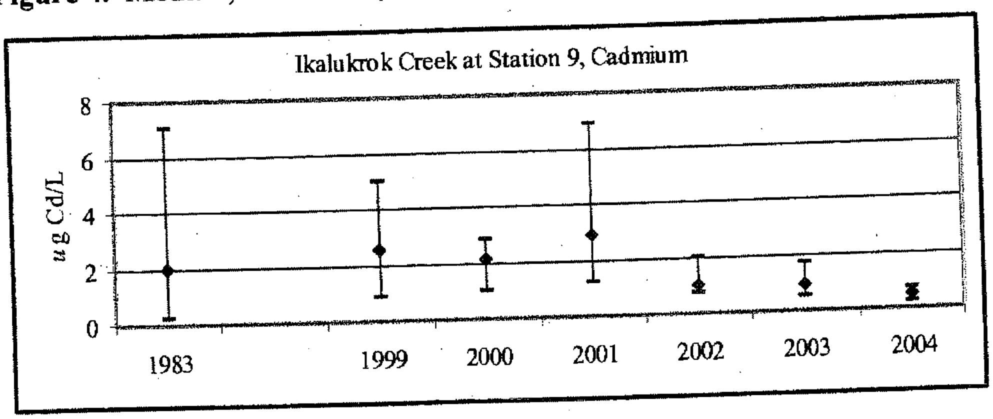


Figure 5. Median, maximum, and minimum concentrations of Cd at Station 9.

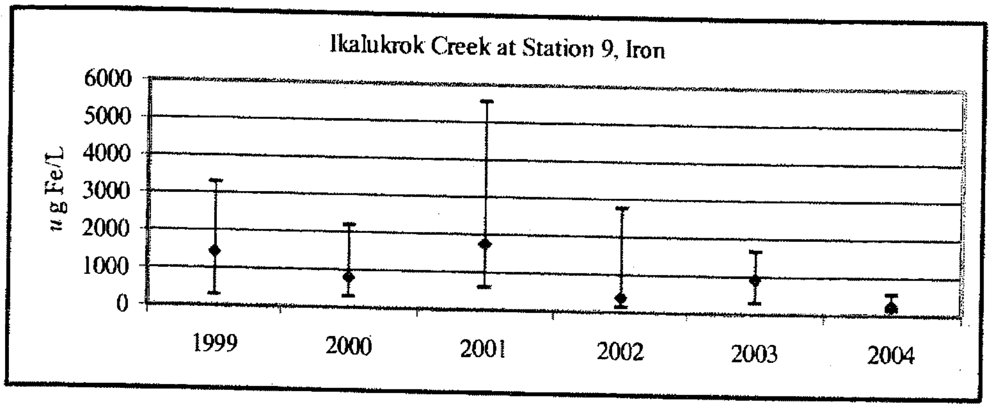


Figure 6. **Median, maximum, and minimum concentrations of Fe at Station 9.**

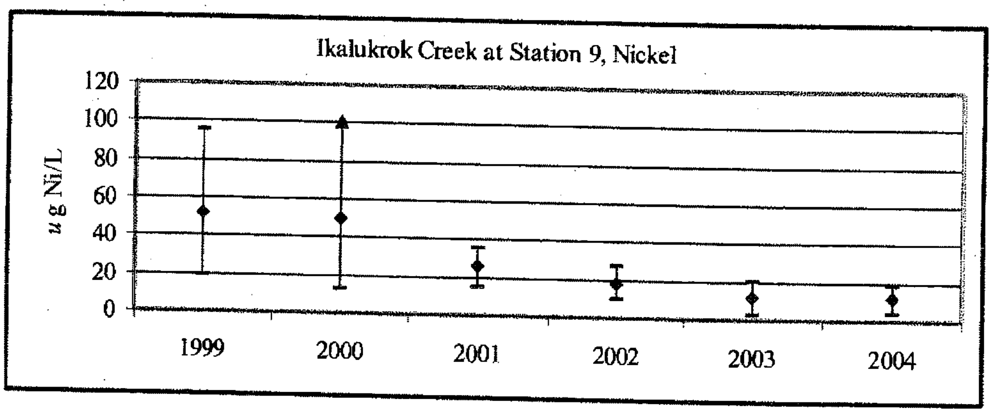


Figure 7. **Median, maximum, and minimum concentrations of Ni at Station 9. The triangle represents a MDL, not a concentration.**

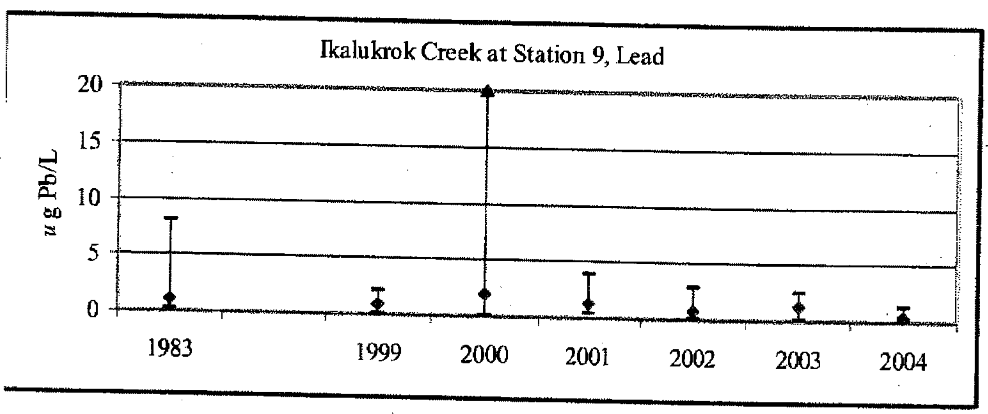


Figure 8. **Median, maximum, and minimum concentrations of Pb at Station 9. The triangle represents a MDL, not a concentration.**

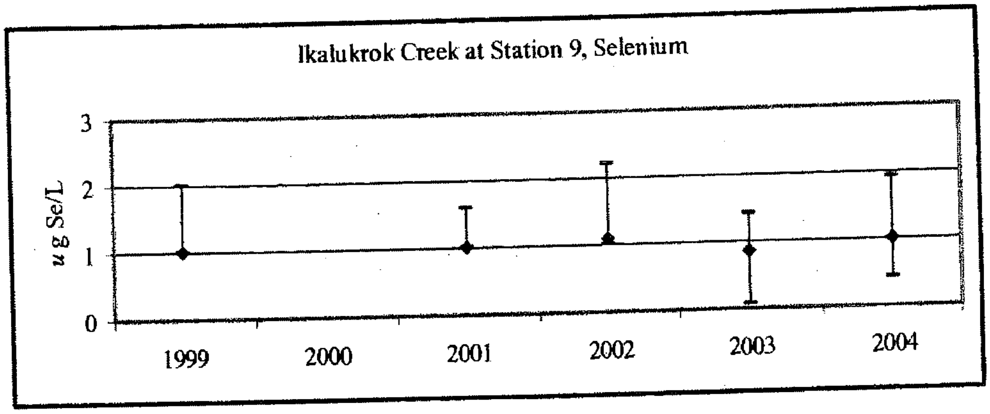


Figure 9. Median, maximum, and minimum concentrations of Se at Station 9. Data from 2000 are not presented due to a high method detection limit of 50 *u*g/L.

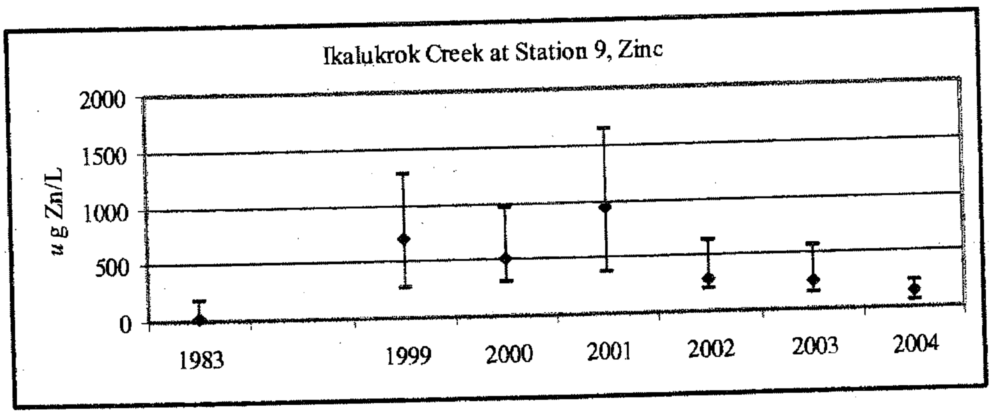


Figure 10. Median, maximum, and minimum concentrations of Zn at Station 9.

Invertebrate Community (Abundance, Density, and Taxa Richness)
Invertebrate abundance (average number of aquatic invertebrates per net) and density (average number of aquatic invertebrates/m^3 of water) were highest in 2001 (Figures 11 and 12). Taxa richness varied from a low of 8 in 1999 to a high of 20 in 2003 (Figure 13). Overall metals concentrations have decreased at Station 9, aquatic invertebrate densities have been variable, but taxa richness has shown an increase with time and may reflect the lower metal concentrations.

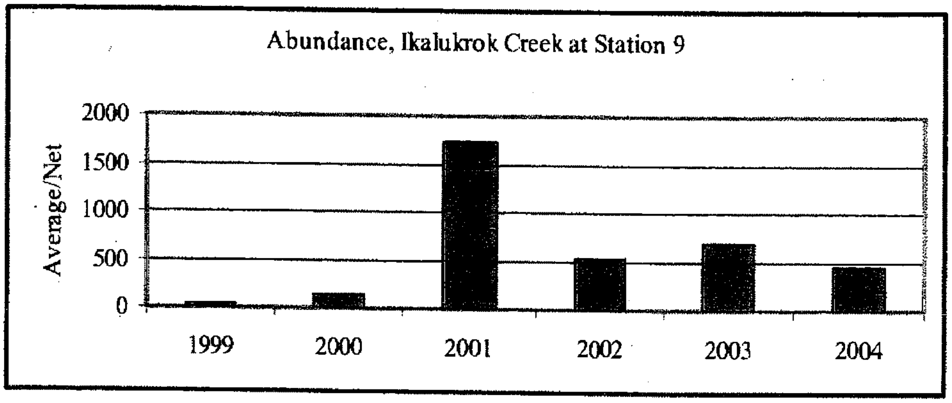


Figure 11. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

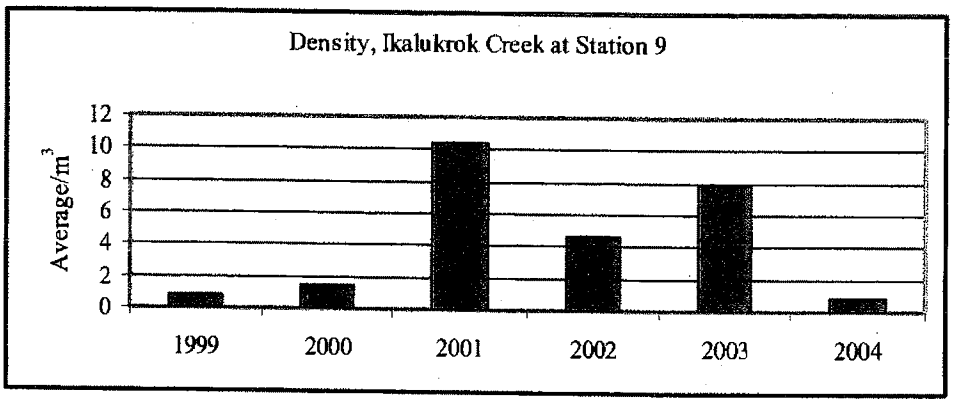


Figure 12. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

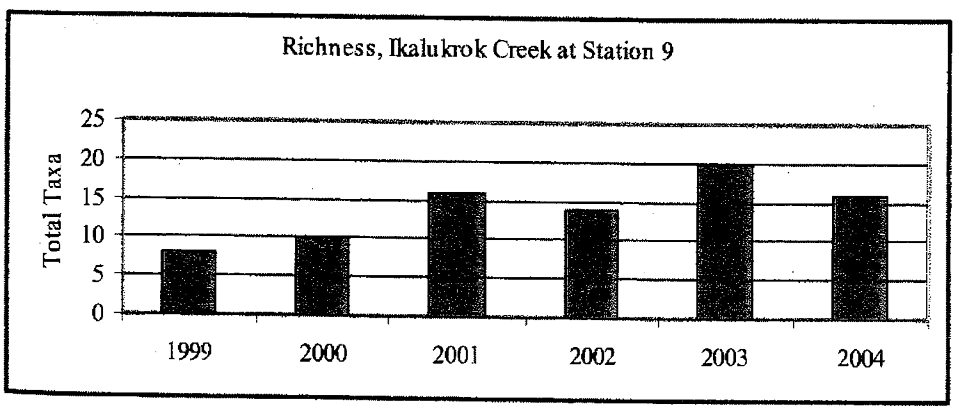


Figure 13. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

Community Structure

Invertebrate samples at Station 9 contained a relatively high proportion of Ephemoptera, Plecoptera, and Tricoptera (EPT taxa) in all years from 1999 through 2004 (Figure 14). EPT proportions recorded for the sample years were 59, 54, 25, 45, 27, and 52%.

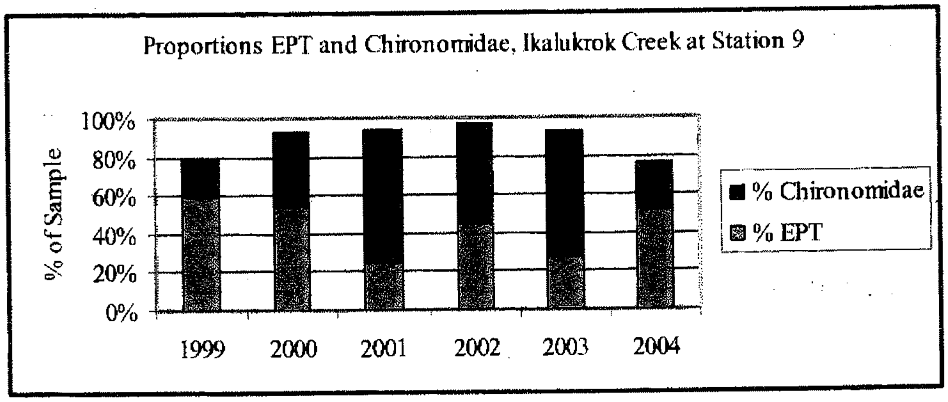


Figure 14. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 9.

Periphyton Standing Crop

Concentrations of chlorophyll-a were highest in 2004 (Figure 15). Increases in chlorophyll-a have been fairly consistent from a low in 2001 to a high in 2004.

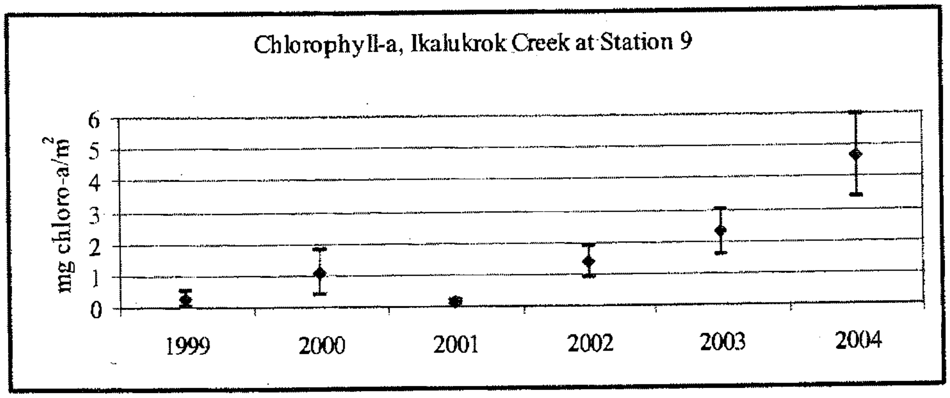


Figure 15. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 9.

Summary of Biomonitoring, Station 9, 1999-2004

Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 4.

Table 4. Summary of biomonitoring, Ikalukrok Creek at Station 9, 1999 to 2004.

Factor	Changes Observed
Water Quality	General trend, decreasing metals
Invertebrates	Density – higher in 2001 and 2003 Taxa Richness – lowest 8, highest 20 %EPT – similar, a low of 25 to a high of 59%
Periphyton	Highest in 2004, increasing trend 2001 to 2004
Larval Fish	Arctic grayling present in 1997, 1999, 2000, and 2004

Ikalukrok Creek at Station 8

Site Description

Ikalukrok Creek downstream of Mainstem Red Dog Creek is a relatively fast flowing stream with medium sized gravel to small cobble substrate (Figure 16). Stream banks are covered with various species of willows and gravel bars are exposed at lower flows. During the summer months, the stream bottom is frequently covered with filamentous algae.

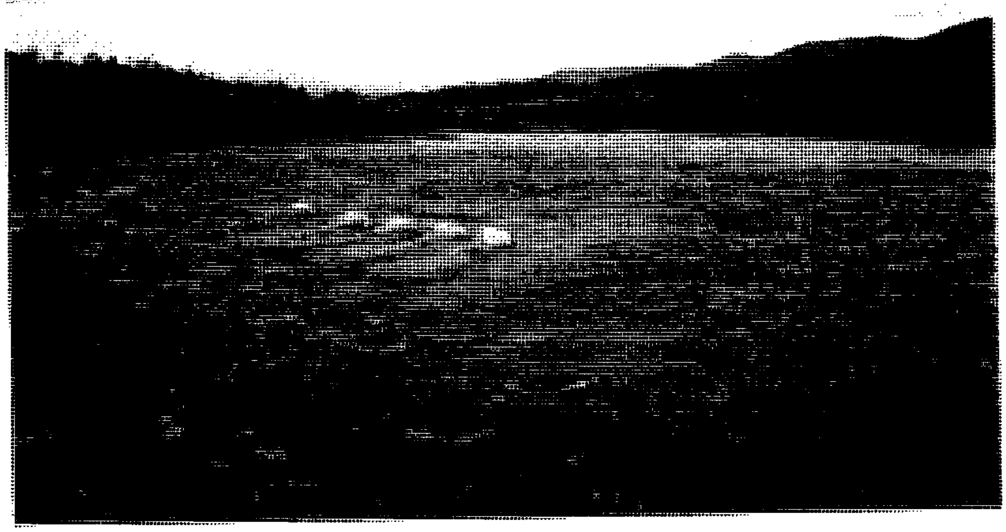


Figure 16. Ikalukrok Creek downstream of Mainstem Red Dog Creek, Station 8.

Water Quality

Water samples have not been collected from this site in recent years because the water from Mainstem Red Dog Creek and Ikalukrok Creek is not mixed. Water samples are now collected at Station 150 about 0.5 km below the original Station 8.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Abundance, density, and taxa richness of aquatic invertebrates found in Ikalukrok Creek at Station 8 was highest in 2003 (Figures 17, 18, and 19). An average of 1,280 aquatic organisms per net and 9.9 organisms per m^3 of water was found in 2003. The number of taxonomic groups varied from a low of 10 in 2000 to a high of 24 in 2003.

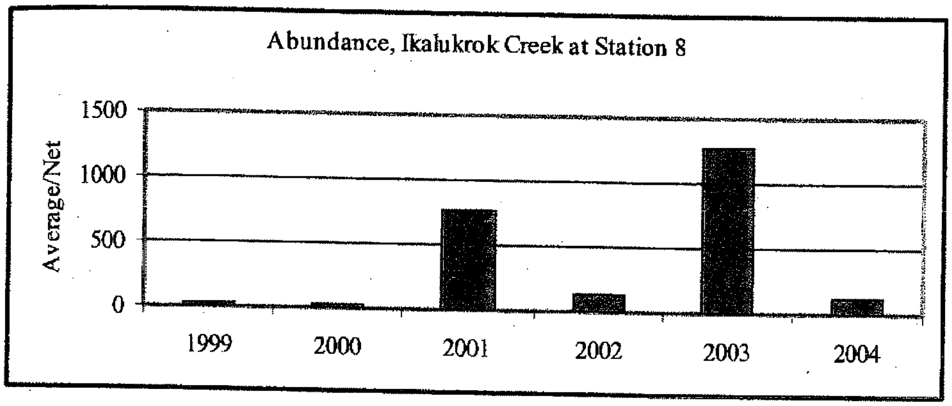


Figure 17. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 8.

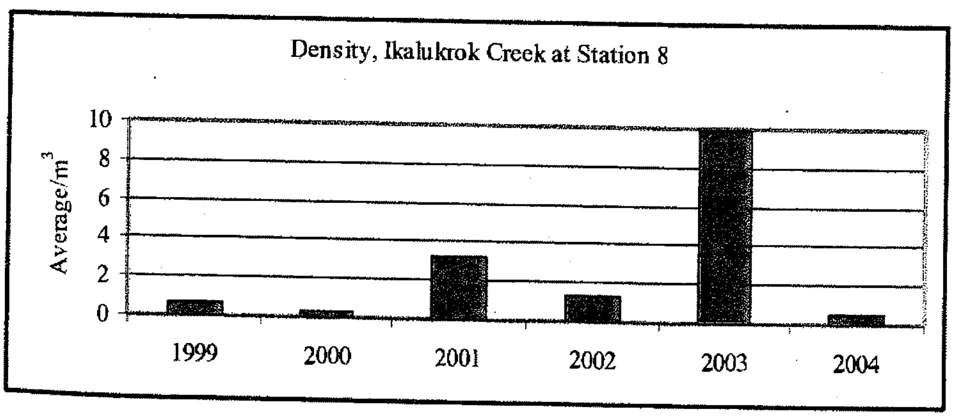


Figure 18. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 8.

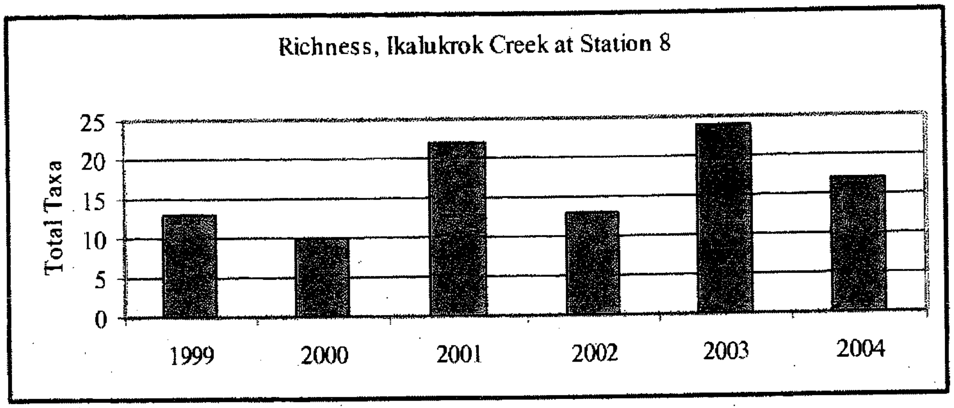


Figure 19. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 8.

Community Structure

The invertebrate community contained a large proportion of EPT in 1998 (71%) when the stonefly *Capnia* was mature and prevalent in drift samples (Weber Scannell et al. 2000). From 1999 through 2004, the proportion of EPT was lower than in 1998, but reached a high of 55% in 2004 (Figure 20). While the invertebrate community was dominated by Chironomidae from 1999 through 2003, EPT was most prevalent in both 1998 and again in 2004.

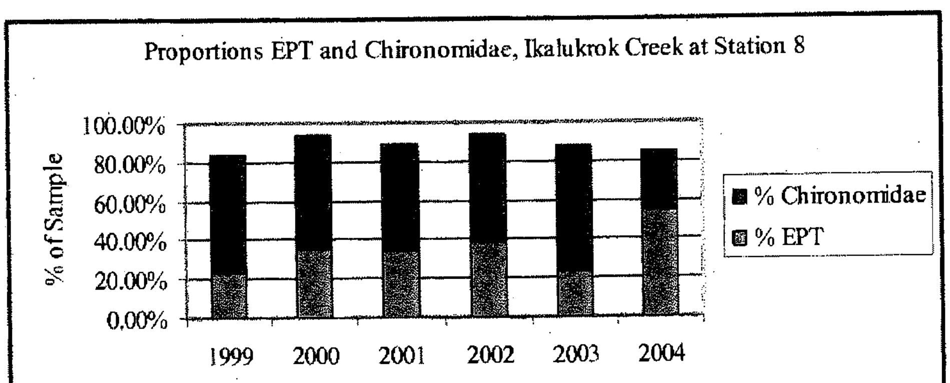


Figure 20. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 8.

Periphyton Standing Crop

The abundance of attached algae, estimated by chlorophyll-a concentrations was highest in 2004 (Figure 21). A general trend for increasing chlorophyll-a concentrations appears to occur from 2000 through 2004.

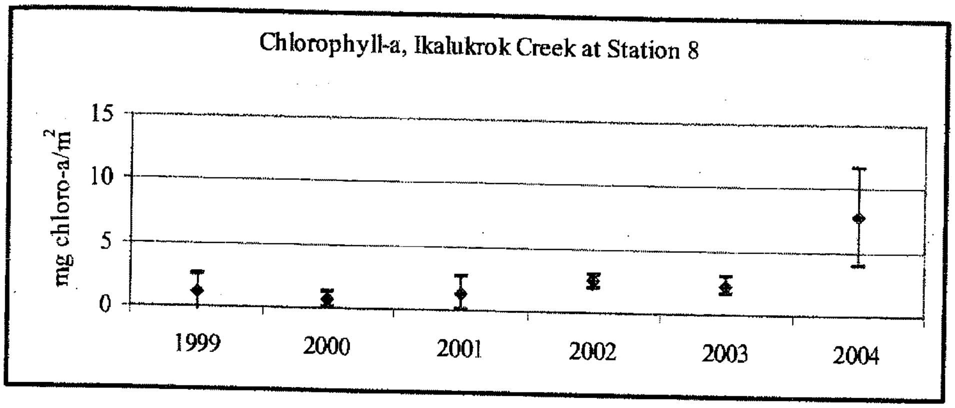


Figure 21. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 8.

Summary of Biomonitoring at Station 8, 1999-2004

Changes in invertebrates, periphyton, and presence of larval fish that have been documented over time at Station 8 are summarized in Table 5.

Table 5. Summary of biomonitoring, Ikalukrok Creek at Station 8, 1999 to 2004.

Factor	Changes Observed
Water Quality	Ikalukrok and Mainstem not mixed, data unreliable all years
Invertebrates	Density – highest in 2003 Taxa Richness – lowest 10, highest 24 %EPT – similar, a low of 23.5 to a high of 55%
Periphyton	Highest in 2004, increasing trend 2000 to 2004
Larval Fish	Arctic grayling present in 2000 and 2002

Ikalukrok Creek Upstream of Dudd Creek

Site Description

Ikalukrok Creek, upstream of Dudd Creek, is a wide, fairly shallow stream up to 40 m wide and 0.5 to 1.5 m deep during summer low flows (Figure 22). Pools along cut banks or adjacent to rock bluffs are 2 to 4 m deep. The substrate contains mostly small cobble mixed with medium sized gravel. Streambanks are thickly vegetated with willows and herbaceous plants and grasses.

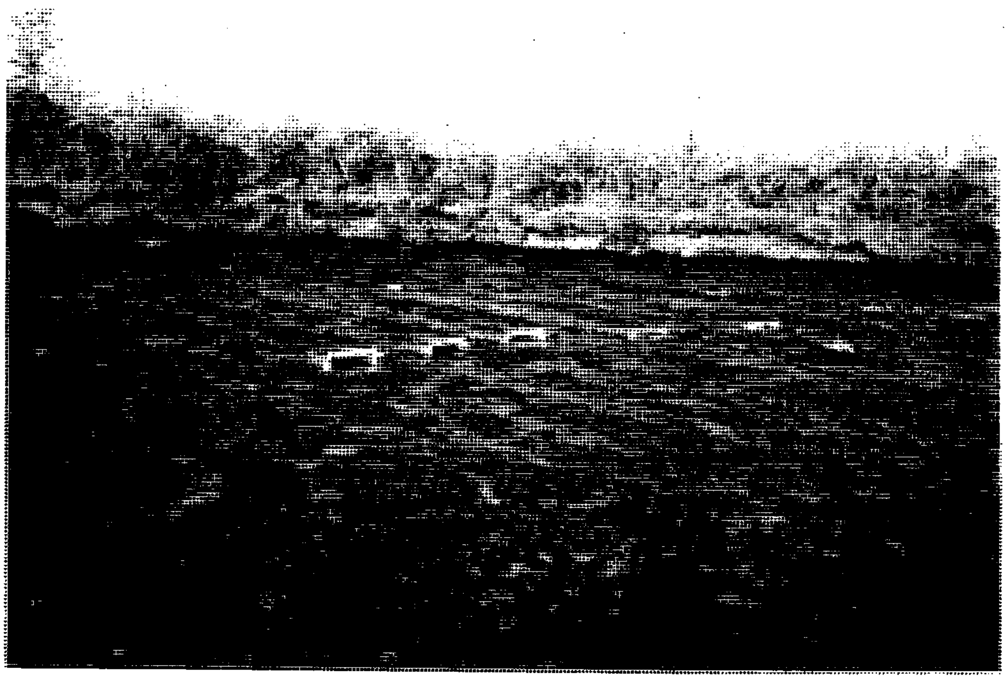


Figure 22. Ikalukrok Creek upstream of Dudd Creek.

Water Quality

Water is not sampled in Ikalukrok Creek at our biomonitoring sample location. Water samples are collected at Station 73 that is located about 6 km upstream. Water quality at Station 73 is affected by water discharged from the Red Dog water treatment facility and from water that is bypassed through the pit area. Concentrations of Al, Cd, Fe, Ni, Se, and Zn are presented in Figures 23 through 29 (data from TCAK). Baseline dat were available for Al, Cd, Pb, and Zn and are included. Peaks in Cd were seen in 2 and 2004, but a gradual trend for deceasing median concentration was observed for and Zn.

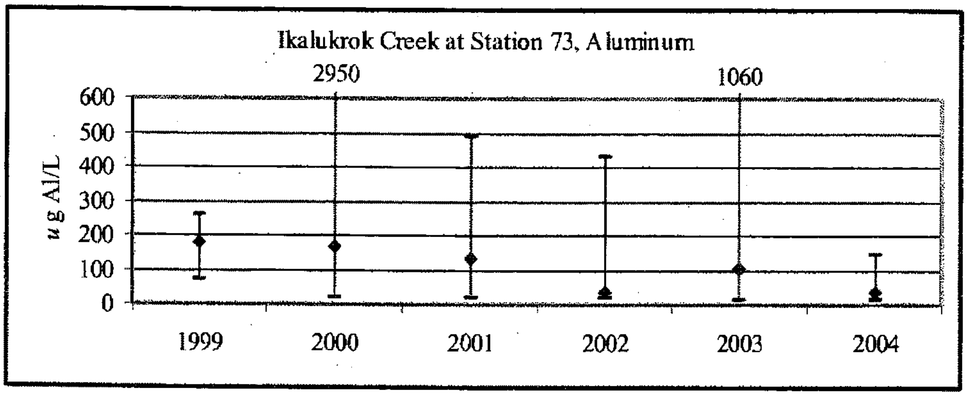


Figure 23. Median, maximum, and minimum concentrations of Al at Station 7

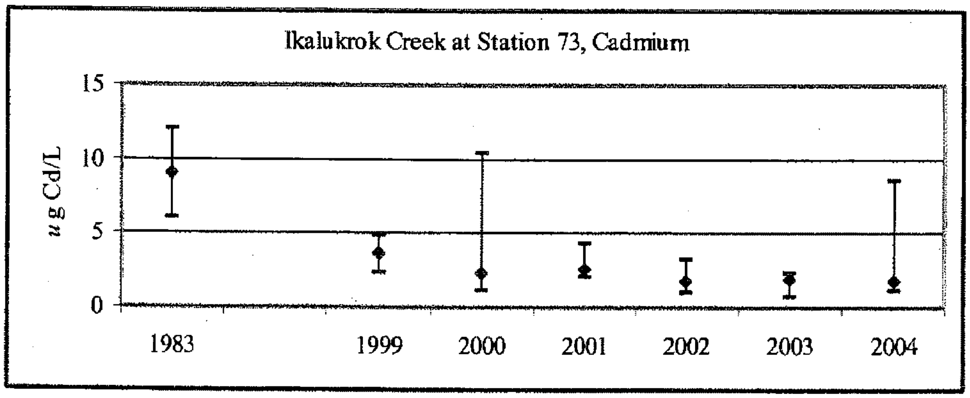


Figure 24. Median, maximum, and minimnm concentrations of Cd at Station 73

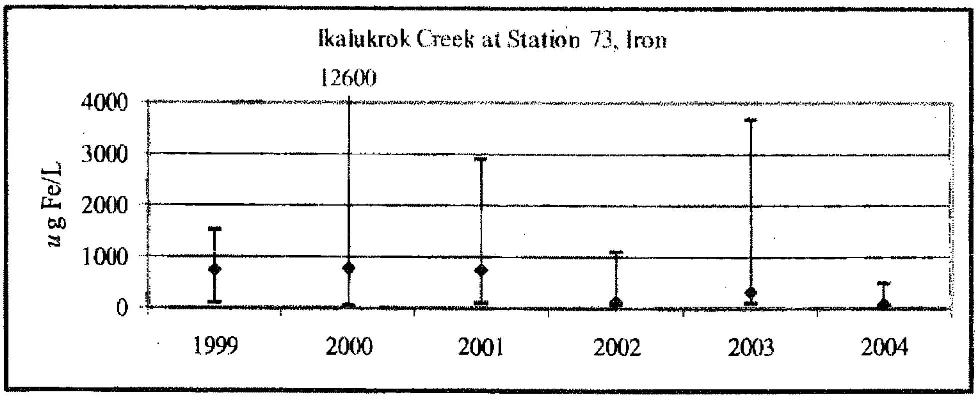


Figure 25. Median, maximum, and minimum concentrations of Fe at Station 73.

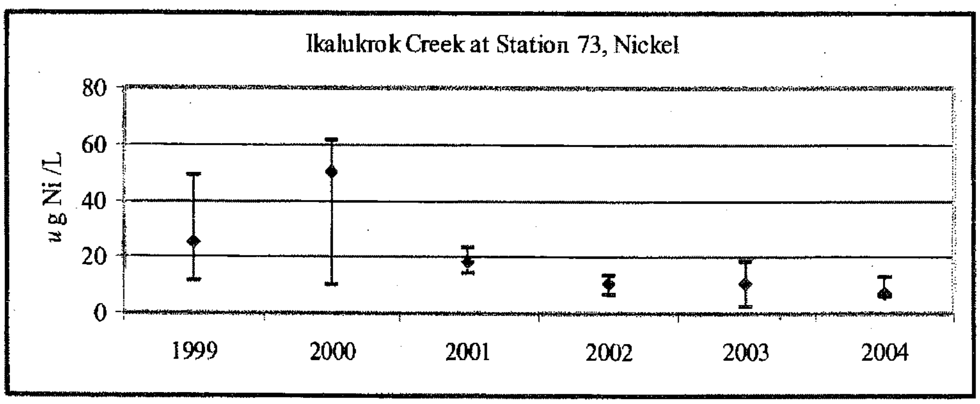


Figure 26. Median, maximum, and minimum concentrations of Ni at Station 73.

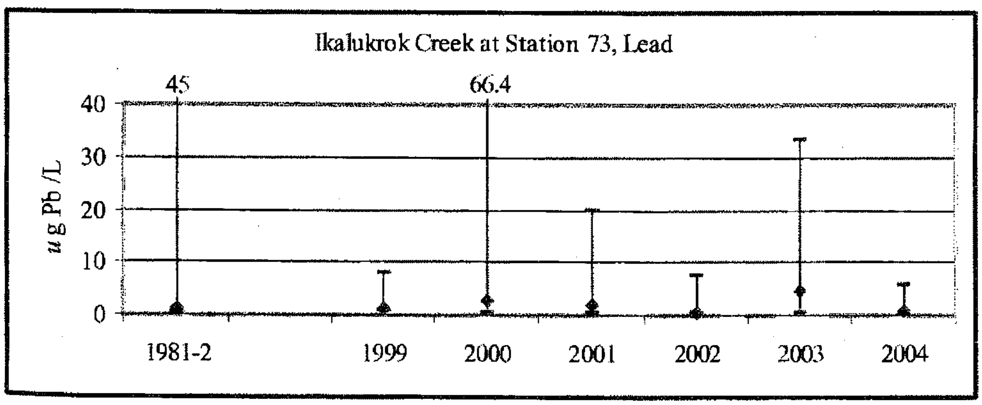


Figure 27. Median, maximum, and minimum concentrations of Pb at Station 73.

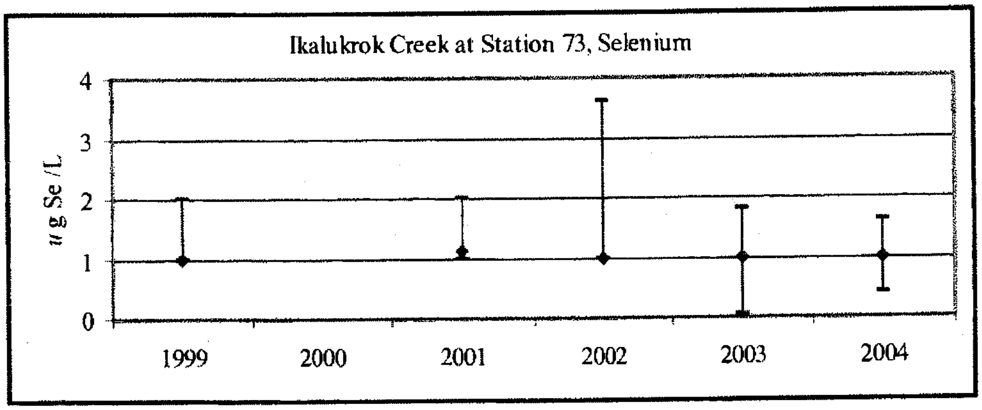


Figure 28. Median, maximum, and minimum concentrations of Se at Station 73. Data from 2000 are not presented due to a high method detection limit of 25 *u*g/L.

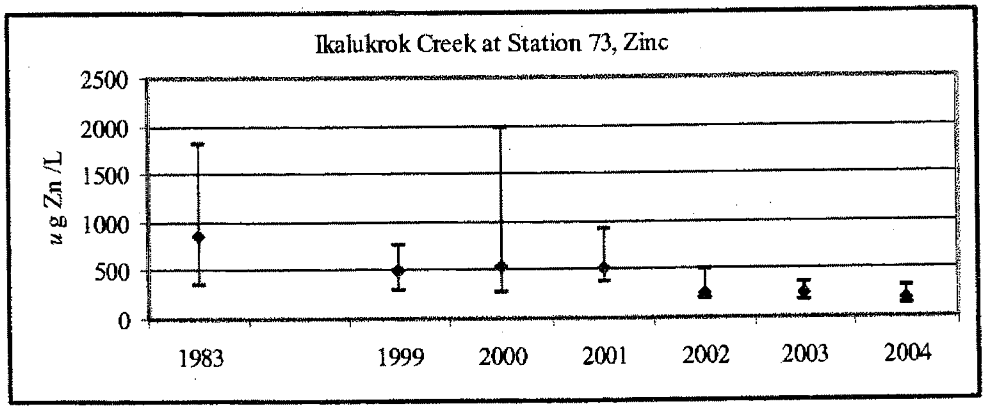


Figure 29. Median, maximum, and minimum concentrations of Zn at Station 73.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance gradually increased from 1999 through 2001, decreased slightly in 2002, was highest in 2003, and then decreased again in 2004 (Figure 30). The density of aquatic invertebrates was lowest in 2004 (Figure 31) and taxa richness was similar for all sample years (Figure 32).

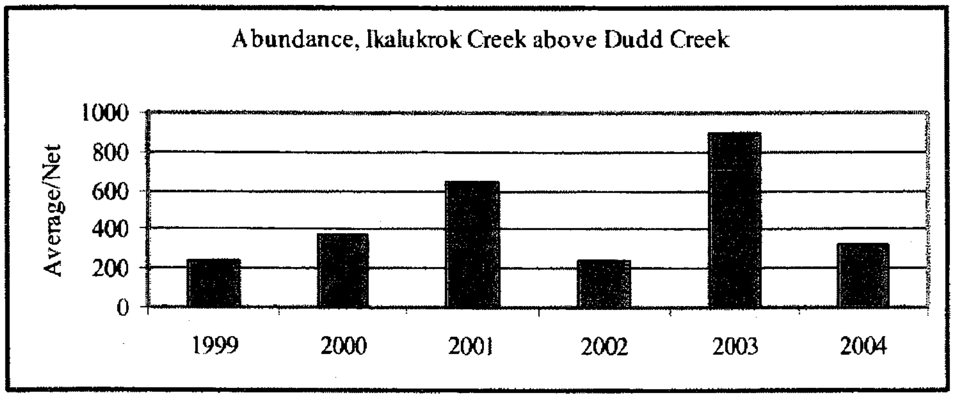


Figure 30. Abundance of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

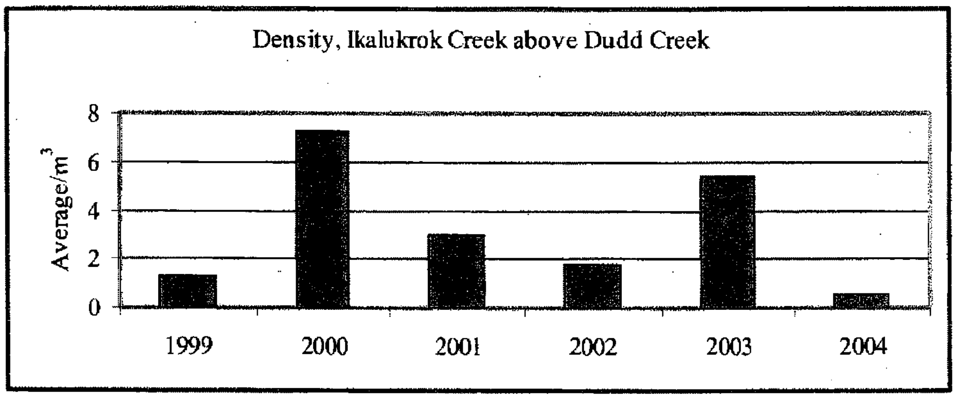


Figure 31. Density of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

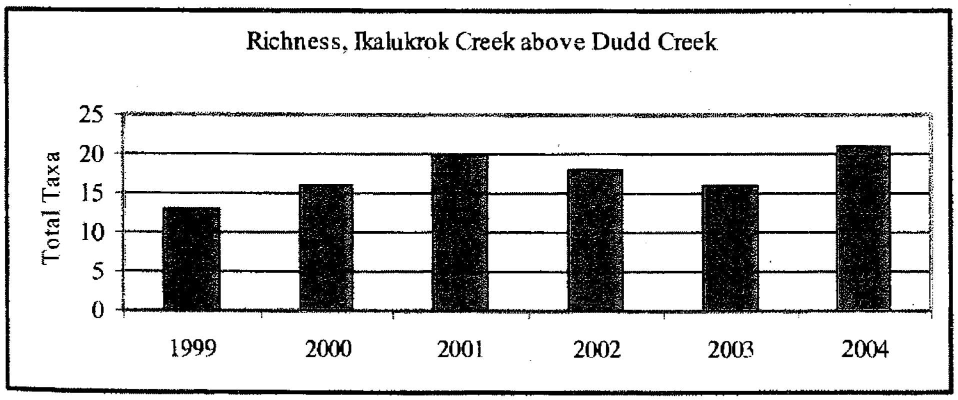


Figure 32. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

Community Structure

There were a low proportion of EPT taxa compared to Chironomidae during five of the six years of sampling (Figure 33). In 2002 and 2003, the proportions of EPT and Chironomidae were low due to the high numbers of Simulidae.

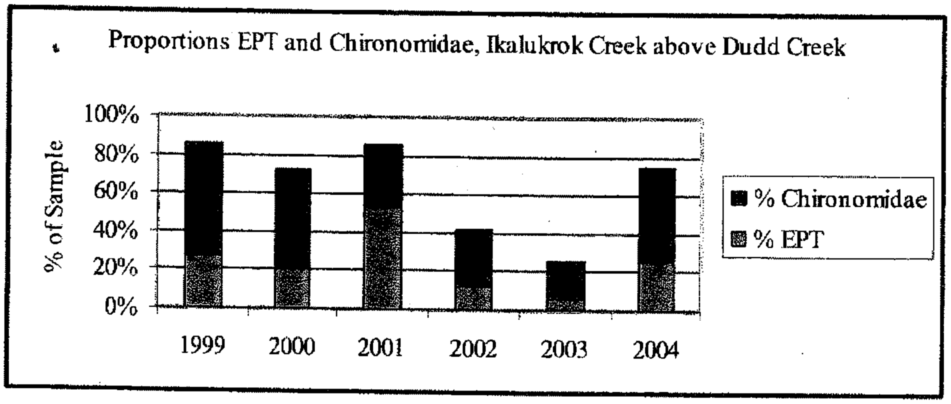


Figure 33. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek upstream of Dudd Creek.

Periphyton Standing Crop

Periphyton was sampled from benthic substrates in Ikalukrok Creek just upstream of Dudd Creek during the last week of June or the first week of July. Average chlorophyll-a concentrations were similar among years, but appear to have a decreasing trend from 2001 through 2004 (Figure 34).

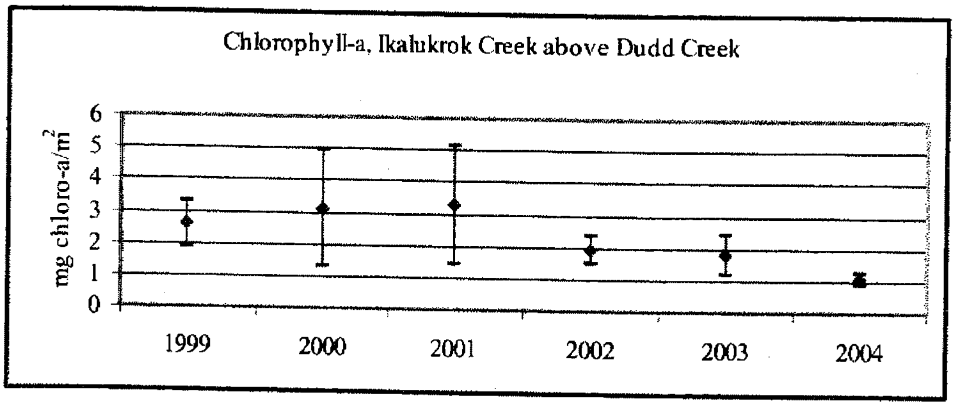


Figure 34. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek upstream of Dudd Creek.

Summary of Biomonitoring, Ikalukrok Creek Upstream of Dudd Creek, 1999-2004. Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 6.

Table 6. Summary of biomonitoring, Ikalukrok Creek upstream of Dudd Creek, 1999 to 2004.

Factor	Changes Observed
Water Quality	Peak in Cd seen in 2000, gradual trend for decreasing Ni and Zn
Invertebrates	Density – lowest in 2004, highest in 2000 Taxa Richness – lowest 13, highest 21 %EPT – variable, low of 6% to a high of 53%
Periphyton	Decreasing trend from 2001 through 2004
Larval Fish	Arctic grayling present in 2000, 2002, and 2003

Ikalukrok Creek at Station 7

Site Description

Ikalukrok Creek below Dudd Creek (Station 7, Figure 35) has widths from about 10 to 40 m and depths from 0.3 to 1.2 m. The substrate consists of small to medium sized gravel with prevalent gravel bars exposed at low flows. Ikalukrok Creek and Dudd Creek are not completely mixed at Station 7; complete mixing of the two creeks does not occur until about 8 km downstream.

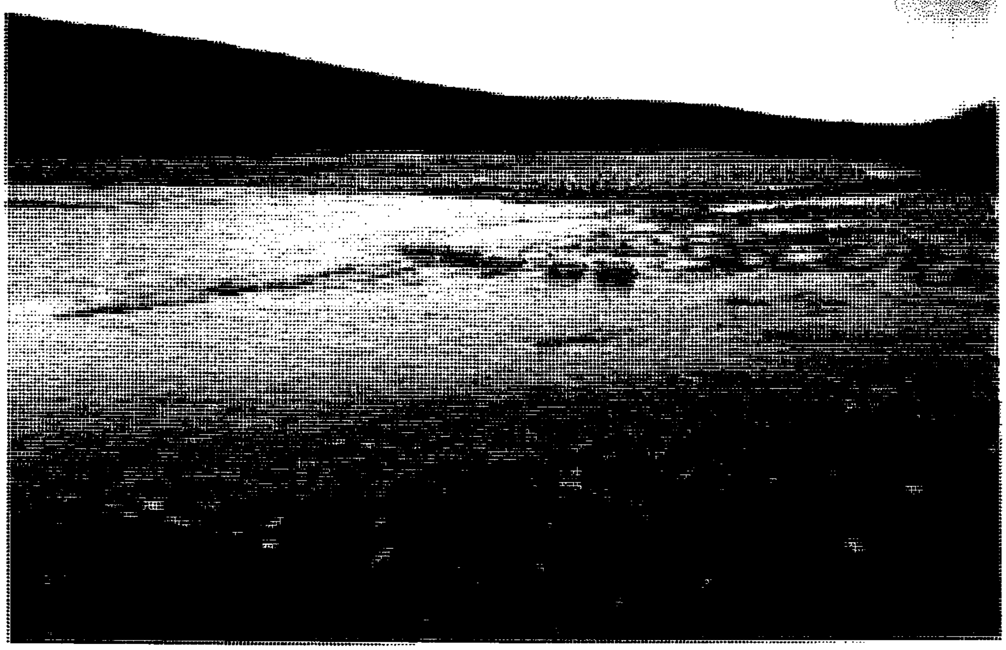


Figure 35. Ikalukrok Creek downstream of Dudd Creek, Station 7.

Water Quality

In May 1999, the stream gauge and monitoring station were moved from Station 7 near Dudd Creek downstream to Station 160. The new sampling station is located below complete mixing of Dudd and Ikalukrok creeks and in a more stable stream reach. Baseline data when presented would be from Station 7 while only water quality data from Station 160 are presented for 1999 through 2004.

Concentrations of TDS at Station 160 are shown in Figure 36. During summer 2004, TDS concentrations never exceeded 400 mg/L. The wastewater discharge is regulated from July 25 through October 31 to ensure that TDS concentrations do not exceed 500 mg/L at Station 160. Dolly Varden and chinook and chum salmon spawn in Ikalukrok Creek downstream of Station 160. Data on TDS indicate that TCAK was in compliance with the 500 mg/L limit in 2004.

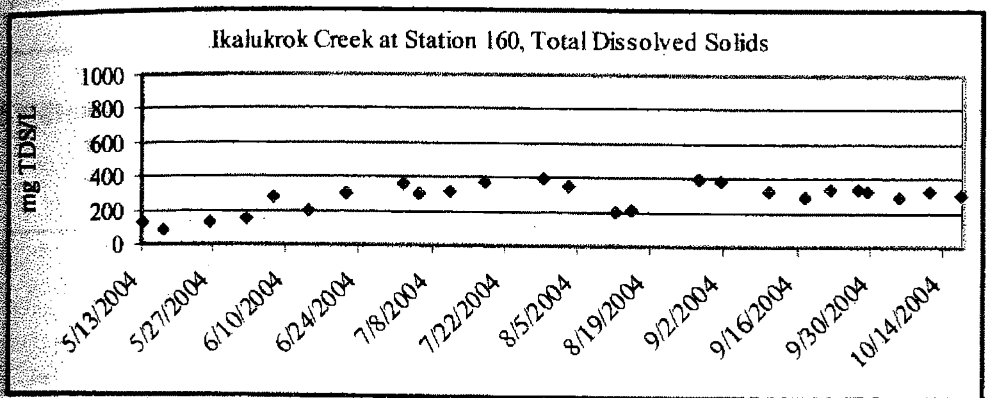


Figure 36. TDS concentrations in Ikalukrok Creek at Station 160.

Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 37 through 43. From 1999 through 2004, median concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn were similar, but maximum concentrations for Pb were higher than in baseline data. Median concentrations of Cd and Zn from 1999 to 2004 are lower than baseline data. Lower Ni concentrations from 1999 to 2004 probably are associated with a decreasing input of Ni from Cub Creek, located on Ikalukrok Creek upstream of Red Dog Creek. The decrease in Ni also was seen at Station 9 (Figure 7).

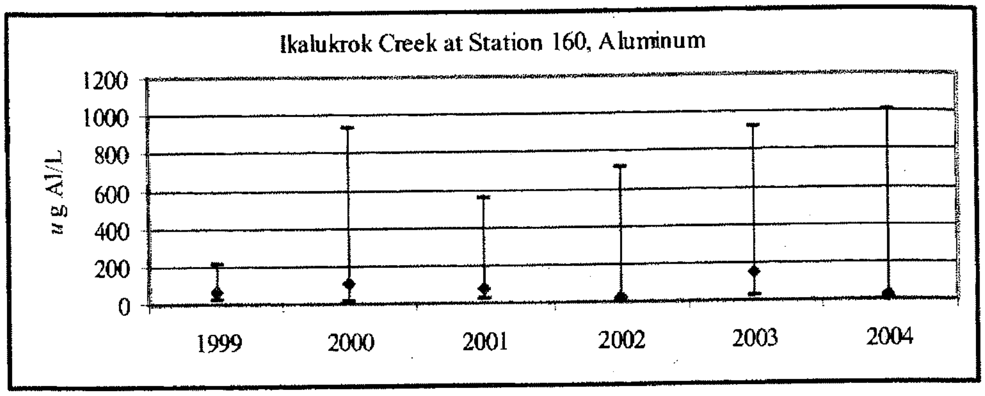


Figure 37. Median, maximum, and minimum concentrations of Al at Station 160.

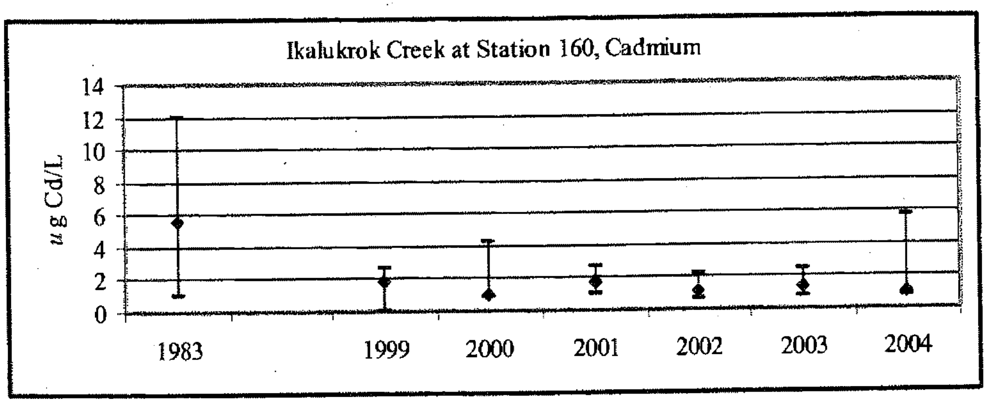


Figure 38. Median, maximum, and minimum concentrations of Cd at Station 160.

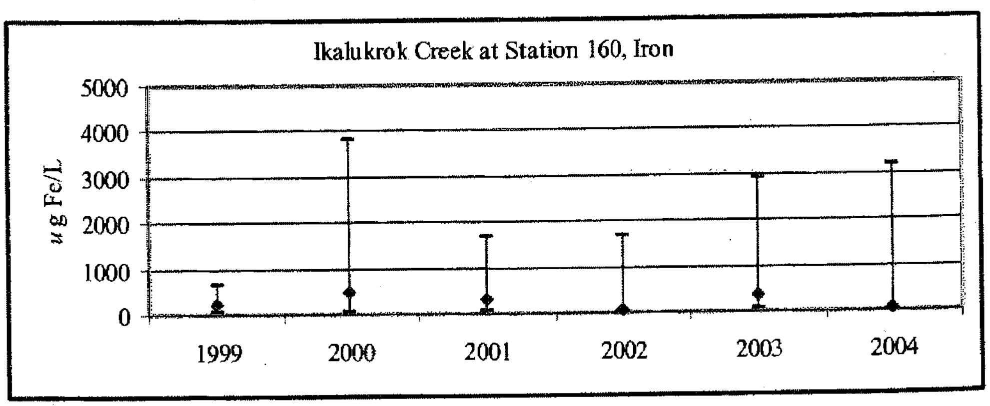


Figure 39. Median, maximum, and minimum concentrations of Fe at Station 160.

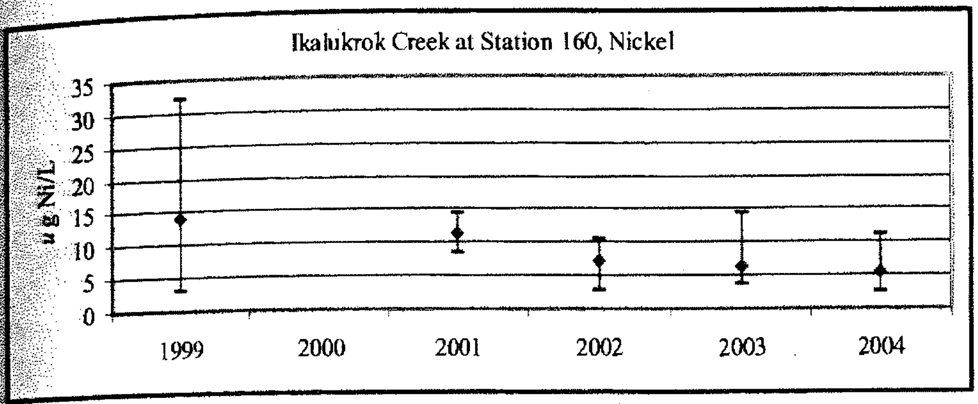


Figure 40. Median, maximum, and minimum concentrations of Ni at Station 160. Data from 2000 and one data point from 2001 are not presented due to a high detection limit of 50 *u*g/L.

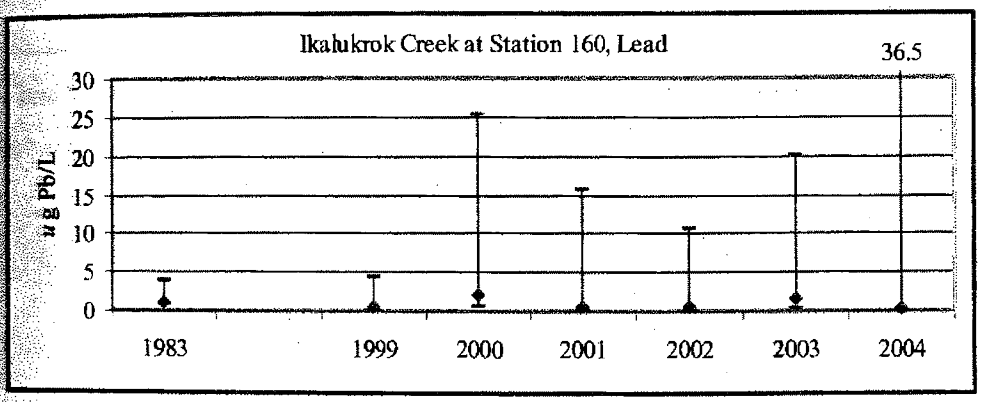


Figure 41. Median, maximum, and minimum concentrations of Pb at Station 160.

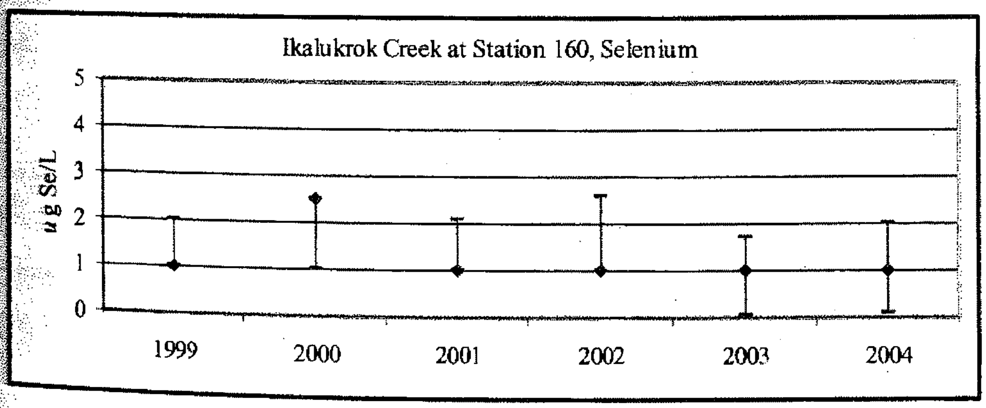


Figure 42. Median, maximum, and minimum concentrations of Se at Station 160.

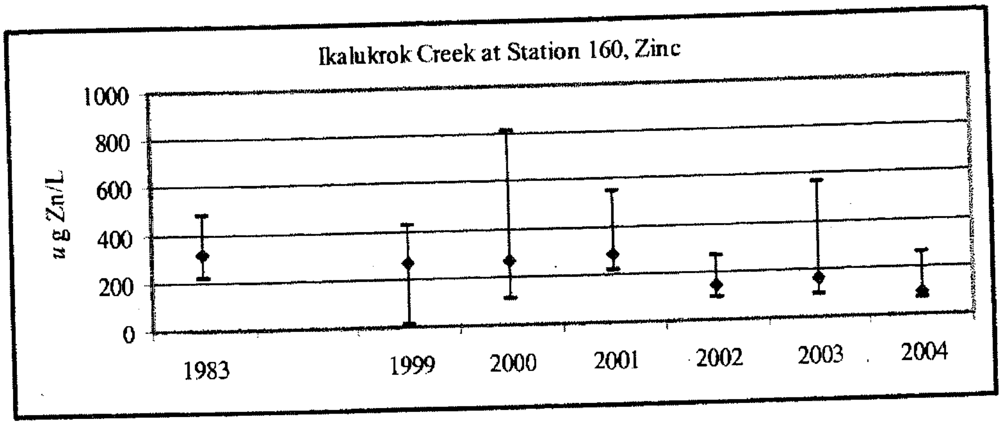


Figure 43. Median, maximum, and minimum concentrations of Zn at Station 160.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Both aquatic invertebrate abundance and density were highest in 2003 (Figures 44 and 45). Density of aquatic invertebrates was lowest in 2004 (Figure 45). Taxa richness has varied from a low of 10 (in 1999 and 2000) to a high of 24 in 2004 (Figure 46).

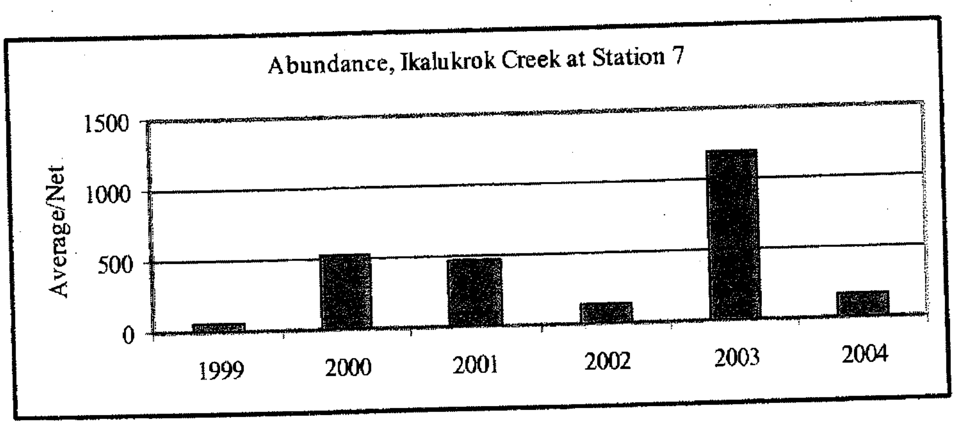


Figure 44. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

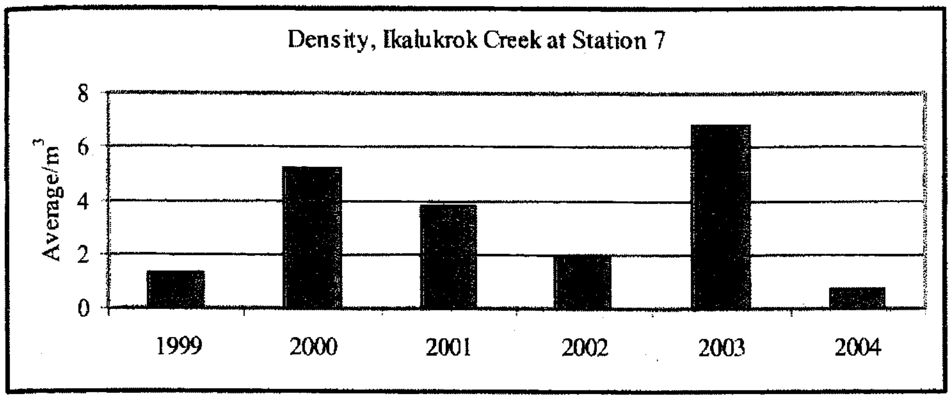


Figure 45. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

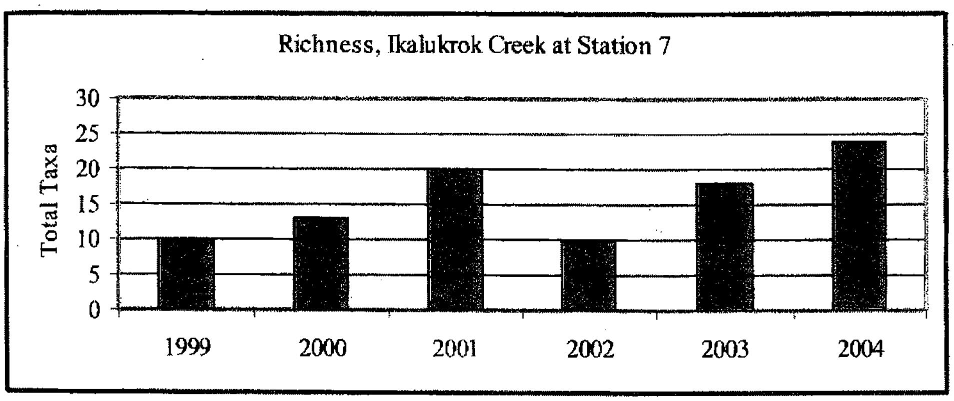


Figure 46. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

Community Structure

The highest proportion of EPT among the sample years occurred in 2001 when EPT represented 39%. In all the remaining years the EPT proportion was less than 20% (Figure 47).

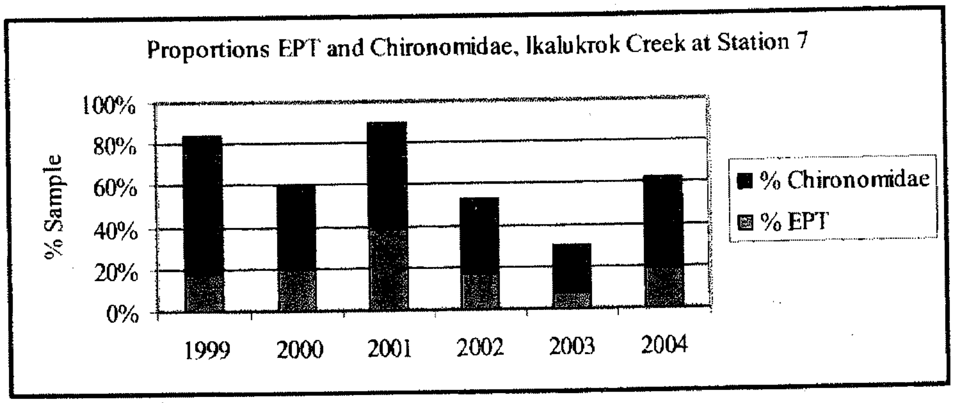


Figure 47. Proportions of EPT and Chironomidae larvae in invertebrate samples in Ikalukrok Creek at Station 7.

Periphyton Standing Crop

Algae biomass, as estimated by chlorophyll-a concentrations has been fairly consistent over the years with the highest average concentration found in 2000 (Figure 48).

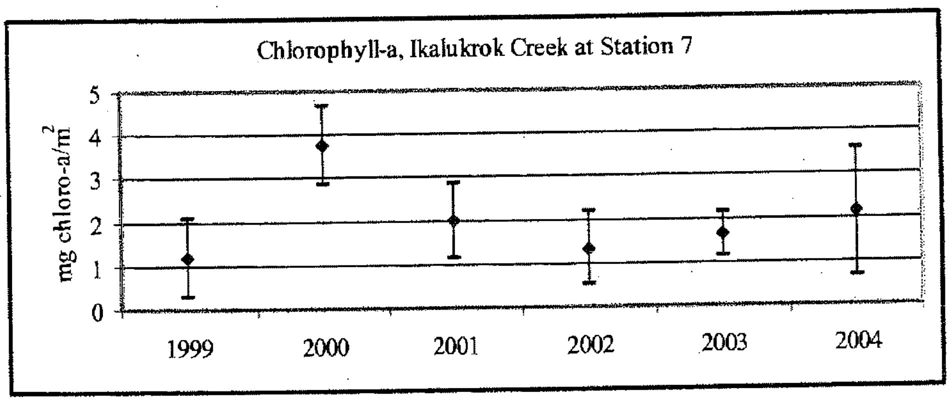


Figure 48. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 7.

Summary of Biomonitoring, Ikalukrok Creek at Station 7, 1999-2004.

Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 7.

Table 7. Summary of biomonitoring, Ikalukrok Creek at Station 7, 1999 to 2004.

Factor	Changes Observed
Water Quality	TDS concentrations below 500 mg/L Median concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn similar 1999 to 2004 Maximum concentrations of Al, Fe, and Pb higher than baseline, Cd and Zn were lower
Invertebrates	Density – lowest in 2004, highest in 2003 Taxa Richness – lowest 10, highest 24 %EPT – variable, low of 6% to a high of 39%
Periphyton	Fairly consistent in all sample years
Larval Fish	Arctic grayling 2000, 2002, 2003

Mainstem Red Dog Creek at Station 10

Site Description

Mainstem Red Dog Creek (Figure 49) drains an area of 64 km^2. Widths of the creek range from 3.5 to 18 m and water depths vary from 0.06 to 2.5 m. The streambed consists mostly of gravel, small cobble, and boulders. The creek has some meanders and areas where the channel has shifted location.

Figure 49. Mainstem Red Dog Creek, Station 10

Water Quality

The volume of the effluent from the mine controls TDS concentrations in Mainstem Red Dog Creek. Concentrations of TDS are limited in the creek to less than 500 mg/L during Arctic grayling spawning. Arctic grayling are sampled, depending upon flow and ice conditions, with fyke nets and by angling in both Mainstem Red Dog and North Fork Red Dog creeks. After Arctic grayling spawning has been completed in Mainstem Red Dog Creek, the TDS concentrations can be increased to not exceed 1,500 mg/L at Station 10

(Figure 50). Arctic grayling spawning was determined to be complete on May 31, 2004. Measured TDS concentrations did not exceed 500 mg/L until after Arctic grayling had spawned (Figure 50).

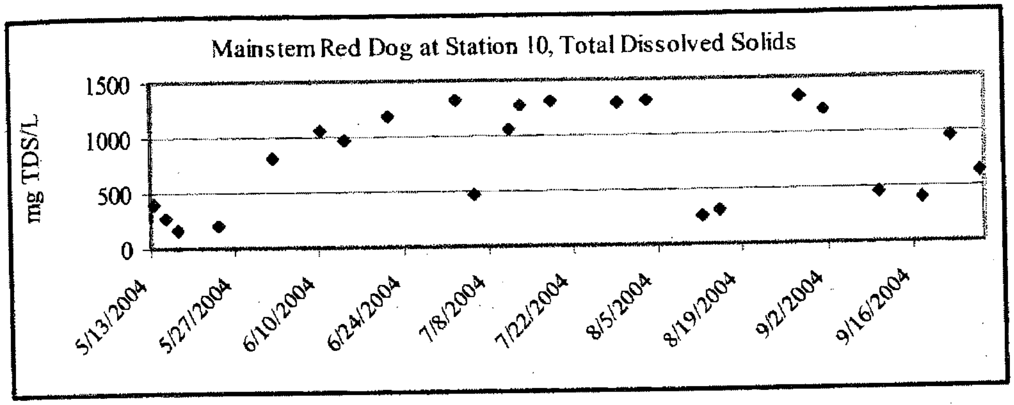


Figure 50. Seasonal variation in TDS concentrations in Mainstem Red Dog Creek at Station 10.

Concentrations of certain metals in Mainstem Red Dog Creek at Station 10 were high before mining, highest in 1989 and 1990, and lower after construction of the clean water bypass in March/April of 1991. The pH values reflect these conditions with the lowest pH measured in 1990 and higher pH reported from 1999 through 2004 as compared with either premining or 1990 (Figure 51).

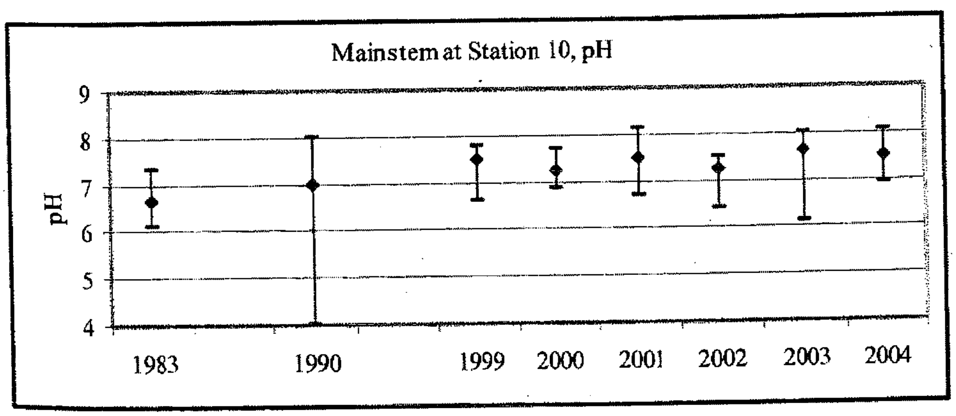


Figure 51. Median, maximum, and minimum pH values in Mainstem Red Dog Creek at Station 10.

Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 52 through 58. Median concentrations of Cd are lower than premining, but the median concentration increased slightly in 2004, with a peak of 28.9 *u*g/L.

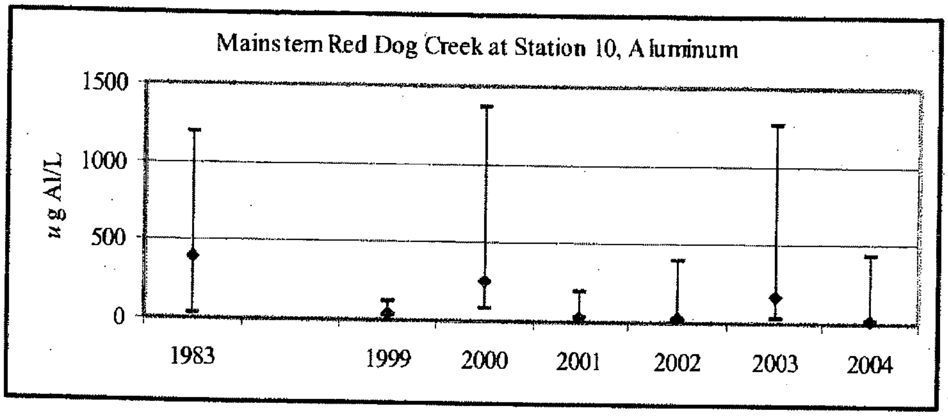


Figure 52. Median, maximum, and minimum concentrations of Al at Station 10.

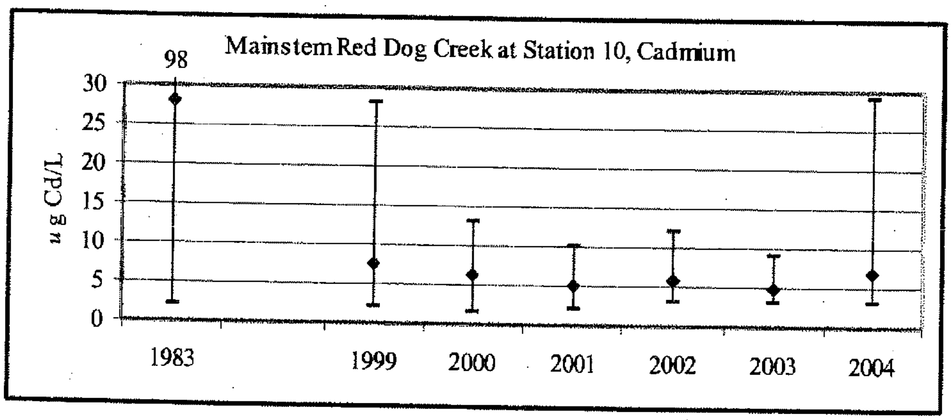


Figure 53. Median, maximum, and minimum concentrations of Cd at Station 10.

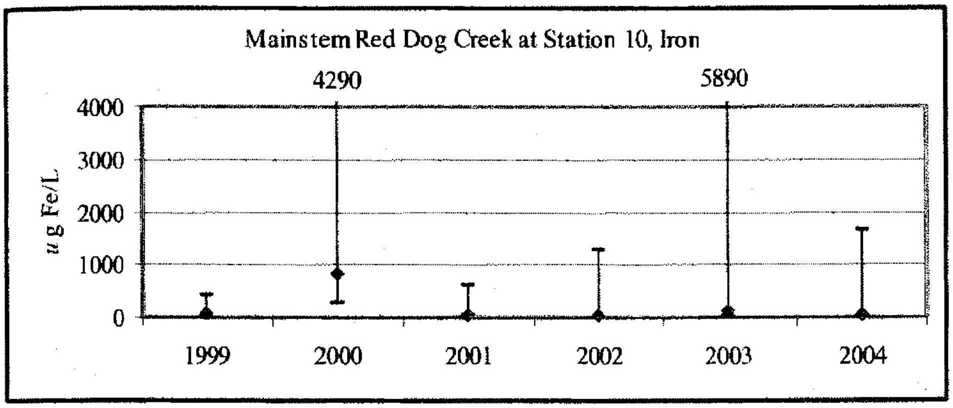


Figure 54. Median, maximum, and minimum concentrations of Fe at Station 10.

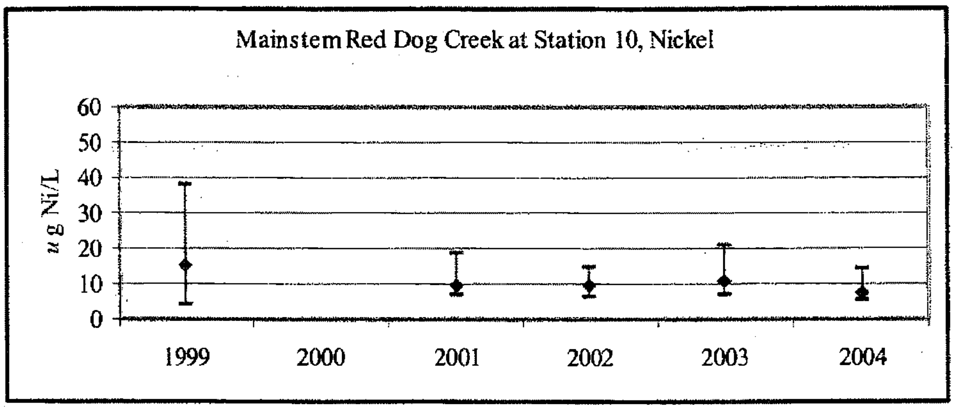


Figure 55. Median, maximum, and minimum concentrations of Ni at Station 10. Data from 2000 are not presented due to a high detection limit of 50 *u*g/L.

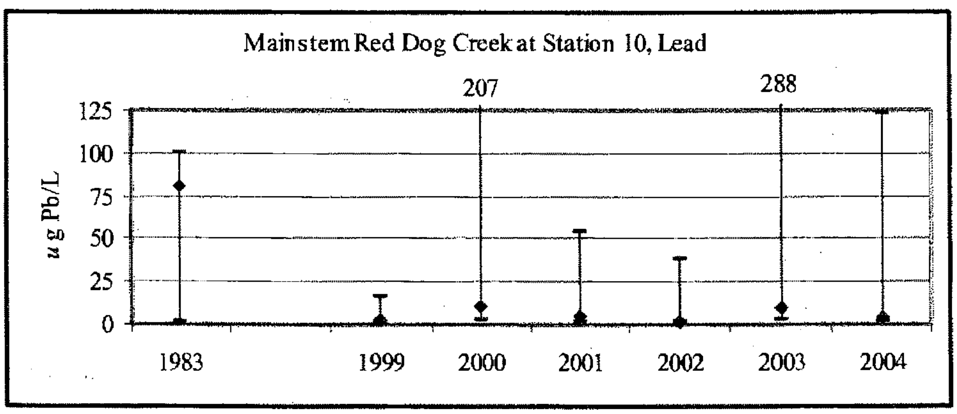


Figure 56. Median, maximum, and minimum concentrations of Pb at Station 10.

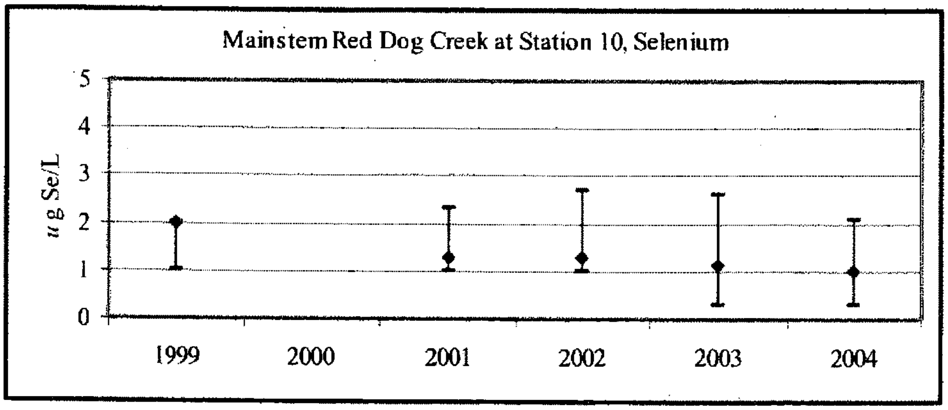


Figure 57. Median, maximum, and minimum concentrations of Se at Station 10. Data from 2000 are not presented due to a high detection limit of 25 *u*g/L.

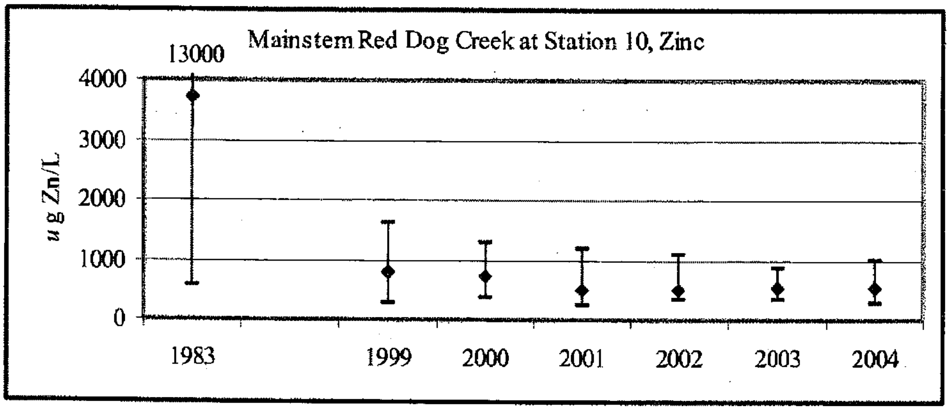


Figure 58. Median, maximum, and minimum concentrations of Zn at Station 10.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance and density were highest in 2003 (Figures 59 and 60). Taxa richness was highest in 2001 and 2003 when 20 different taxa were collected (Figure 61). The lowest number of taxa identified was 10 in 2000 (Figure 61).

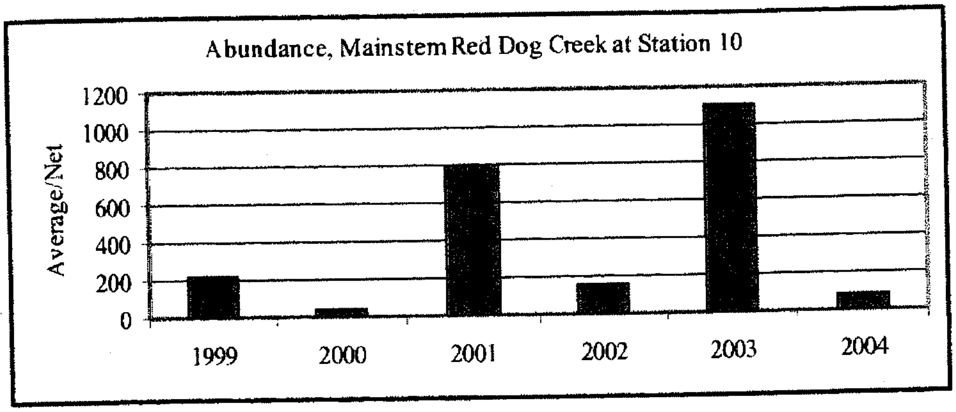


Figure 59. Abundance of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

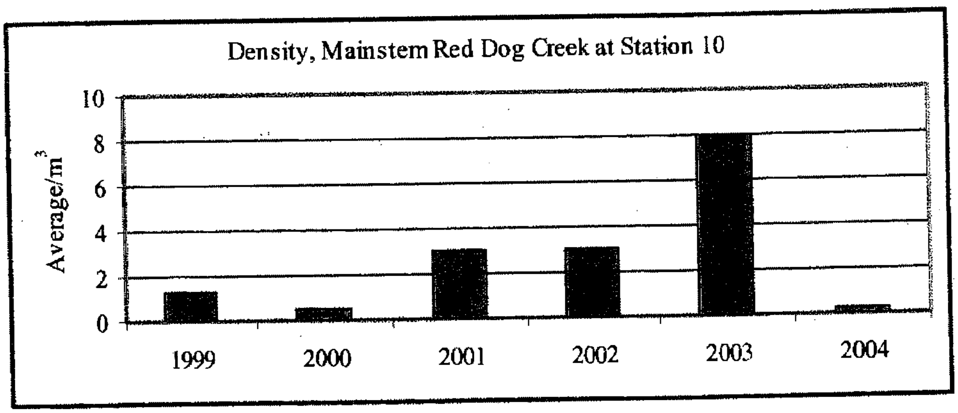


Figure 60. Density of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

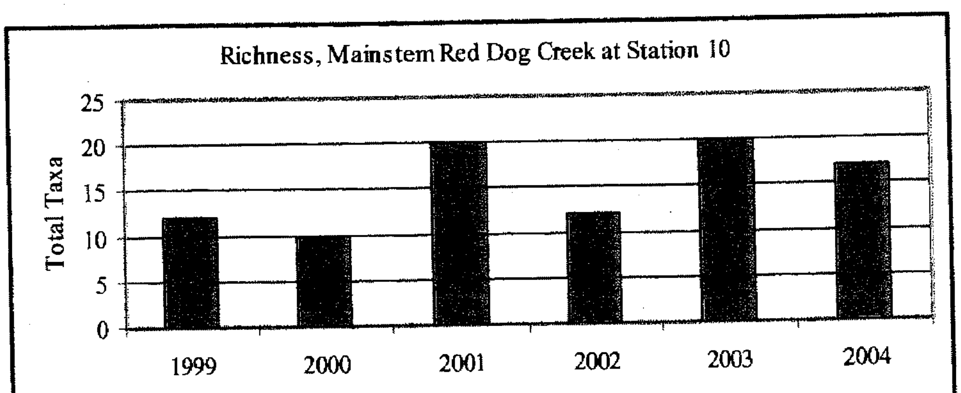


Figure 61. Taxa richness of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

Community Structure

Invertebrate samples from Mainstem Red Dog Creek contained a high proportion of EPT in 2000, 2003, and 2004 (Figure 62). In 2004, the EPT represented 51% of the aquatic invertebrates in the samples (Figure 62).

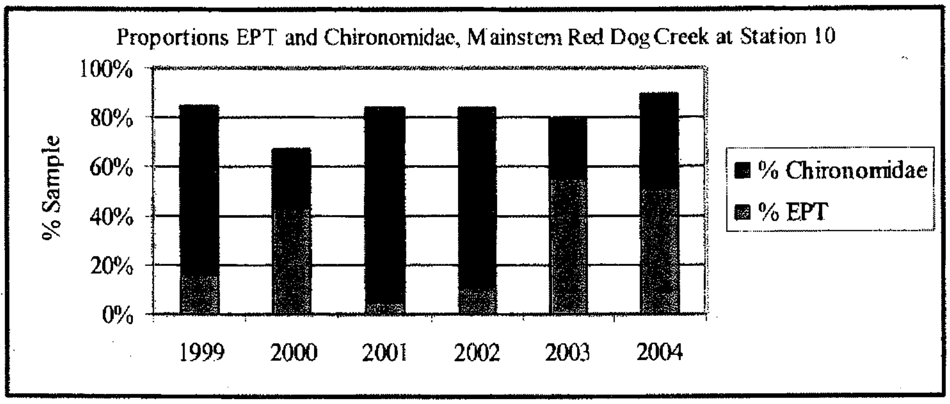


Figure 62. Proportions of EPT and Chironomidae larvae in invertebrate samples in Mainstem Red Dog Creek at Station 10.

Periphyton Standing Crop

The highest average concentration for chlorophyll-a at Station 10 in Mainstem Red Dog Creek was found in summer 2004 (Figure 63).

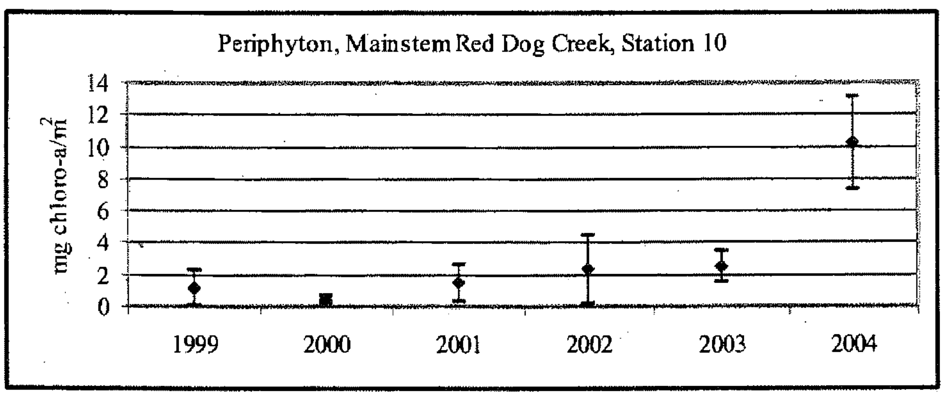


Figure 63. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Mainstem Red Dog Creek at Station 10.

Summary of Biomonitoring, Mainstem Red Dog Creek at Station 10, 1999-2004. Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 8.

Table 8. Summary of biomonitoring, Mainstem Red Dog Creek at Station 10, 1999 to 2004.

Factor	Changes Observed
Water Quality	TDS concentrations below 500 mg/L during Arctic grayling spawning Median concentrations of Ni, Se, and Zn decreasing with time from 1999 to 2004 Maximum concentrations of Cd higher and Cd Median concentration increased in 2004
Invertebrates	Density – lowest in 2004, highest in 2003 Taxa Richness – lowest 10, highest 20 %EPT – variable, low of 5% to a high of 55%
Periphyton	Chlorophyll-a concentrations substantially higher in summer 2004
Larval Fish	Arctic grayling present in 1999, 2000, 2002, and 2003

Middle Fork Red Dog Creek at Station 20

Site Description

Middle Fork Red Dog Creek has a drainage area of 12 km^2 with the flow coming from the clean water bypass channel (Station 140) and the treated mine effluent. Upper Middle Fork Red Dog Creek and tributaries (Rachael, Connie, Shelly, and Sulfur creeks) flow into the clean water bypass system. Sulfur Creek flows intermittently. Middle Fork Red Dog Creek has wide meanders with channel widths from 3 to 10 m and depths from 0.03 to 0.45 m (Figure 64). Migration of fish into Middle Fork Red Dog Creek is blocked by a gabion basket weir structure located just above the confluence of North Fork and Middle Fork Red Dog creeks.

Figure 64. Middle Fork Red Dog Creek, Station 20

Water Quality

Station 20 was not sampled regularly for water quality. Before mining, pH ranged from 5.7 to 6.9 (Figure 65). The pH values from 2000 through 2004 are higher than values that were recorded before mining. Higher pH values are directly related to higher pH values in the effluent from the water treatment plant.

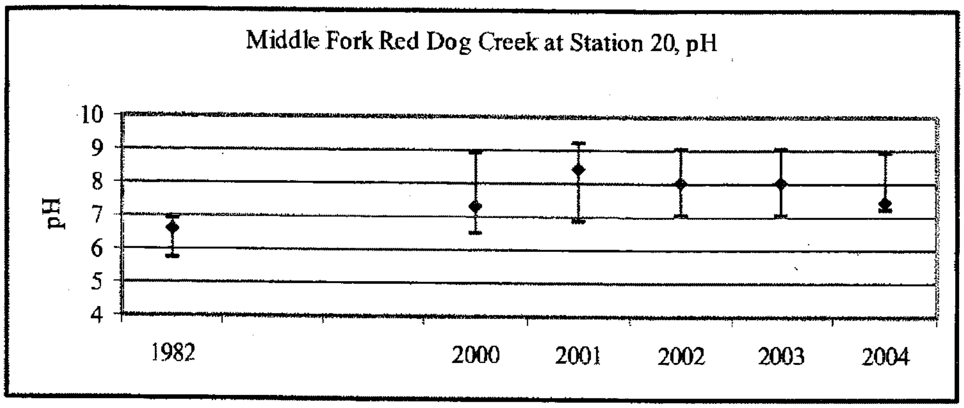


Figure 65. Median, maximum, and minimum pH values in Middle Fork Red Dog Creek at Station 20.

Median concentrations of metals in Middle Fork Red Dog Creek were similar among all years of the NPDES Permit monitoring period (1999-2004, Figures 66 through 72). Median concentrations of Ni and Se appear to have decreased from 1999 to 2004 (Figures 69 and 71). Concentrations of Cd and Zn have consistently been lower than those reported from baseline studies (Figures 67 and 72). Lead concentrations also have been lower than baseline, but there have been peaks (maximum concentrations) that exceeded those found premining (Figure 70).

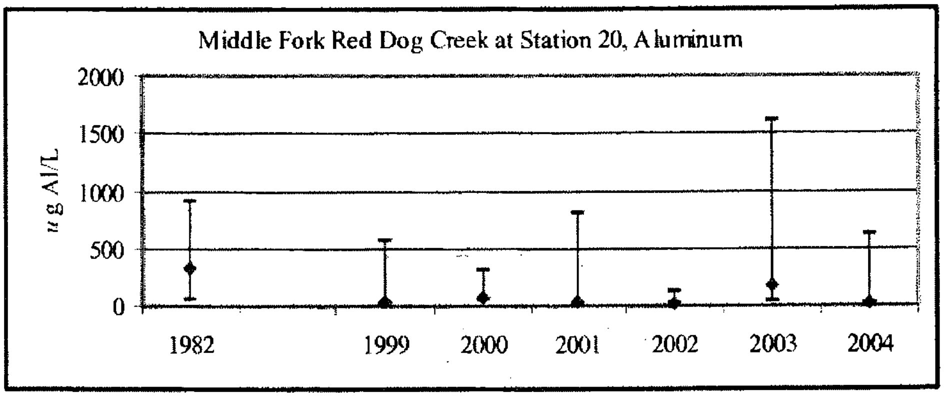


Figure 66. Median, maximum, and minimum concentrations of Al at Station 20.

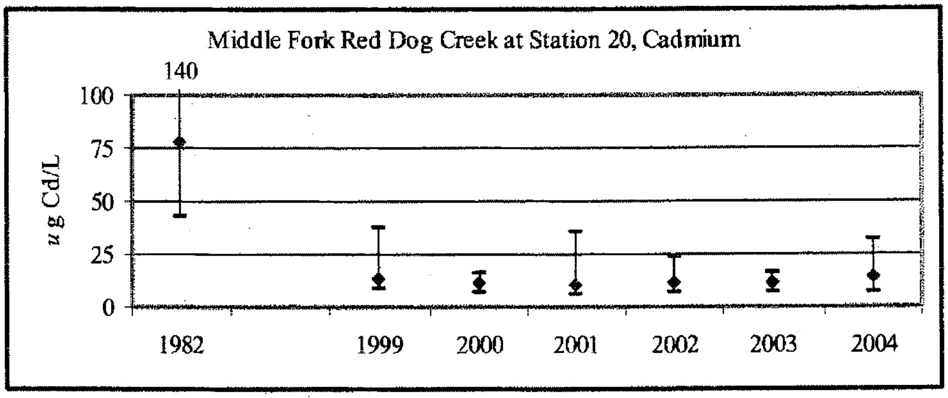


Figure 67. Median, maximum, and minimum concentrations of Cd at Station 20.

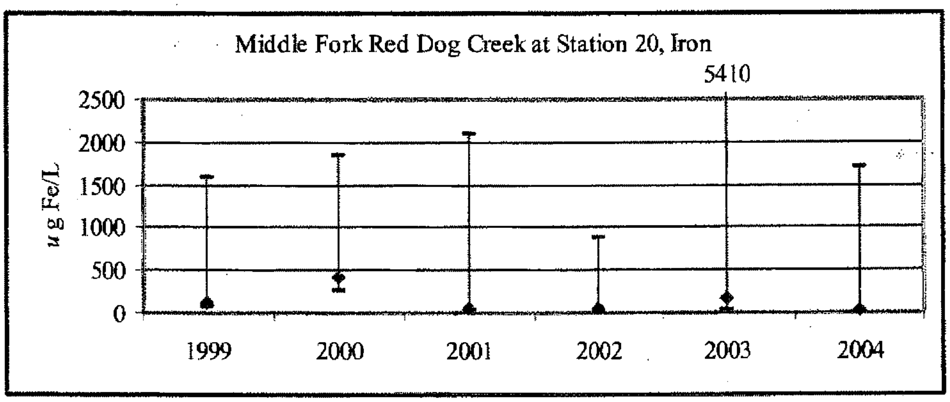


Figure 68. Median, maximum, and minimum concentrations of Fe at Station 20.

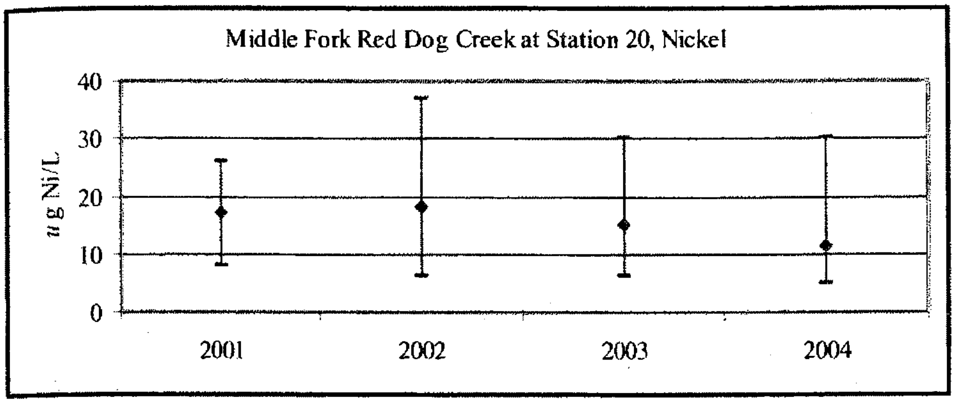


Figure 69. Median, maximum, and minimum concentrations of Ni at Station 20. Data from 1999 are not presented, only one data point available. Data from 2000 are not presented due to a high detection limit of 50 *u*g/L.

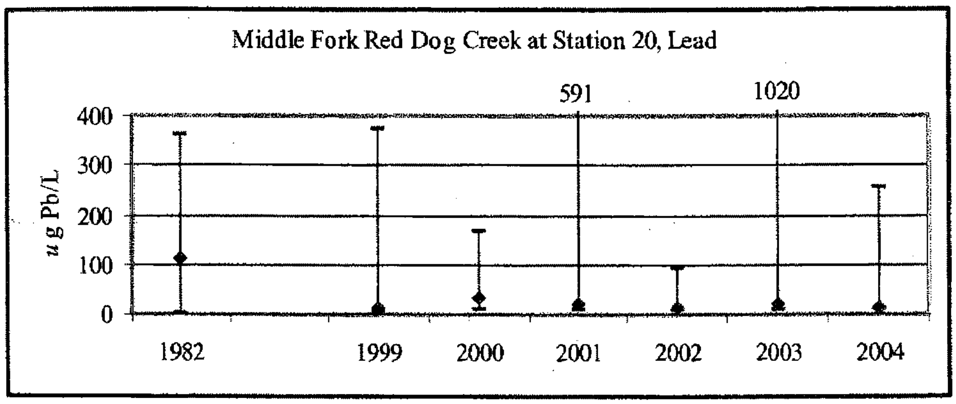


Figure 70. Median, maximum, and minimum concentrations of Pb at Station 20.

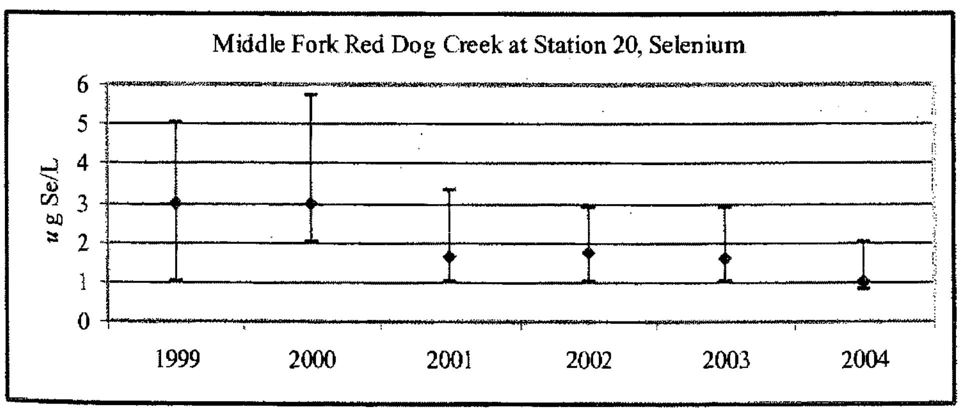


Figure 71. Median, maximum, and minimum concentrations of Se at Station 20.

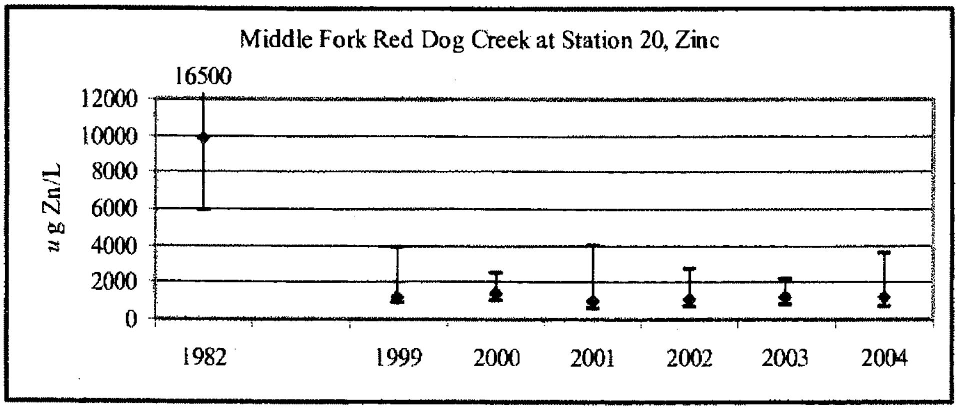


Figure 72. Median, maximum, and minimum concentrations of Zn at Station 20.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance, density, and taxa richness were highest in 2003 (Figures 73, 74, and 75). Taxa richness ranged from a low of 14 in 1999 to a high of 28 in 2003 (Figure 75).

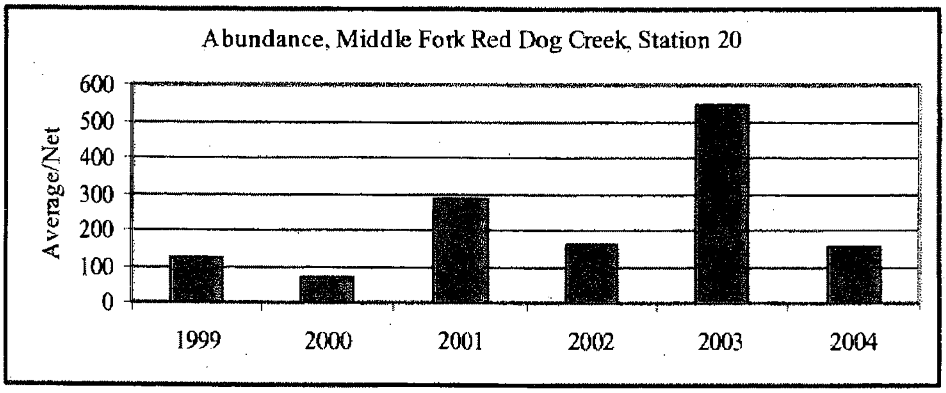


Figure 73. Abundance of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

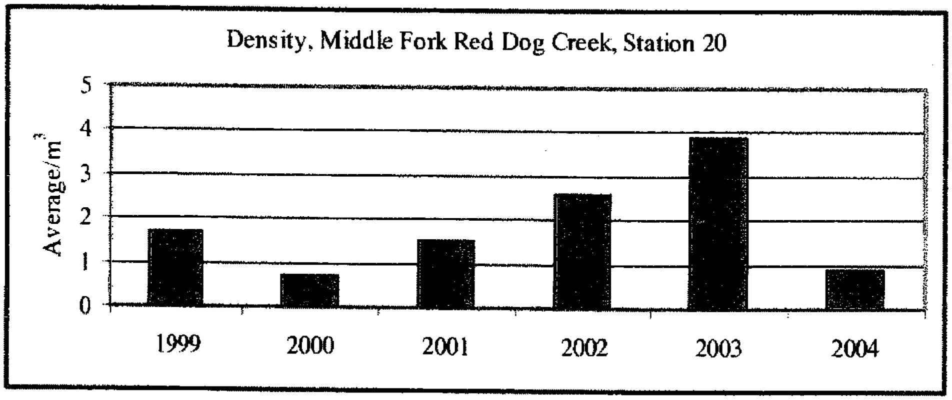


Figure 74. Density of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

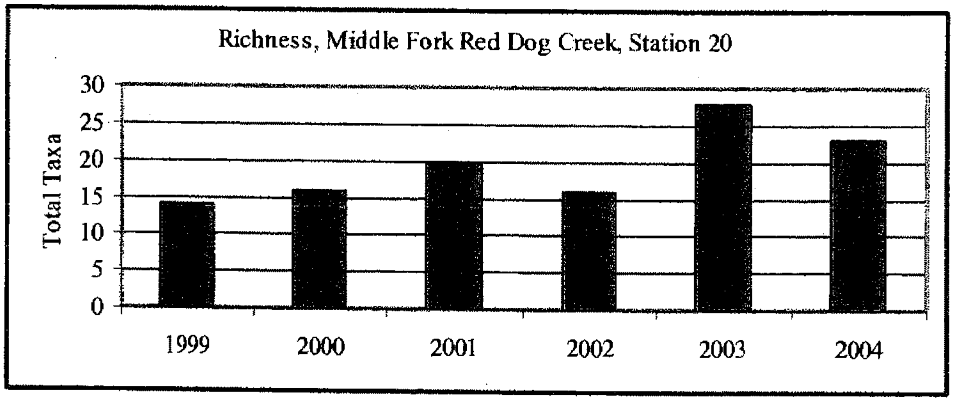


Figure 75. Taxa richness of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

Community Structure

The invertebrate community in Middle Fork Red Dog Creek contained a low percentage of EPT from 1999 through 2003 that ranged from 7 to 20%. In 2004, the EPT represented 55% of the aquatic invertebrates sampled (Figure 76). In 2004, 28% of the aquatic invertebrates were Ephemoptera and 24% were Plecoptera (Figure 76).

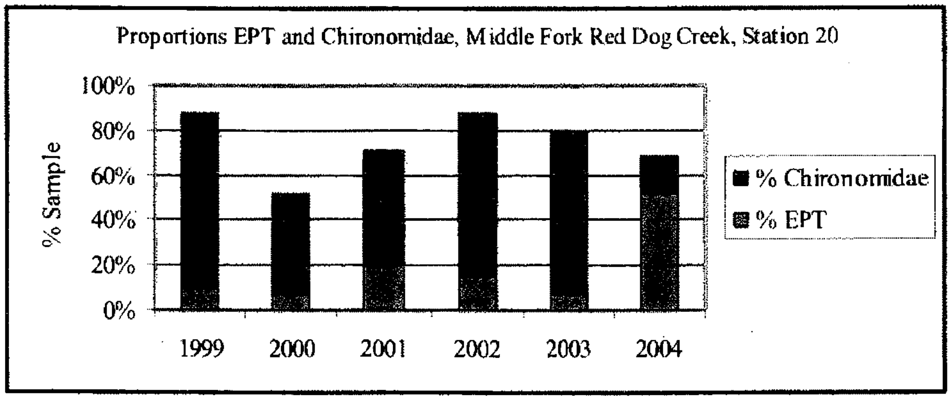


Figure 76. Proportions of EPT and Chironomidae larvae in invertebrate samples in Middle Fork Red Dog Creek at Station 20.

Periphyton Standing Crop

The concentration of chlorophyll-a in Middle Fork Red Dog Creek at Station 20 has been consistently lower than any of the other NPDES sample sites (Figure 77). Only in 2001 did samples have sufficient amounts of chlorophyll to distinguish the three major pigments (Ott and Weber Scannell 2003).

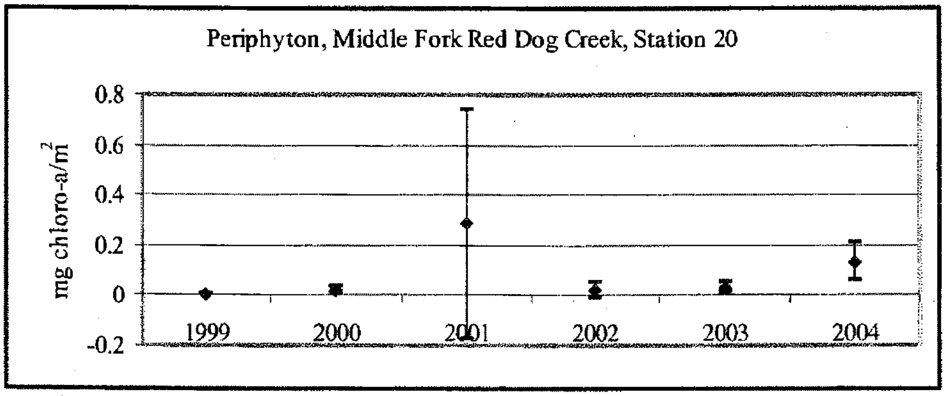


Figure 77. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Middle Fork Red Dog Creek at Station 20.

Summary of Biomonitoring, Middle Fork Red Dog Creek at Station 20, 1999-2004. Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 9.

Table 9. Summary of biomonitoring, Middle Fork Red Dog Creek at Station 20, 1999 to 2004.

Factor	Changes Observed
Water Quality	Median concentrations metals similar 1999 to 2004 Median concentrations of Cd and Zn decreasing Cd and Zn consistently lower than premining
Invertebrates	Density – lowest in 2000, highest in 2003 Taxa Richness – lowest 14, highest 28 %EPT – variable, low of 7% to a high of 52%
Periphyton	Below detections limits all years except 2001
Larval Fish	none

North Fork Red Dog Creek at Station 12

Site Description

North Fork Red Dog and Middle Fork Red Dog creeks merge to form Mainstem Red Dog Creek. North Fork Red Dog Creek has a drainage area of 41 km^2, abundant streamside vegetation, deep pools, and wide riffle areas (Figure 78). Widths range from 7 to 15 m and depths from 0.1 to 2 m. Arctic grayling spawn in North Fork Red Dog Creek and juvenile Dolly Varden and Arctic grayling rear in this system during the ice-free season.

Figure 78. North Fork Red Dog Creek, Station 12

Water Quality

North Fork Red Dog Creek is a clearwater stream that drains an area containing ice-rich soils. Thermal degradation in the upper part of the watershed has caused periodic increased turbidity in the system since about 2000. Turbid water conditions and deposited sediments have been observed each year since 2000, although at most times North Fork Red Dog Creek flows clear. Concentrations of metals in North Fork Red Dog Creek generally are below the USEPA standard for aquatic life (Weber Scannell and Anderson 2000). Metals concentrations are shown in Figures 79 through 85. Some of maximum coneentrations of Al, Fe, and Pb exceeded baseline data and may be related to the input of sediment laden waters to North Fork Red Dog Creek from thermal/hydraulic erosion.

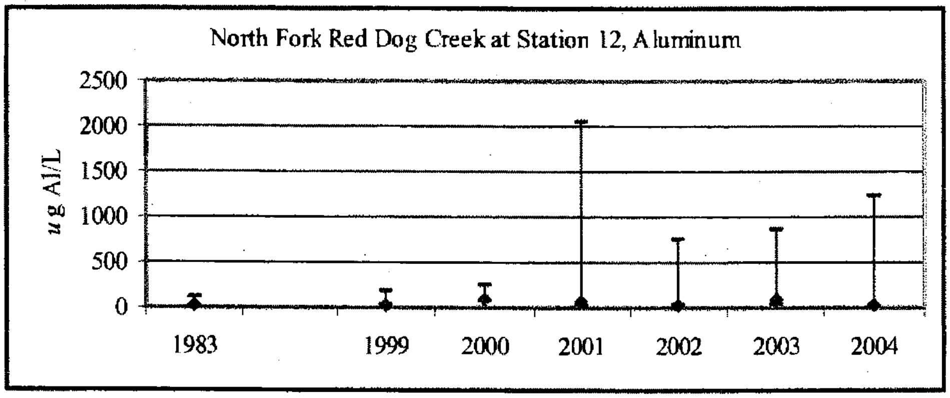


Figure 79. Median, maximum, and minimum concentrations of Al at Station 12.

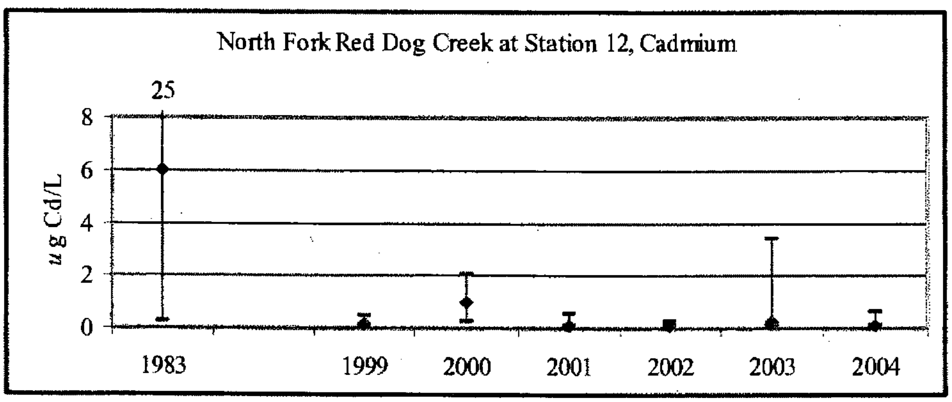


Figure 80. Median, maximum, and minimum concentrations of Cd at Station 12.

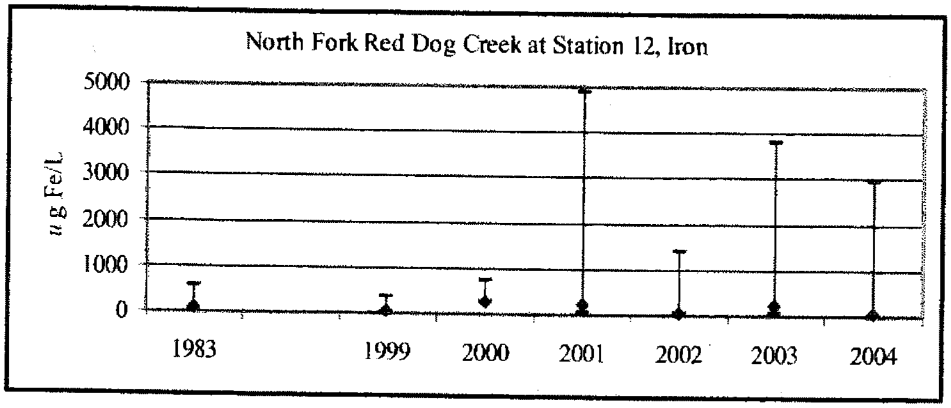


Figure 81. Median, maximum, and minimum concentrations of Fe at Station 12.

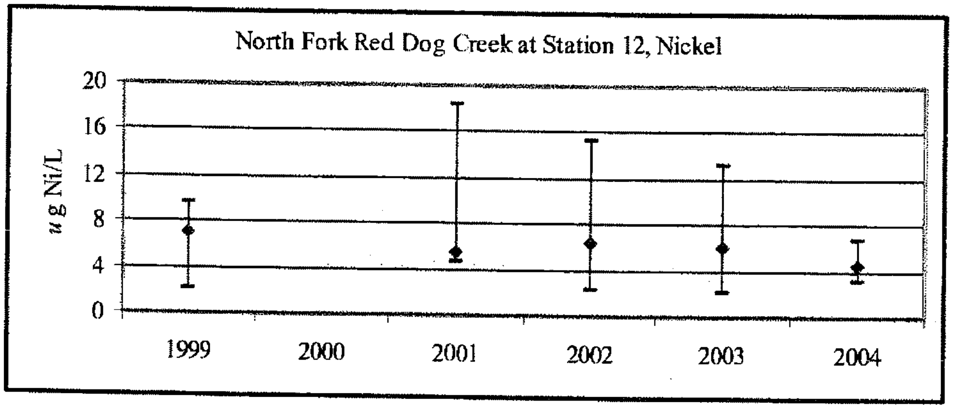


Figure 82. Median, maximum, and minimum concentrations of Ni at Station 12.

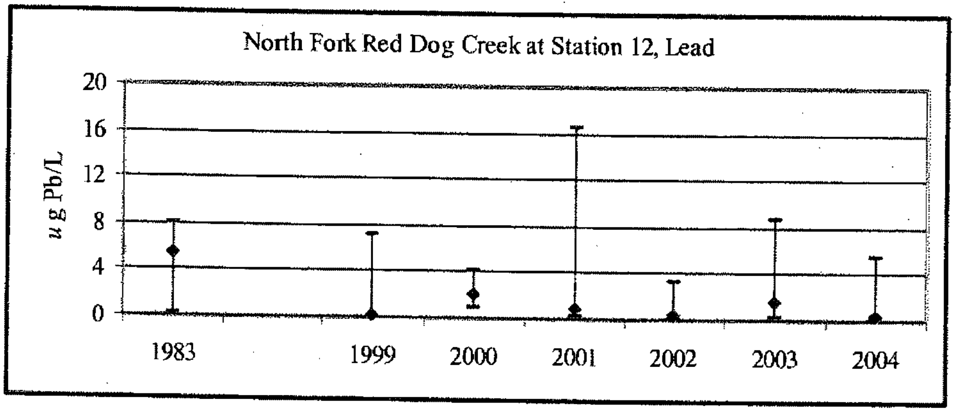


Figure 83. Median, maximum, and minimum concentrations of Pb at Station 12.

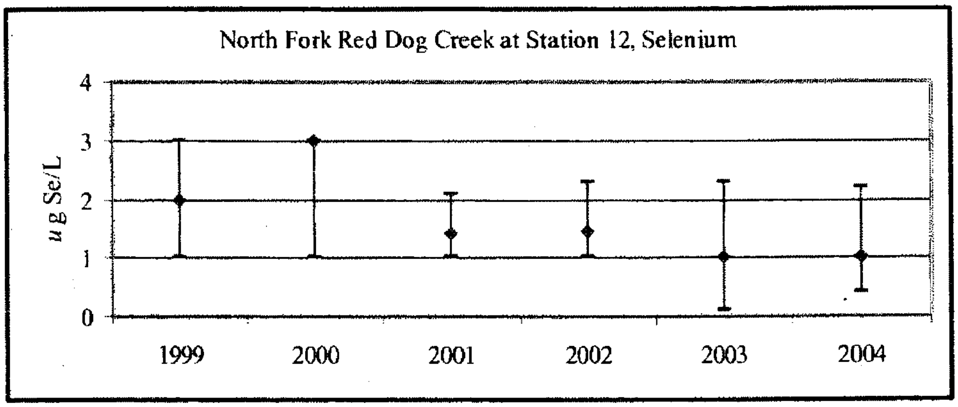


Figure 84. Median, maximum, and minimum concentrations of Se at Station 12.

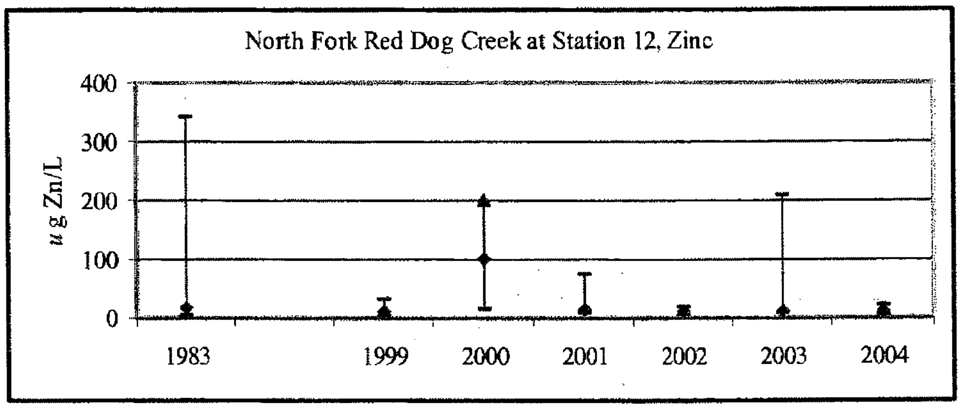


Figure 85. Median, maximum, and minimum concentrations of Zn at Station 12. The triangle in 2000 represents a MDL, not a concentration.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance in North Fork Red Dog Creek at Station 12 ranged from a low of 87 in 2004 to a high of 1,502 in 2001 (Figure 86). Densities of aquatic invertebrates were fairly consistent and high from 1999 through 2003, but low in 2004 (Figure 87). Densities from 1999 through 2003 ranged from 7 to 11, but in 2004 the density was 0.6 aquatic invertebrates/m^3 of water. Taxa richness has been fairly consistent with a low of 13 and a high of 26 (Figure 88).

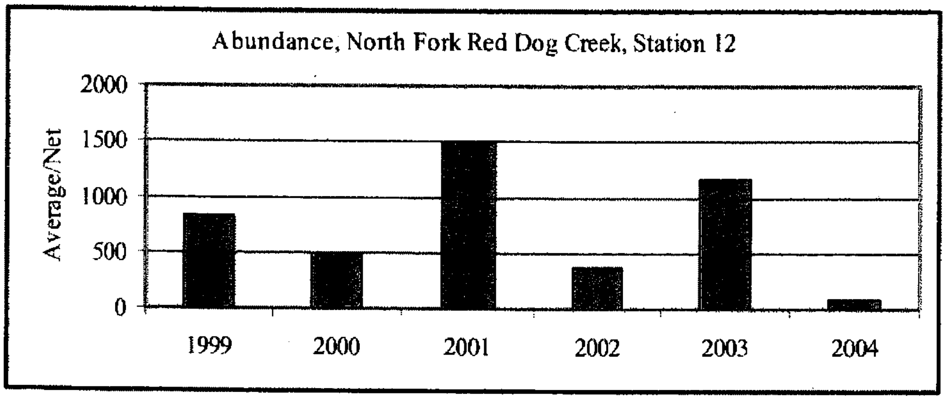


Figure 86. Abundance of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

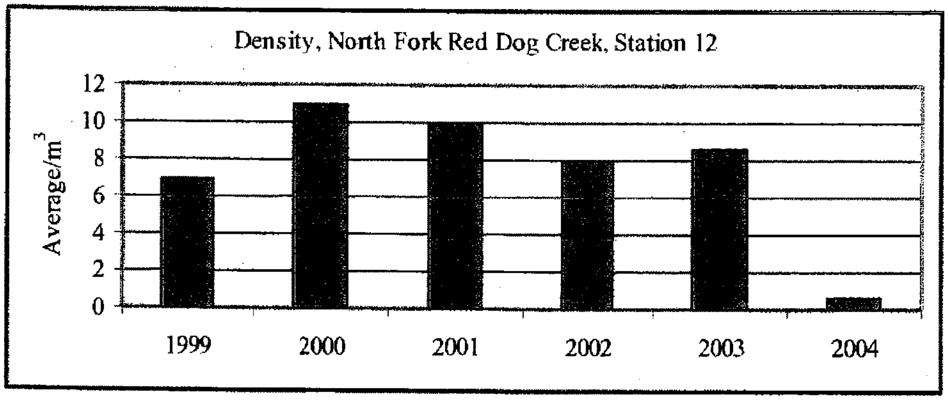


Figure 87. Density of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

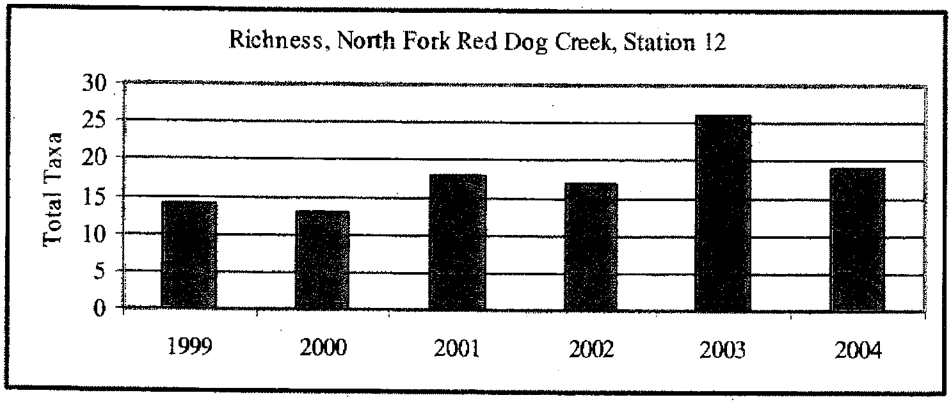


Figure 88. Taxa richness of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

Community Structure

Invertebrate samples from North Fork Red Dog Creek contained low proportions of EPT (less than 25%) in most sample events, except for 2002 and 2004 when EPT was greater than 50% (Figure 89).

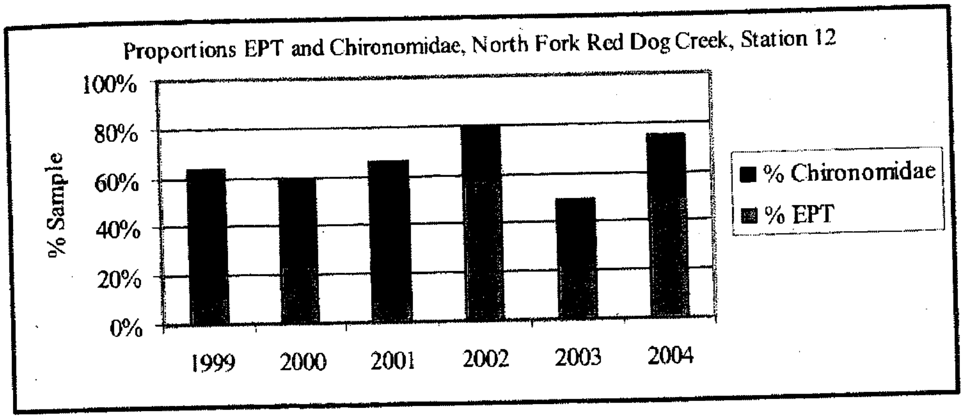


Figure 89. Proportions of EPT and Chironomidae larvae in invertebrate samples in North Fork Red Dog Creek at Station 12.

Periphyton Standing Crop

North Fork Red Dog Creek contained abundant attached algae in all sample years from 1999 through 2003, but not in 2004 (Figure 90).

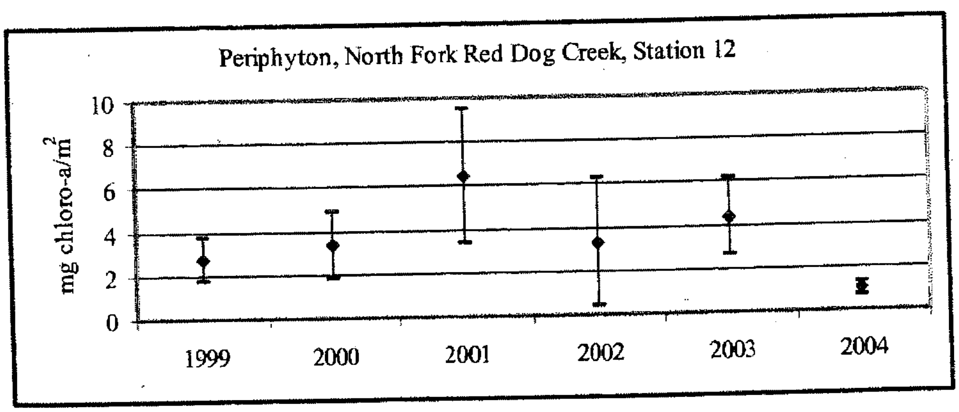


Figure 90. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in North Fork Red Dog Creek at Station 12.

Summary of Biomonitoring, North Fork Red Dog Creek at Station 12, 1999-2004. Changes in water quality, invertebrates, and periphyton and presence of larval fish that have been documented over time are summarized in Table 10.

Table 10. Summary of biomonitoring, North Fork Red Dog Creek at Station 12, 1999 to 2004.

Factor	Changes Observed
Water Quality	Maximum Al values higher than premining In some years, the maximum Fe values higher than premining Median Cd and Pb values lower than premining
Invertebrates	Density – lowest in 2004, highest in 2000 Taxa Richness – lowest 13, highest 26 %EPT – variable, low of 9% to a high of 55%
Periphyton	Lowest concentrations found in 2004
Larval Fish	Arctic grayling present in 1997, 1999, 2000, and 2001

Middle Fork Red Dog Creek at Station 140

Site Description

Station 140 is located in Middle Fork Red Dog Creek downstream of the clean water bypass and upstream of the discharge point from the wastewater treatment plant. Fish, invertebrate, and periphyton sampling is not done at Station 140, but water quality data are collected. The pH values are presented in Figure 91. The pH values have consistently been higher and less acidic since construction and use of the clean water bypass system.

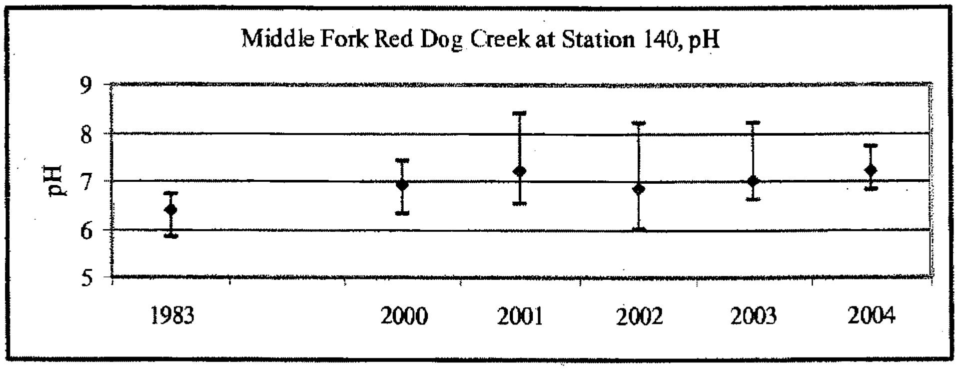


Figure 91. Median, maximum, and minimum pH values in Middle Fork Red Dog Creek at Station 140.

Concentrations of Cd, Pb, and Zn are presented in Figures 92 through 95. These analytes were selected because premining data are available. Median concentrations of Cd, Pb, and Zn at Station 140 are consistently lower (1999 through 2004) than premining, indicating that the clean water bypass system is working to minimize downstream loading of metals to receiving waters. Immediately adjacent to the clean water bypass and at a lower elevation is the dirty water collection system that takes water to a pump-back site where the water is transferred to the tailing impoundment for treatment.

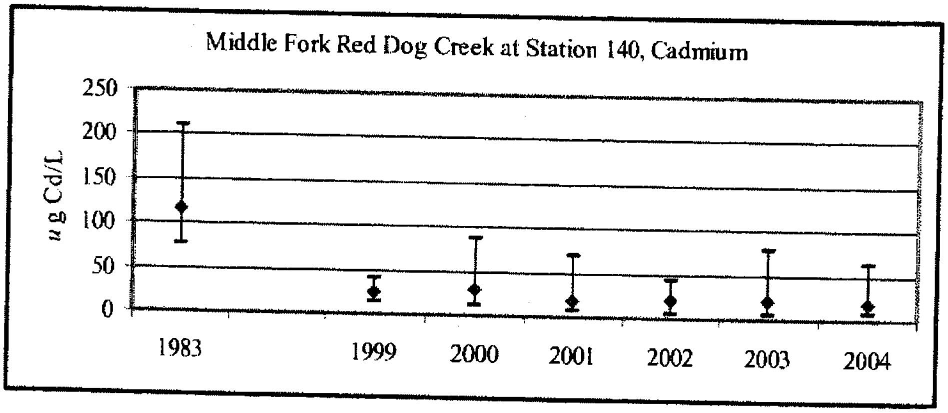


Figure 92. Median, maximum, and minimum concentrations of Cd at Station 140.

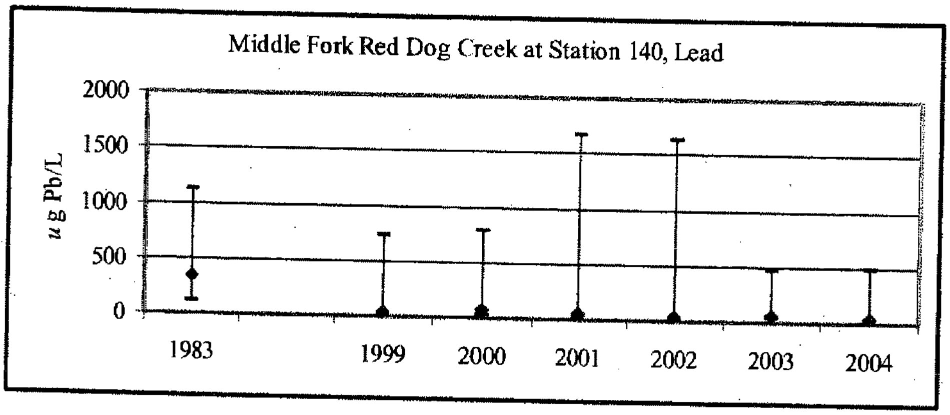


Figure 93. Median, maximum, and minimum concentrations of Pb at Station 140.

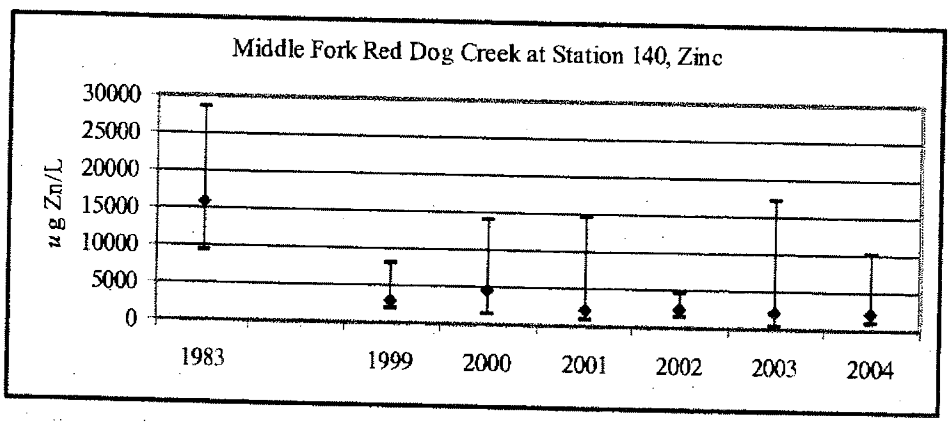


Figure 94. Median, maximum, and minimum concentrations of Zn at Station 140.

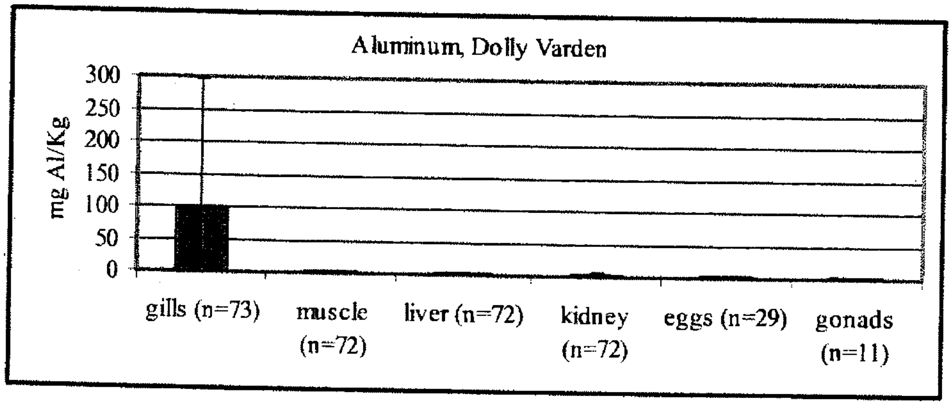
Metals Concentrations in Adult Dolly Varden, Wulik River

Since 1990, we have sampled adult Dolly Varden from the Wulik River for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle (Weber Scannell et al. 2000). In 1997, we included Se analysis and in 1998 we started sampling reproductive tissues when available. In 2003, we added Hg and Ca to the analytes being tested. In 2004, Dolly Varden tissues were analyzed for Al, Cd, Cu, Pb, Se, and Zn. The number of fish in each sample period was six, except for fall 2002 when only five fish were caught.

The purpose of sampling adult Dolly Varden for metals concentrations is to monitor long-term condition over the life of the Red Dog Mine and to identify changes in metals concentrations that may be related to mining activities. All laboratory work, beginning in 1990, has been done with Level III Quality Assurance.

Metals are known to concentrate preferentially in certain organs; however, the relationship of organ concentration of metals to the ambient environmental concentrations is not known. Concentrations of metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals vary with exposure to freshwater and marine environments. Our data from Wulik River Dolly Varden suggest the following:

- Al concentrates in gill tissue (Figure 95);
- Cd concentrates in kidney tissue (Figure 96);
- Cu concentrates in liver tissue (Figure 97);
- Pb concentrates in gill tissue (Figure 98);
- Se concentrates in kidney and ovarian tissue (Figure 99);
- Zn concentrates in ovarian tissue (Figure 100);
- Hg concentrates in kidney tissue (Figure 101); and
- None of the analytes concentrate in muscle tissue.



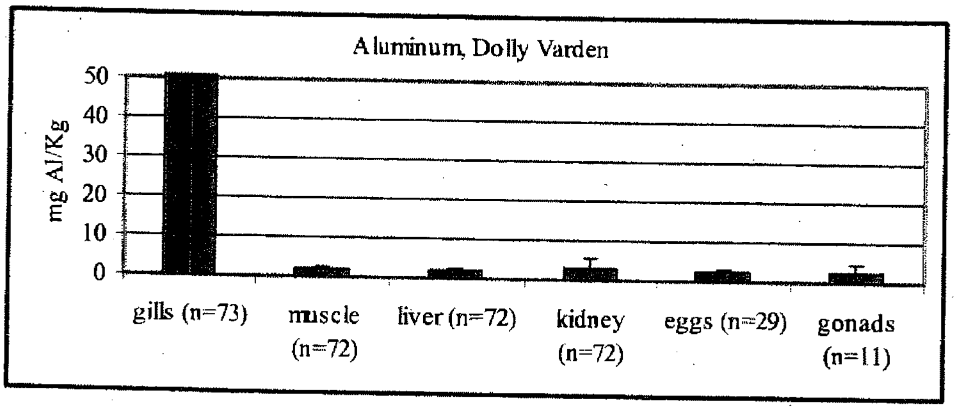


Figure 95. Al concentrations (two graphs with identical data, but different scales) are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

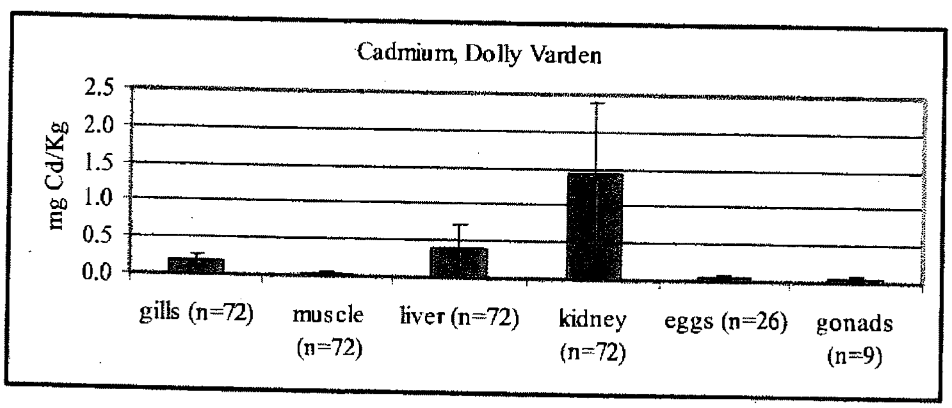


Figure 96. Cd concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

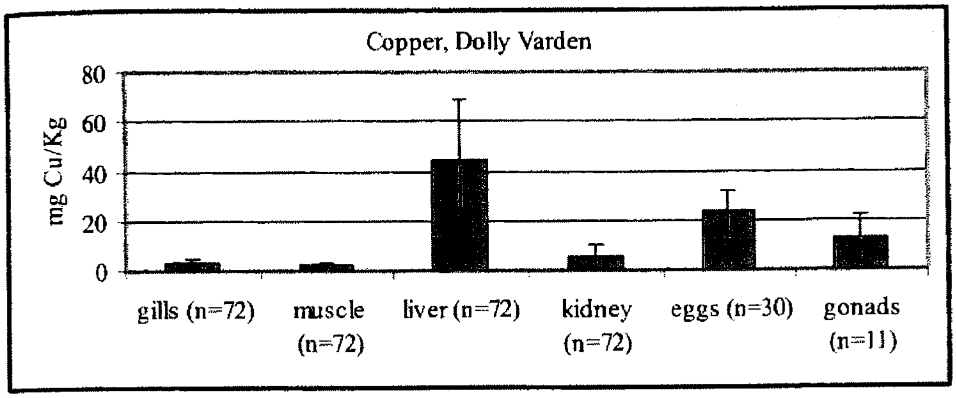


Figure 97. Cu concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

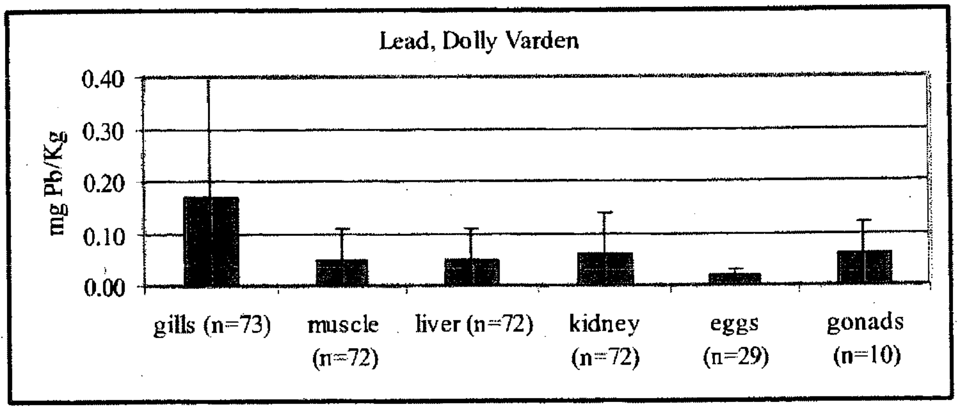


Figure 98. Pb concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

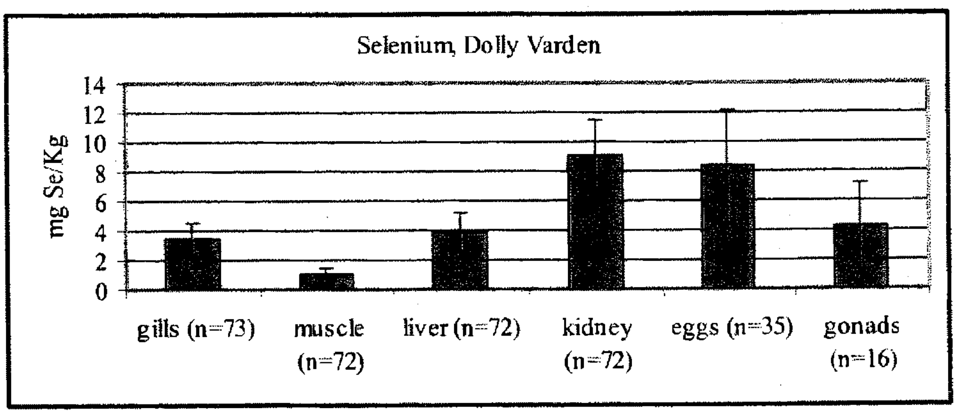


Figure 99. Se concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

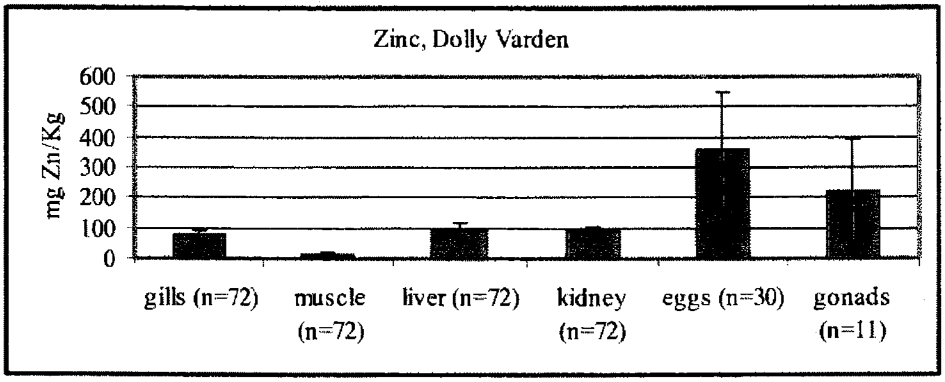


Figure 100. Zn concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation.

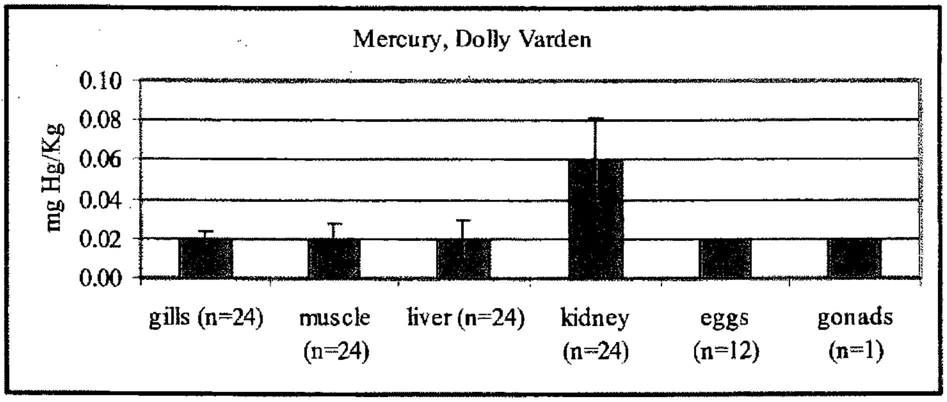


Figure 101. Hg concentrations are the average of all fish collected during the NPDES sample period (1999-2004) plus and minus one standard deviation. Detection limit for Hg was 0.02 mg/Kg.

To determine trends in metals concentrations, we focused on these relationships: Al in gill; Cd in kidney; Cu in liver; Pb in gill; Se in ovary; Zn in ovary, and Hg in kidney. Two years of data (24 fish) were available for Hg. Hg is not present in the ore body and is not used in the process at the mine.

Aluminum

Median concentrations of Al in gill tissue have been highly variable within samples and among the spring and fall sample periods (Figure 102). No real pattern or trend appears to exist for Al in gill tissue, other than the fact that it is highly variable.

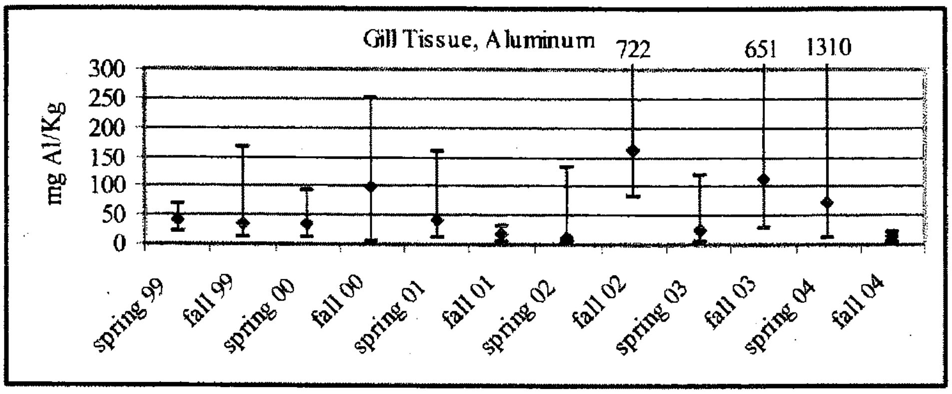


Figure 102. Median, maximum, and minimum concentrations of Al (dry weight) in Dolly Varden gill tissue (1999-2004). Baseline data for Al not available.

Cadmium

Median Cd concentrations in Dolly Varden kidney tissues from 1999 through 2004, both spring and fall, were lower than those reported in baseline sampling (Figure 103). Cd concentrations in fall-caught fish generally are lower the spring-caught fish (Figure 103).

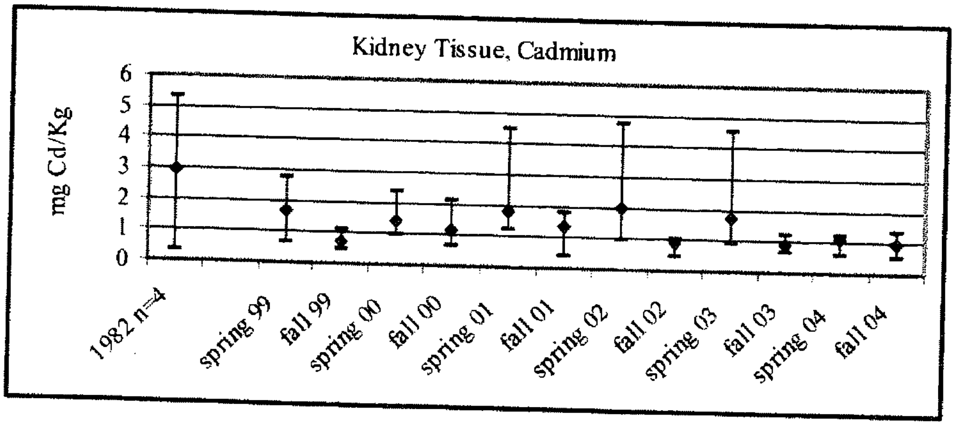


Figure 103. Median, maximum, and minimum concentrations of Cd (dry weight) in Dolly Varden kidney tissue (1999-2004). Baseline data for Cd are included.

Copper

Median concentrations of Cu have consistently been higher from 1999 through 2004 than reported from baseline studies (Figure 104). Virtually no change in Cu concentrations has been seen from 1999 through 2004. Fall-caught fish have lower median Cu concentrations than spring-caught fish. Copper water quality data were not presented in the water quality section of this report, because most results are below the detection limit.

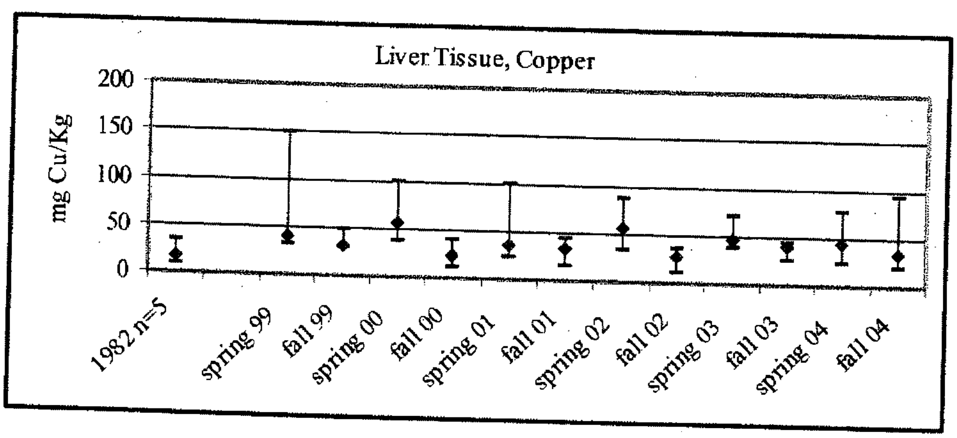


Figure 104. Median, maximum, and minimum concentrations of Cu (dry weight) in Dolly Varden liver tissue (1999-2004). Baseline data for Cu are included.

Lead

The concentration of Pb in Dolly Varden gill tissue from fish collected prior to mining was below the detection limits used in 1982 and 1983 (0.03 or 0.04 mg/Kg). Median concentrations of Pb in Dolly Varden gill tissue from 1999 through 2004 were higher than those found in baseline sampling (Figure 105). Median concentrations of Pb in fall 2004 in gill tissue were the lowest measured to date for post mining sampling with three of the six fish having Pb concentrations less than the detection limit (0.02 mg/Kg).

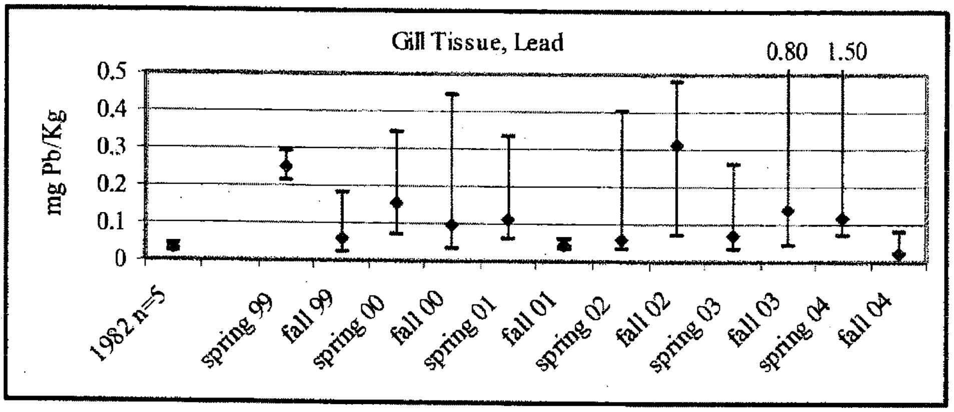


Figure 105. Median, maximum, and minimum concentrations of Pb (dry weight) in Dolly Varden gill tissue (1999-2004). Baseline data for Pb are included.

Selenium

Median Se concentrations in Dolly Varden were consistently higher in fall-caught fish (Figure 106). The highest median concentrations of Se were found in the fall 2002 sample. Se concentrations appear to have remained similar for 2003 and 2004.

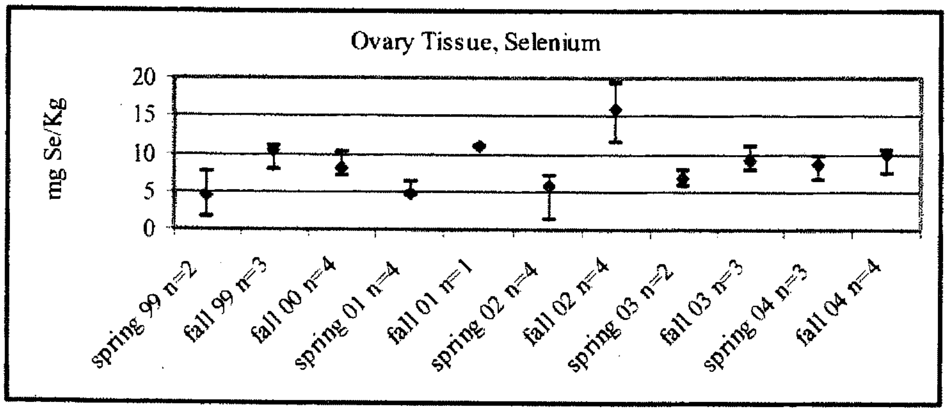


Figure 106. Median, maximum, and minimum concentrations of Se (dry weight) in Dolly Varden ovarian tissue (1999-2004). Baseline data for Se not available.

Zinc

Median Zn concentrations in ovarian tissue have remained fairly consistent during the sample period (Figure 107). Generally, Zn concentrations are higher in fall-caught fish than those captured in the spring (Figure 107).

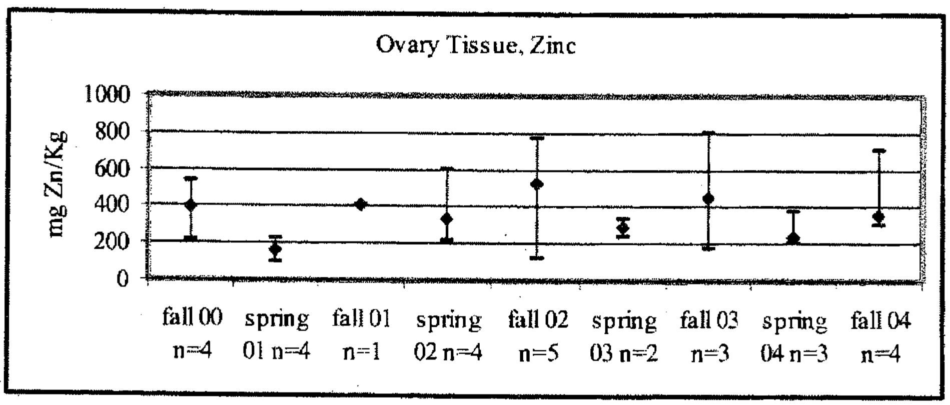


Figure 107. Median, maximum, and minimum concentrations of Zn (dry weight) in Dolly Varden ovarian tissue (1999-2004). Baseline data for Zn not available.

Mercury

Concentrations of Hg in all tissues, except kidney, were generally below the detection limit of 0.02 mg/Kg. Hg concentrations in kidney tissue appear to be similar for the two years that samples have been analyzed (Figure 108).

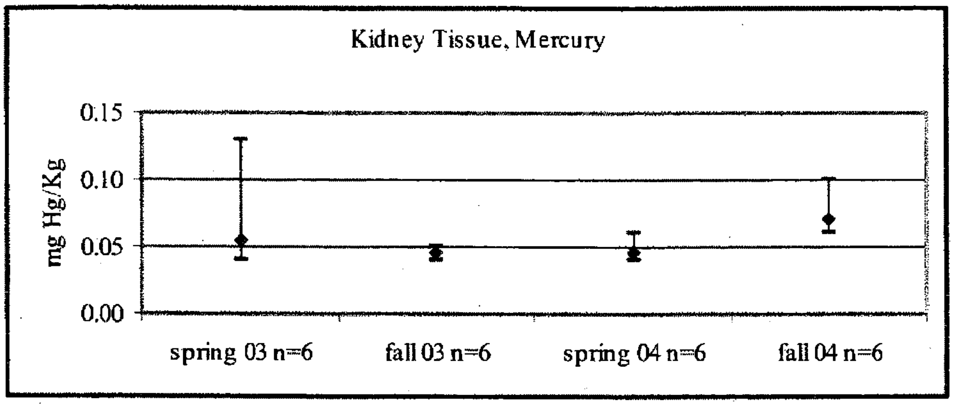


Figure 108. Median, maximum, and minimum concentrations of Hg (dry weight) in Dolly Varden ovarian tissue (2003-2004). Baseline data for Hg not available.

Distribution of Fish in the Wulik River Drainage

Overwintering Dolly Varden

The Dolly Varden fall aerial survey in the Wulik River in 2004 was conducted on September 13, 2004. Survey conditions in 2004 were mostly clear skies in the upper half of the drainage, and mostly overcast in the lower part (DeCicco 2004). In the lower four to five km of the Wulik River, due to overcast skies, fish were seen in some areas but counts could not be made. The estimated number of Dolly Varden is an underestimate of actual number present (DeCicco 2004).

The number of Dolly Varden counted in fall has varied annually (Figure 109, Appendix 2). Surveys conducted through fall 2002 suggest that over 90% of the Dolly Varden in the Wulik River continue to be observed downstream of Ikalukrok Creek. In 2004, 84% of the Dolly Varden was seen below the mouth of Ikalukrok Creek, but as DeCicco (2004) noted, observations in the lower several km of the river could not be made due to overcast skies.

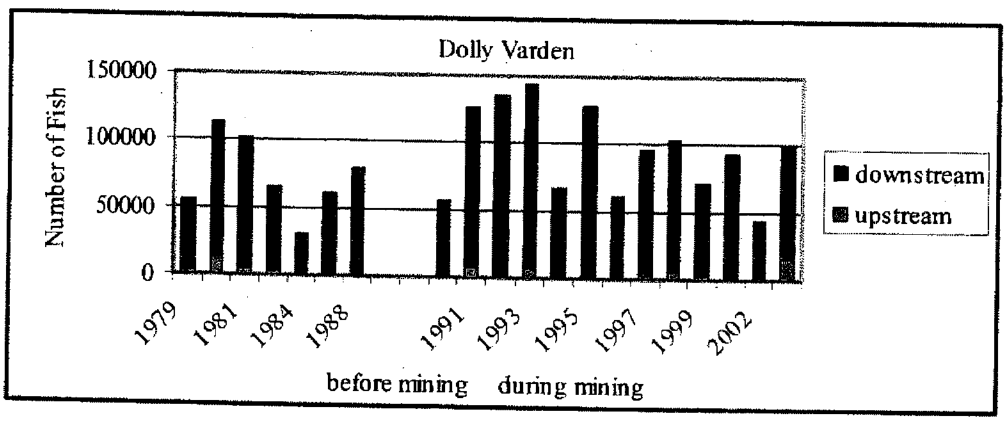


Figure 109. The number of Dolly Varden counted in aerial surveys in the Wulik River upstream and downstream of Ikalukrok Creek.

Chum Salmon Surveys

ADNR conducts annual surveys to assess the distribution of adult chum salmon in Ikalukrok Creek from its mouth upstream to Dudd Creek (Table 11, Appendix 3). In fall 2004, a helicopter survey was conducted on August 26 (Townsend and Conley 2004). In the lower portion of Ikalukrok Creek (downstream of Station 160), 397 live and 8 dead chum salmon were counted. Chinook salmon (56) spawners were observed in a slough of Ikalukrok Creek, located downstream of Station 160. The 56 adult chinook salmon is the highest number recorded since our surveys began in 1990.

Counts of chum salmon in Ikalukrok Creek made after mine development in 1990 and 1991 were lower than reported in baseline studies. Surveys were begun again in 1995, with the highest return of chum salmon seen in 2001 and the highest number of chinook salmon found in 2004. Large numbers of chum salmon in recent years, particularly 2001 and 2002, are good indications that the population has recovered from the low numbers reported in the early 1990s.

Table 11. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek.

Survey Time	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August September 1982	353 to 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990b
August 1986	1,985	DeCicco 1990b
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 16, 1995	49	Townsend and Lunderstadt 1996
August 1995	300 to 400	DeCicco 1995
August 11, 1996	180	Townsend and Hemming 1996
August 12, 1997	730 to 780	Ott and Simpers 1997
1998	no survey	
August 9, 1999	75	Ott and Morris 1999
2000	no survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco 2001a
August 5, 2002	890	Ott and Townsend 2002
August 11, 2003	218	Townsend and Ingalls 2003
August 26, 2004	405	Townsend and Conley 2004

Juvenile Dolly Varden

Limited pre-mining juvenile Dolly Varden distribution and use data were available for most of the streams in the vicinity of the Red Dog Mine, including Ikalukrok, Evaingiknuk, Buddy, Mainstem Red Dog, and North Fork Red Dog creeks. We found in the early 1990s that the highest use by juvenile Dolly Varden was in Anxiety Ridge Creek, also identified as the most productive stream system in the project area by Houghton and Hilgert (1983).

We have conducted annual surveys of juvenile Dolly Varden in Evaingiknuk, Anxiety Ridge, and Ikalukrok creeks since summer 1990 to determine seasonal patterns of fish use. Since 1990, we have added new sample sites and increased the number of minnow traps per site. Currently, we sample ten sites as listed in Table 12 (Appendix 4) using ten minnow traps per sample reach.

Table 12. Locations of juvenile Dolly Varden fish trap sites.

Site Name	Station No.	Year First Sampled
Evaingiknuk Creek		1990
Anxiety Ridge Creek		1990
Buddy Creek		1996
North Fork Red Dog Creek	12	1993
Mainstem Red Dog Creek, below North Fork	11	1995
Mainstem Red Dog Creek, at Ikalukrok	10	1996
Ikalukrok Creek above Mainstem	9	1996
Ikalukrok Creek below Mainstem	8	1996
Ikalukrok Creek above Dudd Creek		1990
Ikalukrok Creek below Dudd Creek	7	1990

Numbers of juvenile Dolly Varden vary considerably among years. Natural environmental variables such as the duration of breakup, patterns and magnitude of rainfall events, and ambient temperature affect distribution of juvenile fish. Perhaps the most significant variable affecting abundance is the number of adult spawners and the survival of age 0 fish. Juvenile Dolly Varden are most abundant in our sample sites, particularly those sites located in the upper portion of the stream, from late July to mid August. In some years, with mild weather conditions, peak usage of streams continues until the onset of freezing when most of the juvenile Dolly Varden outmigrate to overwintering habitats. Past sampling has indicated that some juvenile Dolly Varden remain in Anxiety Ridge and Evaingiknuk creeks to overwinter.

Sampling of the ten NPDES sample sites in July and August has been conducted each year since 1997. The highest catches were recorded in 1999 and the lowest were in 2000 and 2001 (Appendix 5). Late summer catches of Dolly Varden for Anxiety Ridge Creek and Mainstem Red Dog Creek immediately below North Fork Red Dog Creek are presented in Figure 110. From 1997 to 2002, catches followed a similar pattern: when higher in Anxiety Ridge Creek, catches also were higher in Mainstem Red Dog Creek (Figure 110). However, lower catches in Mainstem Red Dog Creek were seen in both 2003 and 2004 in comparison with Anxiety Ridge Creek.

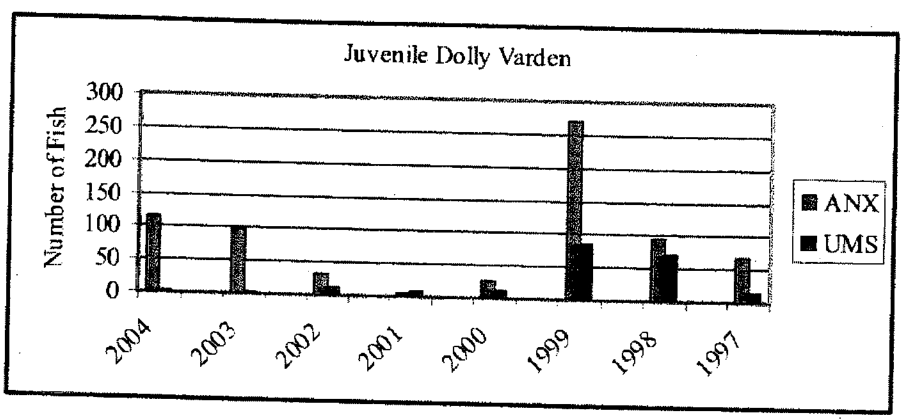


Figure 110. Catches of juvenile Dolly Varden in Anxiety Ridge (ANX) and Upper Mainstem Red Dog Creeks (UMS), 1997-2004.

Catches in Buddy and Upper Mainstem Red Dog creeks from 1997 through 2004 are presented in Figure 111. Similar to the comparison made between Anxiety Ridge and Upper Mainstem Red Dog Creek, catches were lower by comparison in Upper Mainstem Red Dog Creek in both 2003 and 2004 (Figure 111).

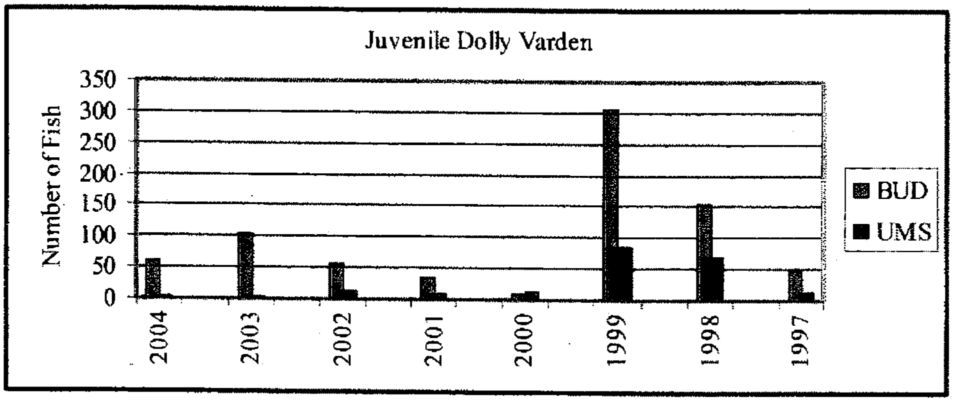


Figure 111. Catches of juvenile Dolly Varden in Buddy (BUD) and Upper Mainstem Red Dog Creeks (UMS), 1997-2004.

The length-frequency distribution of juvenile Dolly Varden, especially the presence of age 0 fish, indicates successful reproduction and survival. Dolly Varden <65 mm in late July and early August are assumed to be age 0 fish. Length-frequency distributions of juvenile Dolly Varden captured in fall 1997 through 2004 are presented in Appendix 6. The highest catches of Dolly Varden <65 mm occurred in 1997, 1998, 1999, and 2004 (Appendix 6). Catches of small Dolly Varden in 1997 and 1998 likely explain the large catch in fall 1999. Smolting can occur as early as age 2, but more commonly at age 3 (DeCicco 1990a); thus these fish are leaving our sample areas to enter marine waters 2 to 3 years after hatching. Catches of small (<65 mm) Dolly Varden in fall 2004 were high (Figure 112), thus one would expect higher catches of juvenile fish in fall 2005.

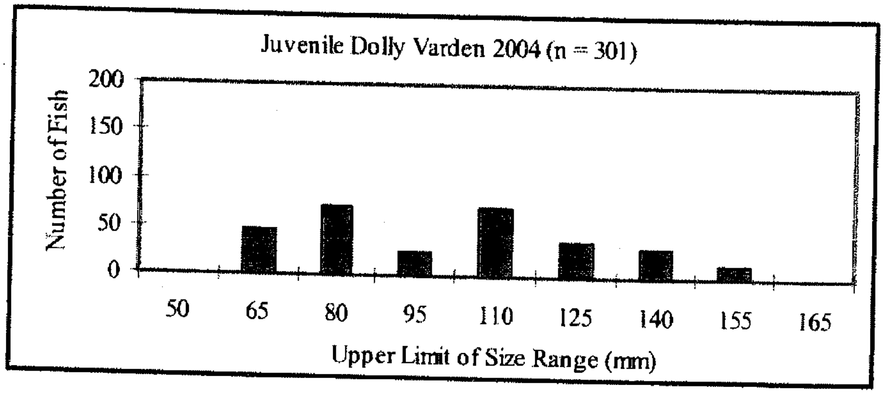


Figure 112. Length-frequency of juvenile Dolly Varden caught in fall 2004.

Dolly Varden, North Fork Red Dog Creek

Fyke nets fished in North Fork Red Dog and Mainstem Red Dog creeks to gather information on Arctic grayling also captured Dolly Varden. In early spring, the size of Dolly Varden was larger than during mid summer (Figures 113 and 114). These larger Dolly Varden in the spring sample are believed to be stream resident fish based on coloration and size. The smaller Dolly Varden captured in mid summer and fall are similar in size to juvenile Dolly Varden found in other streams in the vicinity of the Red Dog Mine (e.g., Anxiety Ridge and Buddy creeks).

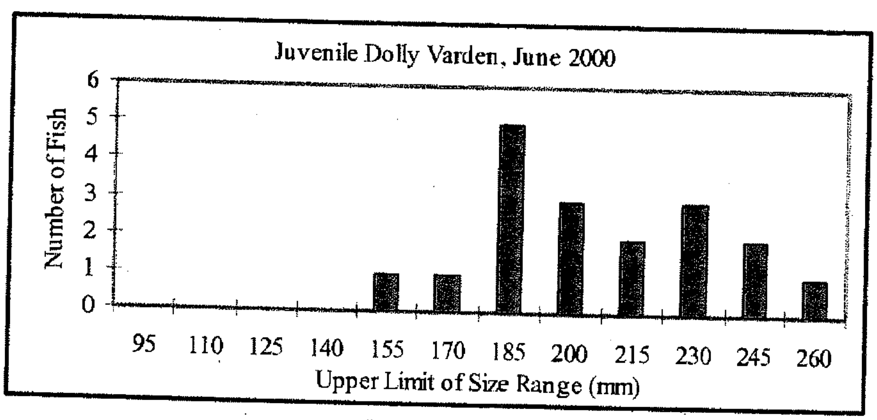


Figure 113. Dolly Varden caught in fyke nets in North Fork Red Dog Creek in June 2000.

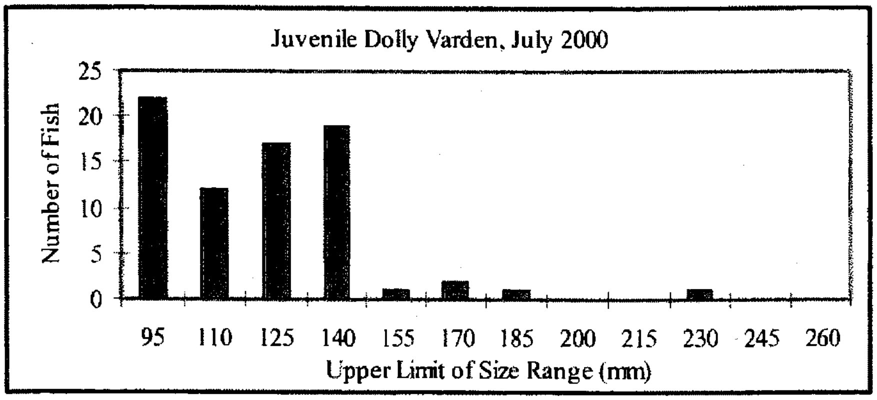


Figure 114. Dolly Varden caught in fyke nets in North Fork Red Dog Creek in July 2000.

In baseline studies, Houghton and Hilgert (1983) only found one Dolly Varden in the headwaters of North Fork Red Dog Creek. Our June, July, and August sampling with fyke nets and minnow traps indicate that substantial numbers of Dolly Varden use North Fork Red Dog Creek. The average size of Dolly Varden caught in spring has remained fairly constant from 2000 to 2004 (Figure 115). It is not known whether this change in fish use reflects general water quality improvement in Mainstem Red Dog Creek or simply is due to increased sample effort and the use of both fyke nets and minnow traps.

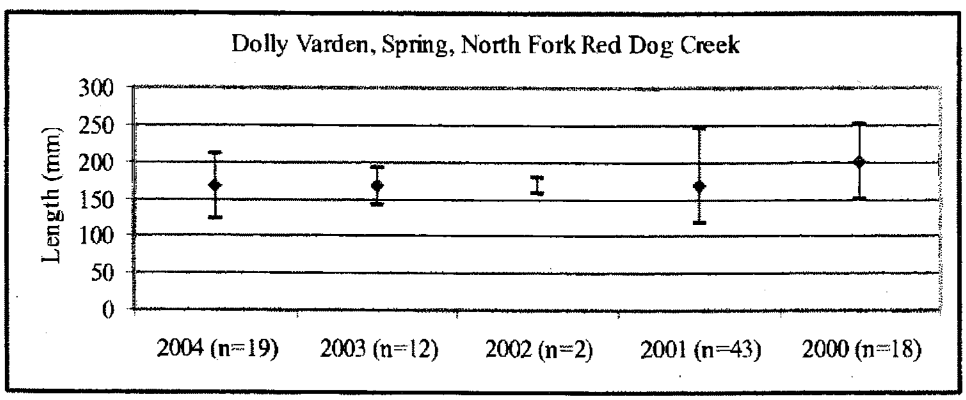


Figure 115. Length (maximum, average, and minimum) of Dolly Varden caught in spring with fyke-nets in North Fork Red Dog and Mainstem Red Dog creeks.

Arctic Grayling

Before mine development, Arctic grayling adults were thought to migrate through Mainstem Red Dog Creek in spring when discharges were high and metals concentrations were low (EVS and Ott Water Engineers 1983, Ward and Olson 1980, Houghton and Hilgert 1983). Arctic grayling moved through Mainstem Red Dog Creek to spawn in North Fork Red Dog Creek, but no spawning by Arctic grayling was documented in Mainstem Red Dog Creek. Arctic grayling fry reared in North Fork Red Dog Creek and were displaced downstream by high-water events or outmigrated as water temperatures cooled in the fall.

Timing of Arctic Grayling Spawning

Water temperature is the most likely factor determining spawning time, emergence of fry, and potential first year growth. We have closely monitored Arctic grayling during spawning in spring in North Fork Red Dog and Mainstem Red Dog creeks. The purpose of the monitoring is to assess the condition of female Arctic grayling and determine when spawning in Mainstem Red Dog Creek is complete. Until spawning is complete, the wastewater discharge from the treatment plant is controlled to ensure that total dissolved solids (TDS) concentration in Mainstem Red Dog Creek, after mixing with North Fork Red Dog Creek, remains <500 mg/L.

In spring 2004, we set hoop traps on May 23 and fished these traps through May 29 to capture Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks. These traps were not effective and no Arctic grayling were captured. Due to high water and ice, our first fyke net set made in Mainstem Red Dog Creek near Station 10 was on May 25. Four adult Arctic grayling were caught in Mainstem Red Dog Creek on May 26, but the net had collapsed and was never reset due to high flows.

A fyke net was set in North Fork Red Dog Creek near Station 12 on May 28. Arctic grayling were observed moving upstream in the creek while the net was being set and there were a fair number of fish that had already moved past the net site. Arctic grayling were captured each day in North Fork Red Dog Creek and the fyke net was pulled on

May 31. All female Arctic grayling (three) caught May 28 in North Fork Red Dog Creek were partially spent. On May 29, we caught eight females of which five were spent and three were ripe. All female Arctic grayling (five) captured on May 31 in North Fork Red Dog creek were spent. We determined, based on condition of females, that spawning was complete in Mainstem Red Dog Creek on May 31. Water temperatures at Station 10 in Mainstem Red Dog Creek are presented in Figure 116.

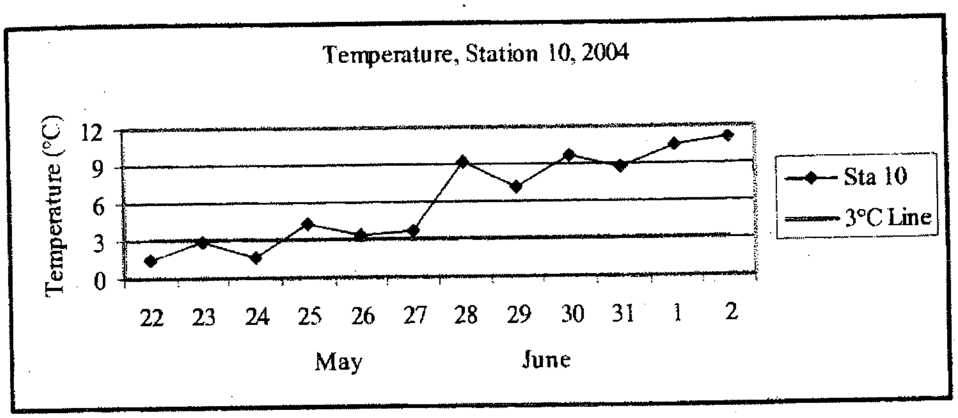


Figure 116. Water temperatures (°C) in Mainstem Red Dog Creek in spring 2004.

A summary of Arctic grayling spawning in Mainstem Red Dog Creek from 2001 to 2004 using water temperature to indicate the beginning of spawning, and condition of captured Arctic grayling to determine when spawning was complete is presented in Table 13. Using all four years of data on water temperature and spawning in Mainstem Red Dog Creek, we found that spawning was judged complete after peak daily water temperatures exceeded 4°C for 5 to 9 cumulative days within the sample year. In those years, when the magnitude of the peak water temperatures was highest, the cumulative days needed to complete spawning were the fewest. We plan to continue active sampling to document completion of spawning, but if the relationship between peak daily temperature, cumulative days with peak temperatures above 4°C, and spawning activity remains consistent for Mainstem Red Dog Creek, temperature data alone could be used to determine completion of spawning.

Table 13. Arctic grayling spawning in Mainstem Red Dog Creek, 2001-2004.

Year	Date When Limited Spawning Started (3°C Water)	Date When Spawning Complete (Condition of Females)
2001	June 6	June 15
2002	May 29	June 8
2003	June 7	June 14
2004	May 25	May 31

Length-frequency distributions for Arctic grayling captured during the spring sample event are shown in Appendix 7 and Figure 117. Length-frequency distributions show strong recruitment in 2001 and 2003. The reason for a near absence of large fish (>375 mm) in spring 2003 is unknown, but these data are consistent with observations made in the Ikalukrok Creek drainage that the larger adult Arctic grayling were not present in areas where concentrations were seen in previous years.

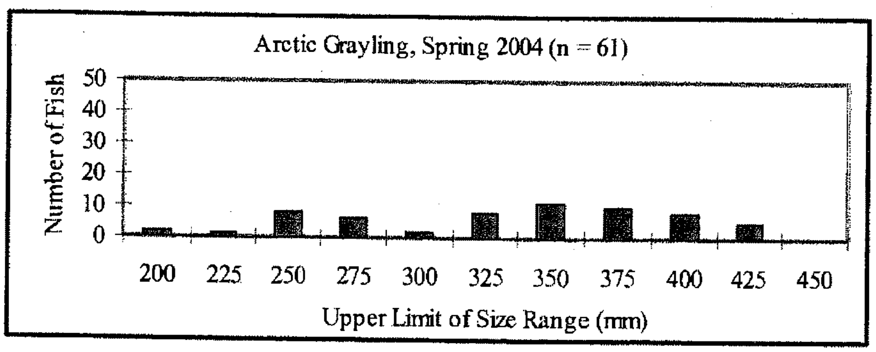


Figure 117. Length-frequency distribution of Arctic grayling caught in spring 2004 using a fyke net fished in North Fork Red Dog Creek.

Arctic Grayling Fry

Since 1992, we have found adult and fry Arctic grayling in North Fork Red Dog Creek. We have visual observations of active spawning in North Fork Red Dog Creek and have captured fry (12-15 mm long) in drift nets at Station 10 in Mainstem Red Dog Creek and at Station 12 in North Fork Red Dog Creek. We also conduct visual surveys along North Fork Red Dog Creek in July to document the relative number of fry (Table 14). Relative numbers of fry appear to be directly related to the timing of breakup, high water events following breakup, and water temperatures during summer. Since observations began, we have observed large numbers of Arctic grayling fry in 1992, 1996, 1997, and 1999.

Arctic Grayling Mainstem Red Dog Creek

Visual surveys of Mainstem Red Dog Creek have been conducted annually from 1994 to 2004 (Appendix 8) to document fish use of Mainstem Red Dog Creek by Arctic grayling and compare these data with information available from baseline studies. Surveys generally are conducted in two reaches: between the mouth of North Fork Red Dog Creek and a rock bluff about 0.8 km downstream where the new Station 151 is now located; and from the mouth of Mainstem Red Dog Creek upstream for about 3 km (Station 10). Use of Mainstem Red Dog Creek prior to mine development was likely limited to migration, with some adult Arctic grayling use of the lower portion of the creek. Arctic grayling use (adults and fry) of Mainstem Red Dog Creek currently is much higher than that described in baseline studies. Changes in use are likely related to overall improvements in water quality, increased primary production, and increased numbers and diversity of benthic invertebrates (Weber Scannell 2005).

Table 14. Relative number of Arctic grayling fry in North Fork Red Dog Creek (1992-2004).

Year	Relative Number of Fry	Comments
1992	high	100's of fry, late July
1993	low	Few fry in early August, high water
1994	low	High water after spawning probably displaced fry
1995	low	Fry small (<25 mm) in mid-July
1996	high	Schools of 50 to 200 fry common
1997	high	Average size of fry was 10 mm greater than in 1996
1998	low	Cold water, late breakup, high water after spawning
1999	high	Low flows, warm water after spawning, schools of 50 to 100 fry common
2000	low	Cold water, late breakup, spawning 90% done June 13/14, fry small (<25 mm) and rare in mid-July
2001	low	Cold water, late breakup, spawning 90% done June 19, fry small (<25 mm) and rare in mid-July
2002	low	High flows, spawning 90% done June 8, fry small (<35 mm) in early August and rare, more fry seen in Ikalukrok Creek in early July, probably displaced by high water
2003	low	Cold water, late breakup, spawning 90% done June 14, fry small (<25 mm) and rare in early August
2004	low	Early breakup, spawning 90% done by May 31, fry (<30 mm) on July 10

Arctic Grayling Mark/Recapture and Distribution

Since 1994, we have marked Arctic grayling >200 mm with floy tags. In 2004, we recaptured 19 fish in Mainstem Red Dog and North Fork Red Dog creeks that had been marked in previous years. Sampling was limited to these two creeks in 2004. All of the recaptured fish had been originally marked in either Mainstem Red Dog or North Fork Red Dog creeks.

In spring 2004, we caught 59 Arctic grayling >200 mm with only 13 recaptures, only 5 of which were seen in spring 2003. Therefore, due to limited recaptures, a population estimate was not made for spring 2003.

Aerial surveys of the Ikalukrok Creek drainage for adult Arctic grayling have been made annually since summer 2000. In summers 2000 through 2002, large numbers of adult Arctic grayling were seen at the mouth of Grayling Junior Creek and/or in East Fork Ikalukrok Creek. In both 2003 and 2004, concentrations of adult Arctic grayling were not found in the Ikalukrok Creek drainage. Length-frequency distributions (Appendix 7) indicate that the larger Arctic grayling also were absent or nearly absent from the spring sample in North Fork Red Dog Creek.

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none in the Red Dog drainage. In 1995, we found slimy sculpin in Mainstem Red Dog and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Slimy sculpin are rare in the Red Dog drainage and in Anxiety Ridge Creek. Catches of slimy sculpin generally have been highest in Ikalukrok Creek in our sample area upstream and downstream of Dudd Creek. The total catch of slimy sculpin for all sample areas, except Evaingiknuk Creek, is presented in Figure 118. Trends in total numbers indicate an increasing presence of slimy sculpin from 1996 through 1999, with a decrease in 2000, and then a steady increase through 2004 (Figure 118). These data may reflect that slimy sculpin were impacted during 1989 and 1990 prior to construction of the clean water bypass in spring 1991. The second decrease in 2000 and low numbers for several years may be related to metals from Cub Creek affecting waters of Ikalukrok Creek. The increasing presence of slimy sculpin in 2002 to 2004 is consistent with decreasing metals from Cub Creek.

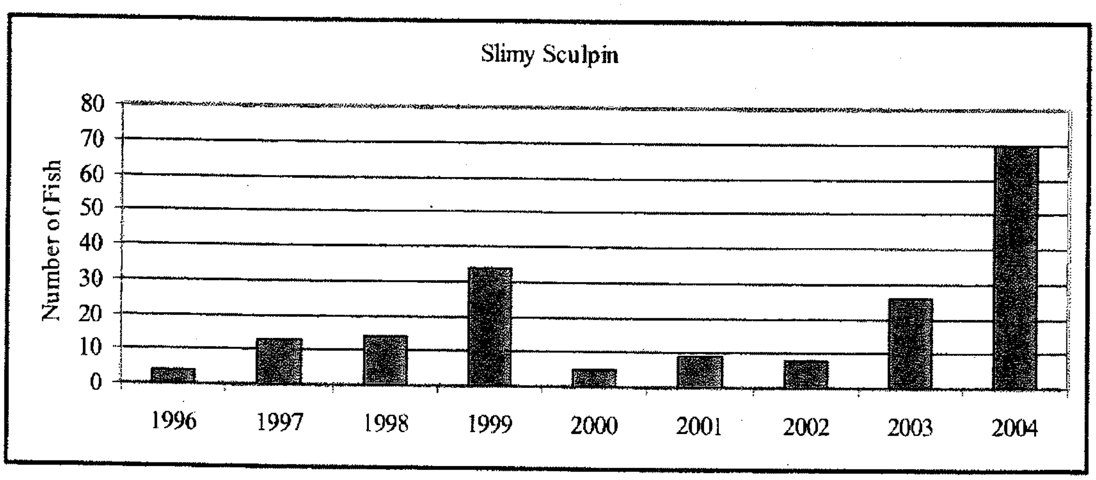


Figure 118. Slimy sculpin collected in Ikalukrok, Red Dog, Buddy, and Anxiety Ridge creeks, 1996-2004.

Literature Cited

ADF&G. 1998. Methods for aquatic life monitoring to satisfy requirements under NPDES permit. NPDES AK-003865-2, Red Dog Mine Site. AK Dept. of Fish and Game. 23 pp.

Ott, A.G. and P. Weber Scannell. 2003. Aquatic biomonitoring at Red Dog Mine, 2002. National Pollution Discharge Elimination System Permit No. AK-003865-2. Technical Report No. 03-03. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 116 pp.

Dames and Moore. 1983. Environmental baseline studies Red Dog Project.

DeCicco, A.L. 2004. Red Dog trip report, September 11 to 15, 2004. Memorandum, AK Dept. of Fish and Game. 2 pp.

DeCicco, A.L. 2002. 2002 Wulik River survey. October 14, 2002. Memorandum, AK Dept. of Fish and Game. 1 p.

DeCicco, A.L. 2001a. 2001 Wulik River survey and Ikalukrok Creek, October 8, 2001. Memorandum, AK Dept. of Fish and Game. 1 p.

DeCicco, A.L. 2001b. Ikalukrok Creek salmon, September 3, 2001. Memorandum, AK Dept. of Fish and Game. 2 pp.

DeCicco, A.L. 2001c. Ikalukrok Creek salmon, September 28, 2001. Memorandum, AK Dept. of Fish and Game. 2 pp.

DeCicco, A.L. 2000. Personal communication to Habitat and Restoration Division. November, 2000.

DeCicco, A.L. 1999. Memorandum, 1999 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1998. Memorandum, 1998 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1997. Memorandum, 1997 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1996a. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1996b. Abundance of Dolly Varden overwintering in the Wulik River, Northwest Alaska during 1994/1995. AK Dept. of Fish and Game, Sport Fish Fishery Data Series No. 96-3. Anchorage, AK.

DeCicco, A.L. 1995. Personal communication. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK.

Literature Cited continued.

DeCicco, A.L. 1994. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1993. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1992. Memorandum, char surveys. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1991. Kotzebue trip report, August 16 to 27, 1991. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 5 pp.

DeCicco, A.L. 1990a. Life history of anadromous Dolly Varden (*S. malma*) in Northwestern Alaska. AK Dept. of Fish and Game, Sport Fish Division. Prepared for the 1990 meeting of the International Society of Arctic char fanatics in Murmansk, USSR. September 1990. 19 pp.

DeCicco, A.L. 1990b. Northwest Alaska Dolly Varden study 1989. Federal Aid in Sport Fish Restoration Act. AK Dept. of Fish and Game. Fishery Data Series No. 90-8. Fairbanks, AK. 42 pp.

DeCicco, A.L. 1990c. Trip report, Red Dog October 3 to 6, 1990. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1989. Memorandum, Wulik River char distribution. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 3 pp.

EVS Consultants Ltd and Ott Waters Engineers. 1983. Toxicological, biophysical and chemical assessment of Red Dog, Delong Mountains, Alaska, 1982. Prepared for Alaska Department of Environmental Conservation, Juneau, by G. Vigers, J. Barrett, R. Hoffman, J. Humphrey, D. Kathman, D. Konasewich, R. Olmsted, and B. Reid. 245 pp.

Houghton, J.F. and P.J. Hilgert. 1983. In Environmental baseline studies Red Dog project. Dames and Moore. 82 pp.

Morris, W.A. and A.G. Ott. 2001. Red Dog mine field trip report, July 28 to August 9, 2001. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 9 pp.

Ott, A.G. and A.H. Townsend. 2002. Red Dog mine field trip report, July 27 to August 7, 2002. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 7 pp.

Ott, A.G. and W.A. Morris. 1999. Red Dog mine field trip report, August 7 to 13, 1999. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 5 pp.

Literature Cited concluded.

Ott, A.G. and S. Simpers. 1997. Red Dog mine field trip report, August 9 to 15, 1997. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 9 pp.

Ott, A.G., P.K. Weber Scannell, and M.H. Robus. 1992. Fish monitoring study, Red Dog Mine in the Wulik River drainage, emphasis on Dolly Varden (*Salvelinus malma*). Technical Report No. 91-4. AK Dept. of Fish and Game, Habitat Division. Juneau, AK. 67 pp.

Townsend, A.H. and L. Conley. 2004. Red Dog field trip report, August 18 to 28, 2004. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Fairbanks, AK. 2 pp.

Townsend, A.H. and L. Ingalls. 2003. Red Dog field trip report, August 6 to 13, 2003. AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Fairbanks, AK. 3 pp.

Townsend, A.H. and C. Lunderstadt. 1995. Trip report, August 11 to 16, 1995. AK Dept. of Fish and Game, Habitat and Restoration Division. Fairbanks, AK. 7 pp.

Ward, D.L. and T.J. Olson. 1980. Baseline aquatic investigations of fishes and heavy metal concentrations in the Kivalina and Wulik Rivers, 1978-79. LGL Ecological Research Associates, Inc. Prepared for GCO Minerals Company. 89 pp.

Weber Scannell, P. 2005. Comparison of Mainstem Red Dog Creek pre-mining and current conditions. Scannell Technical Services. Prepared for AK Dept. of Natural Resources, Office of Habitat Management and Permitting. Fairbanks, AK. 19 pp.

Weber Scannell, P., A.G. Ott, and W.A. Morris. 2000. Fish and aquatic taxa report at Red Dog Mine, 1998-1999. Technical Report No. 00-03. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Weber Scannell, P. and S. Anderson. 2000. Aquatic taxa monitoring study at Red Dog Mine, 1997-1998. Technical Report 00-02. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 214 pp.

Weber Scannell, P. and A.G. Ott. 1998. Fisheries resources and water quality, Red Dog Mine. Technical Report No. 98-02. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Appendix 1. A Summary of Mine Development and Operations with Emphasis on Biological Factors

1982

- Baseline studies initiated, Cominco agreement with NANA finalized

1983

- EIS process initiated, alternatives for mine and road to port site identified

1984

- Stream surveys conducted along proposed road by private consultant

1985

- Permit applications prepared for regulatory agencies
- Implementation of wastewater treatment plant deferred to ADEC by ADF&G
- Wastewater discharge limited to summer
- Potential for acid rock drainage and metals mobilization not recognized

1986

- ADEC solid waste permit and bonding not required
- ADEC permit preceded solid waste regulations
- AIDEA bonds to build road and port site issued

1987

- Construction of road began, budget request to AIDEA prepared by ADF&G
- Reimbursement agreement for logistics with ADF&G to monitor construction made by AIDEA

1988

- Ore body developed
- Road and port site construction began
- Notice of Violation issued to AIDEA by ADF&G for failed road crossing by-passes
- Uniform Summons and Complaint issued for illegal water removal
- AIDEA provided funding to ADF&G for monitoring
- Rehabilitation plans for streams developed and implemented

Appendix 1 (continued).

1989

- Agreement to close-out old solid waste site finalized with Cominco
- Civil work on ore body and surface water drainage control begun
- Complaints about water quality in Ikalukrok Creek received
- Tailing dam becomes full, Cominco's request to siphon untreated water over the dam denied by State
- Elevated metals concentrations identified by red precipitation, were observed in Ikalukrok Creek below the mine
- Winter discharge of treated water authorized by State
- State regulatory agencies and Cominco in disagreement over whether metals exceeded background conditions

1990

- Biomonitoring of fish populations proposed and initiated by ADF&G
- Dead fish from the Wulik River were discovered by the public
- ADF&G sampling indicated very few fish remaining in Ikalukrok Creek
- Installation of sumps and pumps by Cominco prevented metals-laden water from entering Red Dog Creek
- Baseline and current water quality data reviewed by ADF&G
- Clean water bypass system requested by ADF&G
- Zinc levels in Ikalukrok Creek exceeded 40 mg/L
- State regulatory agencies and Cominco in disagreement over cause and extent of water quality problems
- Compliance Order by Consent for water quality violations affecting anadromous fish issued by ADEC
- Notice of Violation for water quality violations affecting anadromous fish issued by ADF&G
- Cominco directed to design and construct a clean water bypass system
- Perceived impairment to the subsistence fishery initiated involvement by the community of Kivalina

1991

- Clean water bypass system designed by Cominco, approved by state agencies
- ADF&G fisheries study funded by Cominco
- Clean water bypass system built
- Clean water bypass system repaired
- Improvements to water quality were documented

Appendix 1 (continued).

1992

- Fish study continued
- Water quality improvements to downstream receiving water continued
- Increasing water volume in tailing impoundment continued
- Water from dirty water collection system entering tailing impoundment increased volume
- Water treatment plant modifications made

1993

- Fish study continued
- Sand filters to remove particulate zinc installed

1994

- Fish study continued
- Use attainability studies of several streams initiated for reclassification
- Water treatment capacity increased by thickening tank conversion
- Wastewater discharge increased from 7.5 cfs to 23 cfs
- Ore processing capability expanded by Cominco

1995

- Fish study expanded to include other aquatic biota
- Work on stream reclassification and site-specific criteria continued by ADF&G
- Metals concentrations in the clean water bypass system increased; contributing sources were identified: Hilltop Creek (Zn), Shelly Creek (Cd), and Rachel Creek (Al)
- Clean water bypass system extended to collect water from Hilltop Creek
- Reserves were doubled after exploration drilling located more ore
- Possible metals contamination in Bons Creek identified by ADF&G

1996

- Public notice for stream reclassification sent out
- Bons Creek water samples from above and below the Kivalina shale dump collected
- Fish and aquatic biota study continued

Appendix 1 (continued).

1997

- Stream reclassification incorporated into regulation (18 AAC 70.50)
- Fish barrier constructed across Middle Fork Red Dog Creek
- Water bypass around the Kivalina shale dump and interceptor trench at the head of the tailing impoundment built
- Gray-white precipitate observed in Middle Fork Red Dog Creek
- Heavy red staining and precipitate seen in Ikalukrok Creek; originated from seep near headwaters of Ikalukrok Creek, located upstream of mining activity
- Laboratory experiments of TDS on egg fertilization and early egg development initiated
- Fish and aquatic biota studies continue
- US EPA brings enforcement action for water quality violations; Cominco initiates Supplemental Environmental Projects
- Two-year aquatic community study in upper Ikalukrok Creek, above and below the Red Dog Mine discharge initiated by ADF&G
- Ground water monitoring wells installed and monitored below tailing dam by Cominco

1998

- Wet fertilization studies to test effects of TDS on fish embryos continued
- Draft 401 certification for a new NPDES permit prepared by ADEC and reviewed by ADF&G
- Discussed extension of the clean water bypass system up Shelly and Connie Creeks to ensure bypass of clean water and collection of seepage water from newly disturbed areas
- Heavy red staining in headwaters of Ikalukrok Creek, originating from seep in headwaters of Ikalukrok Creek, upstream of mining activity, staining extends downstream about 30 km
- Site-specific criteria for Zn in Mainstem Red Dog and Ikalukrok Creeks approved by EPA
- Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
- Plans to increase port site capacity for direct loading of ships released to public
- NPDES permit reissued by US EPA
- Two-year aquatic community study completed
- Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

Appendix 1 (continued).

1999

- Two-year drilling program (Shelly and Connie Creeks) proposed
- New station 7 on Ikalukrok Creek established by Cominco, USGS, and ADF&G
- Fish and aquatic biota study expanded to upper North Fork Red Dog, Ikalukrok, and Ferric creeks
- Biomonitoring and USGS gauging work proposals submitted to Cominco
- Study of periphyton communities exposed to different concentrations of TDS in Mainstem Red Dog Creek done by ADF&G and Cominco Alaska Inc.
- Request to increase TDS for periphyton colonization experiment not approved
- Effects to Ikalukrok Creek from Alvinella Creek seepage water continued to below Dudd Creek mouth
- Arctic grayling females in ripe spawning condition collected from North Fork Red Dog Creek for selenium analysis of livers and ovaries

2000

- Effects to Ikalukrok Creek from Alvinella seepage continued; red stain and precipitate observed several km below mouth of Mainstem Red Dog Creek
- North Fork Red Dog Creek silty at breakup, previously not observed
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall observed
- Civil work performed in Connie Creek to isolate surface from subsurface flows and bypass flow through disturbed areas
- Effectiveness of pump back system at the Kivalina rock dump verified by presence of juvenile Arctic grayling in creek immediately south of dump
- Site-specific criteria for TDS requested by Cominco
- Biomonitoring study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect begun

Appendix 1 (continued).

2001

- Effects to Ikalukrok Creek from Alvinella seepage continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation (natural) less than in summer 2000
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall
- Water quality was monitored in Shelley, Rachel, Connie, and Middle Fork Red Dog creeks upstream and downstream of surface disturbance, catch-box and pipeline (about 430 m) placed in Shelley Creek to move water pass disturbance
- Juvenile Aretic grayling observed in Bons Creek just south of the Kivalina roek dump, pump-back system working based on fish use
- Fish weir repairs made during 2000, no problems observed in 2001
- Stream survey of cross drainage structures made along the Delong Mountains Transportation System, some minor work at some crossings identified
- Site-specific criteria for TDS still being worked, data on Arctic grayling spawning/water temperature collected in North Fork Red Dog and Mainstem Red Dog creeks, supplemental data gathered at the Ft. Knox mine
- Studies expanded to include the Delong Mountains Transportation System based on a National Park Service report that metals concentrations adjacent to road were elevated, water sites established upstream and downstream of road and sampled by Teck Cominco, juvenile Dolly Varden samples collected in Omikviorok River and Aufeis Creek, vegetation sampling started by Teck Cominco
- New haul trucks brought on site, hard-covered trucks to minimize loss of zine and lead concentrates during transport
- Exploratory drilling (ore and shallow gas) continued, focus on North Fork Red Dog Creek and Wulik River basins near Anarraaq and Lik, including west of the Wulik River, another ore prospect found northwest of Anarraaq, shallow gas results promising
- State and Teck Cominco agree to start the state's large mine team to work on issues, key issue identified was development of a solid waste permit with bonding for the tailing dam, other issues include site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect continued for the second field season, four new sites added to study tributaries on west side of Wulik in the area of the Lik Deposit and potential shallow gas development

Appendix 1 (Continued).

2002

- Effects to Ikalukrok Creek from Alvinella seepage continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation minor during summer 2002
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed during summer 2002
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Pit expansion continues to the north of the clean-water bypass system, road crossing added for access
- A bypass was installed for Connie Creek during winter 2001/2002. The bypass captures the upstream creek and carries the water in a pipe to the clean-water bypass system
- The bypass system for Shelly Creek was modified during summer 2002 to correct an overflow problem that occurred during breakup (the overflow water was captured in the pit and did not affect downstream waters). The modification involved adding a lined ditch to contain overflowing clean water and direct the water to the clean-water bypass system
- Juvenile Dolly Varden collected at eight sites located upstream and downstream of the Delong Mountains Regional Transportation System, whole body metals analyses for Cd, Pb, Se, and Zn
- Site-specific criteria for total dissolved solids is still being worked
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with bonding for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect and shallow gas exploration
- Arctic grayling adults remained in North Fork Red Dog Creek through early August, only the second time since 1992 that most of the adults stayed in the creek during summer, most years adults outmigrate shortly after spawning in spring
- Arctic grayling adults present in Buddy Creek just below the falls, about 50 adult fish in sample reach (0.3 km) in early July, all gone by early August
- About 50 to 60 adult Dolly Varden in Ikalukrok Creek at mouth of Dudd Creek from early July through late August
- Effluent discharge ceased on October 5, 2002, to allow time to winterize the water treatment plant

Appendix 1 (continued).

2003

- Effects to Ikalukrok Creek from Alvinella seepage continued but were much less than seen in the last two to three years
- North Fork Red Dog Creek, natural siltation throughout most of the summer was minor in summer 2003
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed during summer 2003
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Site-specific criteria for total dissolved solids was finalized
- USEPA modified the NPDES effective August 22, 2003, to incorporate the ADEC Site Specific Criteria and mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks with conditions that ensure total dissolved solids are at or below 500 mg/L during Arctic grayling spawning in Mainstem Red Dog Creek and during chum salmon and Dolly Varden spawning in Ikalukrok Creek, the modified permit was appealed by the Kivalina Relocation Planning Committee
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with financial assurance for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adult Arctic grayling seen in the Ikalukrok Creek drainage was the lowest seen since aerial surveys were begun in the late 1990s
- Arctic grayling population estimate was completed for Bons Pond the site of a fish transplant made in 1994 and 1995, estimated population in the reservoir was 6,773
- Modification to Shelly Creek bypass ditch completed, a better designed and constructed lined ditch was built and commissioned in August, 2003
- In 2003, a permanent lined ditch was constructed parallel to the Connie Creek diversion pipeline to avoid spring freeze-up issues
- In 2003, a permanent monitoring station was established at the end of the mixing zone in Mainstem Red Dog Creek, the location designation is Station 151, and is fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system
- Station 150, at the end of the mixing zone in Ikalukrok Creek, was fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system

Appendix 1 (concluded).

2004

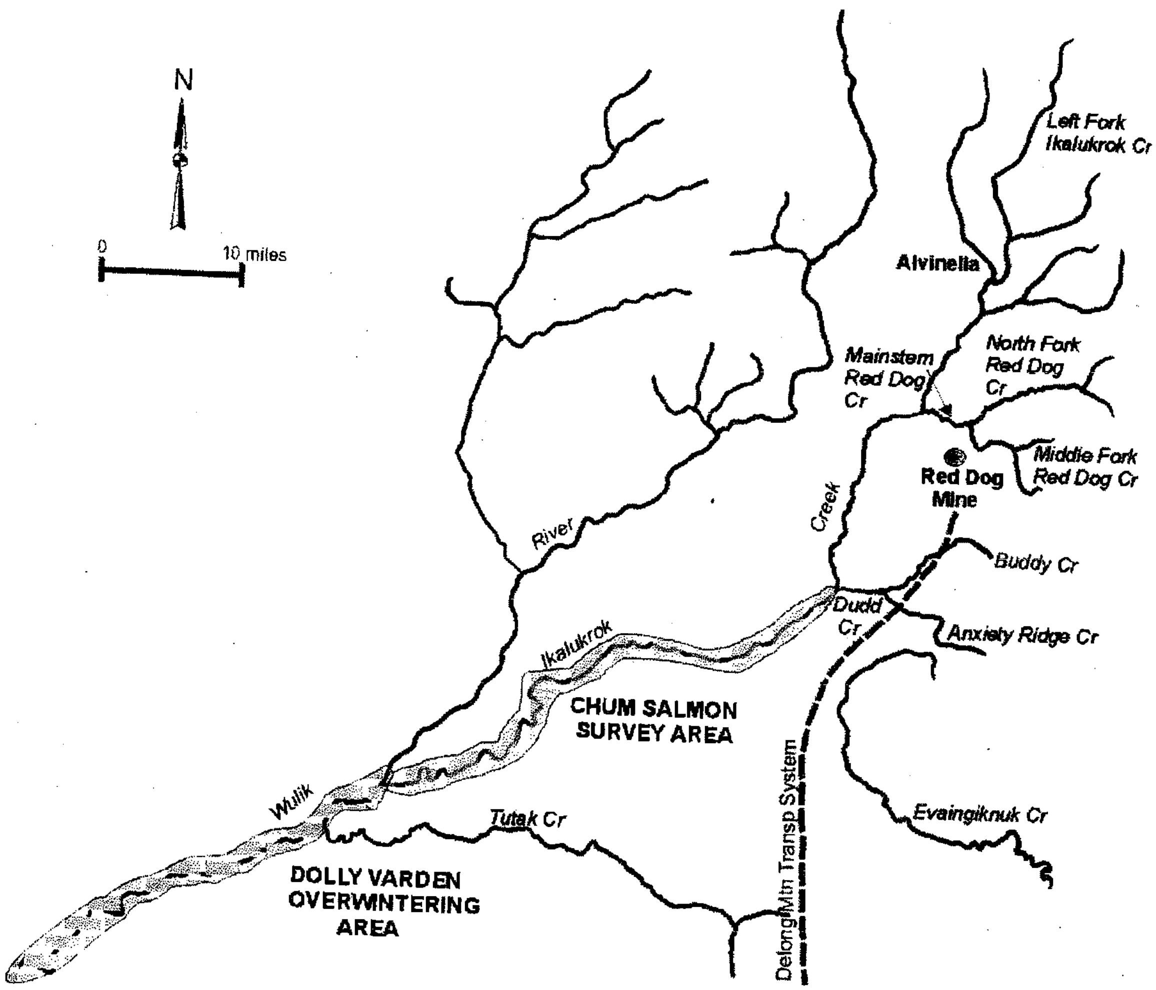
- Wastewater discharge began on May 20, ended on September 26, total discharge about one billion gallons
- Effects to Ikalukrok Creek from Alvinella seepage continued but were minor
- North Fork Red Dog Creek, natural siltation minor during ice-free season
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed
- Arctic grayling spawning/water temperature data collected, Arctic grayling from North Fork Red Dog Creek used for TDS fertilization experiment
- State and Teck Cominco continue to work on key issues associated with the solid waste permit and closure plan for the mine
- Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adults seen in Ikalukrok Creek drainage remained low as in summer 2003
- Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2003 was 6,773 and for summer 2004 was 5,739
- Chinook salmon juveniles were documented for the first time in Ikalukrok Creek, near Dudd Creek, and in Anxiety Ridge Creek
- Age-1 Arctic grayling were caught in minnow traps fished in Ikalukrok, Mainstem, and Buddy creeks, since age-1 fish are seldom captured in minnow traps this may indicate good survival of fry spawned in spring 2003
- Red Dog Creek diversion (clean water ditch) was realigned to the west side of the pit. Realigned configuration is a combination of large diameter culvert and open lined ditch.

Appendix 2. Dolly Varden Aerial Surveys

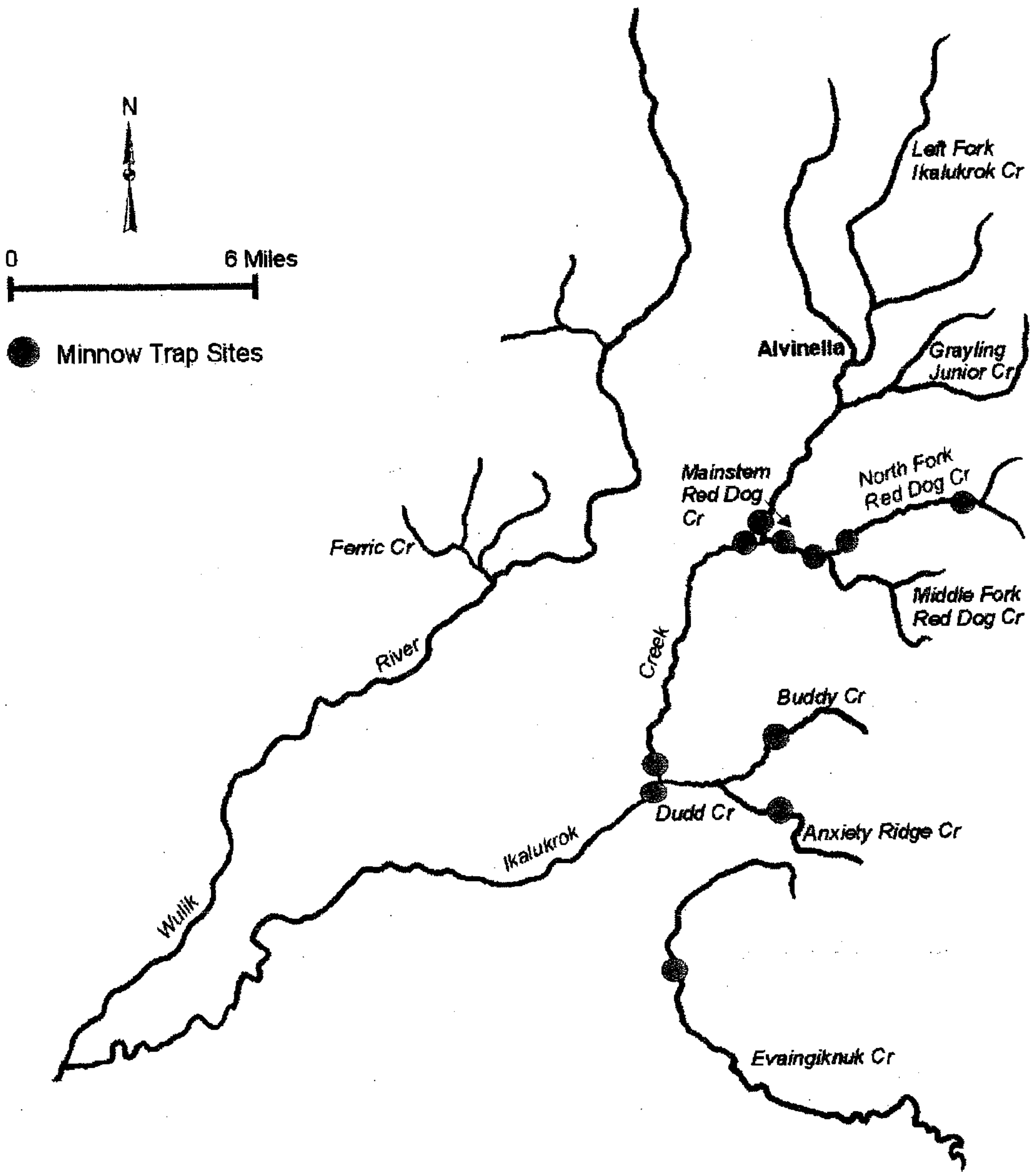
Estimated number of overwintering Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989, 1991-1999, 2001-2002, and 2004.

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1,500	78,644	80,144	98
During Mining				
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2004	16,486	84,320	100,806	84
The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm				
was 76,892 (DeCicco 1990b)				
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm				
was 361,599 (DeCicco 1996c)				
Fall 2000 aerial survey was not made due to weather.				
Fall 2003 aerial survey was not made due to weather.				

Appendix 3. Adult Dolly Varden and Chum Salmon Survey Areas



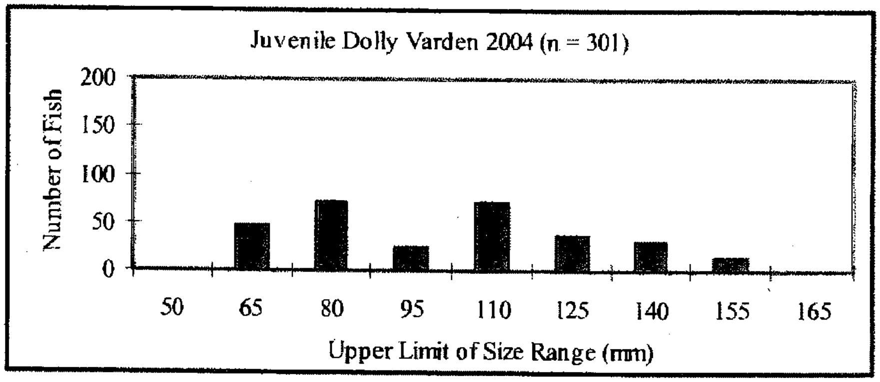
Appendix 4. Juvenile Dolly Varden Sampling Sites

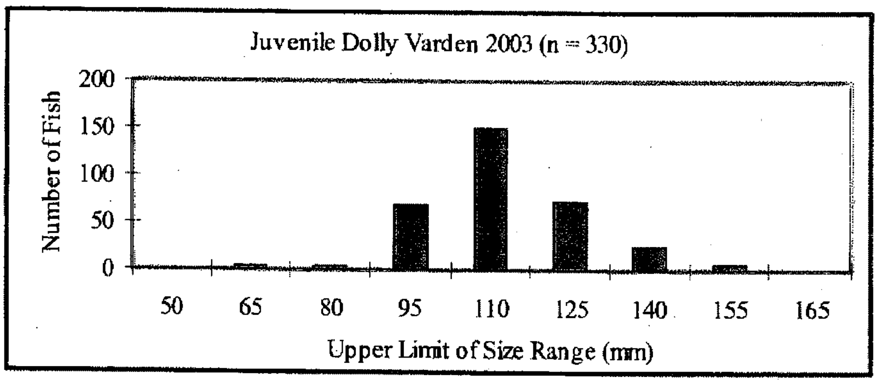


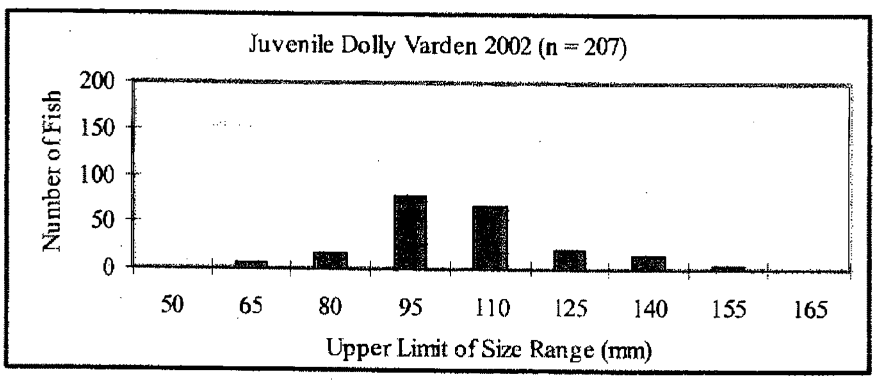
Appendix 5. Juvenile Dolly Varden Catches at NPDES Sample Sites

Number of Dolly Varden Caught in Late-July/Early August with ten minnow traps per sample site								
Sample Site Description	Date 8/19-24/04	Date 8/8-10/03	Date 7/28-29/02	Date 7/30-8/5/01	Date 7/28-8/1/00	Date 8/9-10/99	Date 8/7-10/98	Date 8/10-13/97
Evaingiknuk (Noatak Tributary)	71	64	20	7	2	38	27	54
Anxiety Ridge	116	98	33	6	27	271	94	68
Buddy	59	104	57	34	11	306	154	48
North Fork Red Dog Creek (Sta 12)	1	0	1	1	1	17	12	0
Mainstem (below North Fork)	2	2	12	9	13	86	70	14
Mainstem (Station 10)	0	12	12	3	1	66	21	10
Ikalukrok Creek (below Dudd)	27	17	17	6	31	55	51	13
Ikalukrok Creek (above Dudd)	11	27	22	0	14	37	53	3
Ikalukrok Creek (below Mainstem)	2	3	15	11	6	28	19	4
Ikalukrok Creek (above Mainstem)	12	3	18	2	5	41	44	3
Total Catch Dolly Varden	301	330	207	79	111	945	545	217

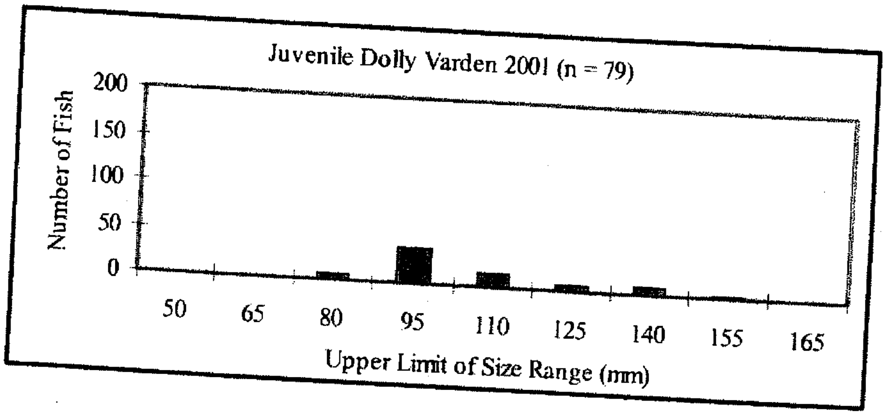
Appendix 6. Length-Frequency Distribution of Juvenile Dolly Varden

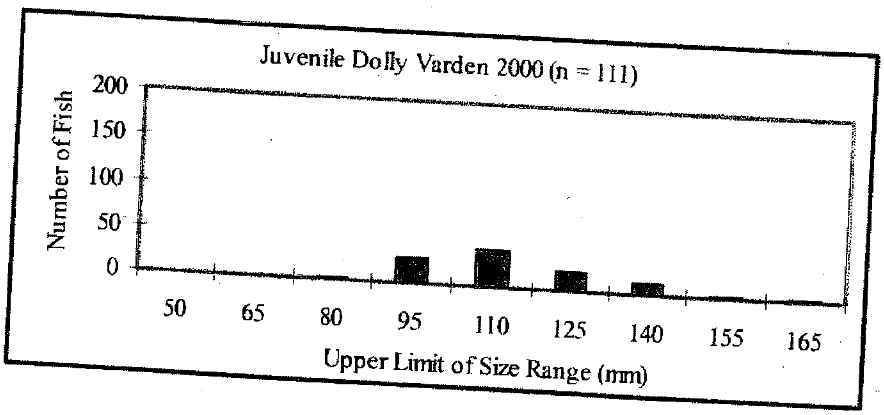


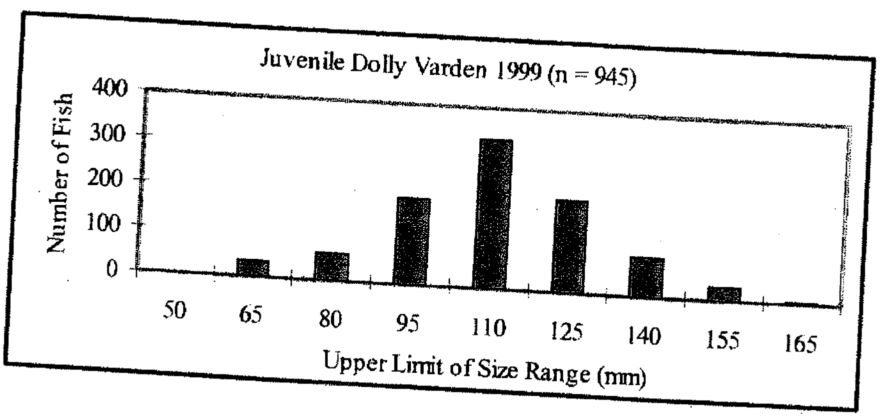




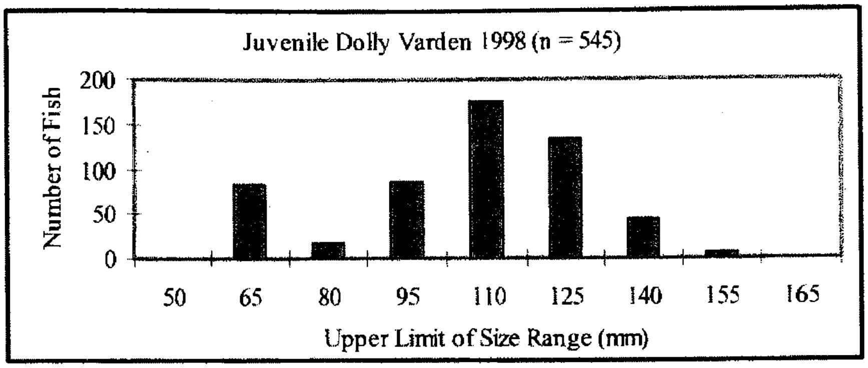
Appendix 6 (continued).

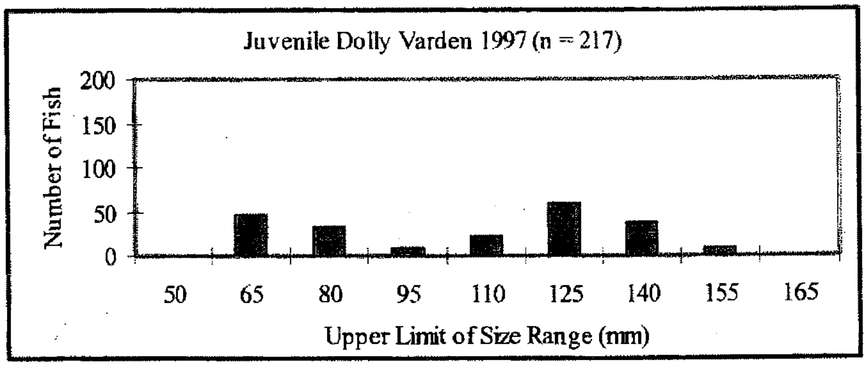




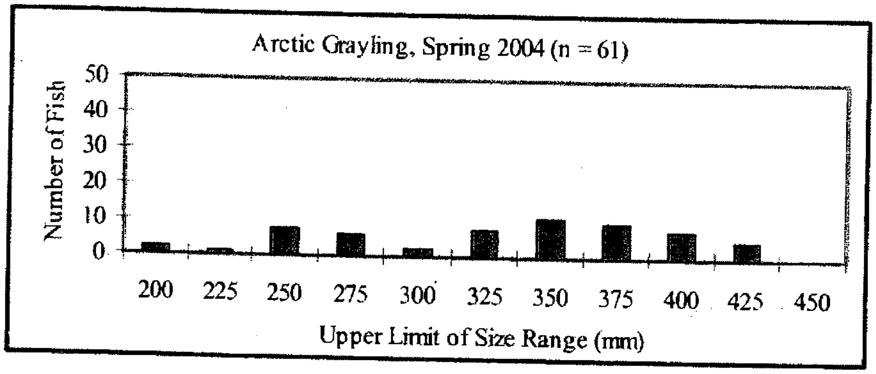


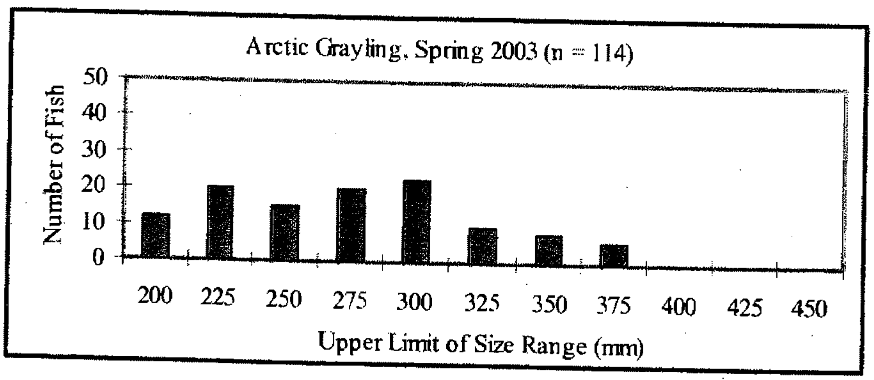
Appendix 6 (concluded).

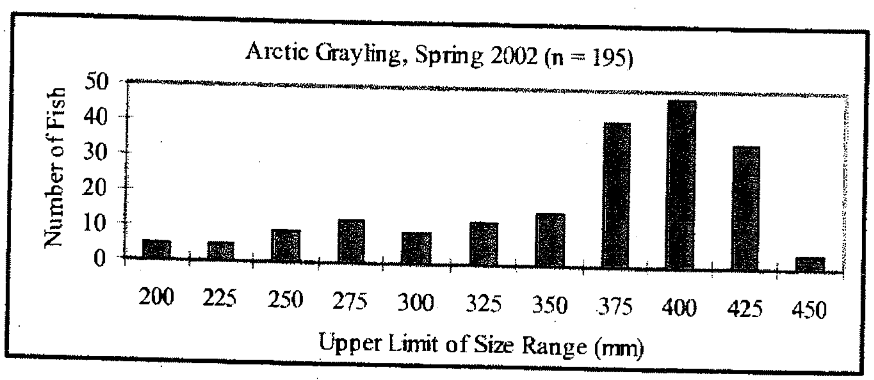




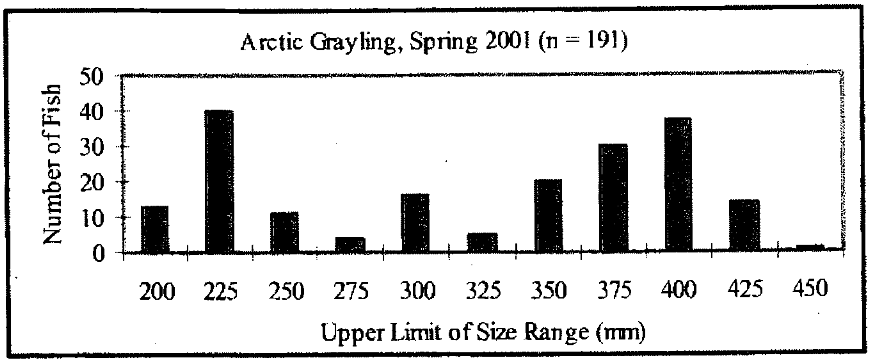
Appendix 7. Length-Frequency Distribution of Arctic Grayling in North Fork Red Dog Creek

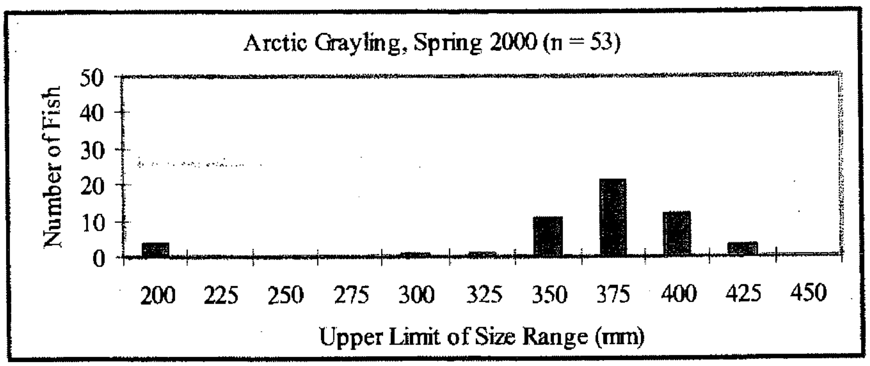






Appendix 7 concluded.





Appendix 8. Arctic Grayling, Mainstem Red Dog Creek

Observations and catches of Arctic grayling in Mainstem Red Dog Creek below confluence of North Fork and Middle Fork Red Dog creeks since 1994.

7/8/04 – angling, three adults (373, 297, 356 mm) near Station 10
7/8/04 – visual, fry in all backwaters near Station 10
7/7/04 – angling, two adults (333, 325 mm) near Station 151
7/7/04 – visual, fry common near Station 151
5/26/04 – fyke net, four adults near Station 10
5/25/04 – visual, two adult males near Station 10

9/7/03 – visual, two adults and five fry near Station 151
7/8/03 – visual, ten adults near Station 10
7/7/03 – visual, fry in backwaters near Station 10, one group of 30
6/14/03 – angling, eight adults, one spent male near Station 10
6/12/03 – visual, ten adults, three active spawning pairs observed near Station 10
6/11/03 – aerial, 48 adults, two spawning pairs seen

7/28/02 – visual, adults present near Station 10, three to four per pool
7/27/02 – visual, few fry (<10) seen
6/7/02 – angling, 10 adults and three juveniles marked and released near Station 10, most of the females were spent
6/4/02 – fyke net, three adults and three juveniles marked and released near Station 10
6/3/02 – fyke net, three adults marked and released near Station 10
6/2/02 – fyke net, eight adults marked and released near Station 10
6/1/02 – fyke net, 31 adults marked and released near Station 10
5/31/02 – fyke net, seven adults marked and released near Station 10

7/29-31/01 – visual, very few fry seen (about 20 mm), late breakup, cold temperatures resulted in late spawning
6/17/01 – angling, 11 adults marked and released near Station 10, all females spent
6/15-18/01 – visual, walked creek to check for spawners in proposed mixing zone, none observed, one adult seen feeding at rock bluff (about 0.8 km below North Fork)

Appendix 8 concluded.

7/28/00 – visual, several fry in backwaters and along stream margins, not numerous
7/6/00 – visual, walked most of creek, tagged three adults near Station 10, most pools held one to three adults
7/5/00 – visual, two adults feeding at rock bluff (0.8 km below North Fork), juvenile observed
6/11-12/00 – fyke net, adults captured, marked, and released

8/9-10/99 – visual, numerous fry in backwaters and along stream margins
7/8-9/99 – angling, two adults captured, marked, and released near Station 10
7/8-9/99 – visual, 12 adults and some fry near Station 10
7/8-9/99 – visual, two adults at rock bluff (0.8 km below North Fork)
5/30/99 – fyke net, 32 adults caught about 100 m below North Fork mouth
5/29/99 – angling, three adults caught just below North Fork mouth

6/28/98 – visual, one adult feeding at rock bluff (0.8 km below North Fork)
6/10/98 – visual, no fish seen between North Fork mouth and rock bluff 0.8 km downstream

9/29/97 – minnow traps, seven fry caught near Station 10
8/10/97 – visual, fry in backwaters
6/27/97 – visual, fry numerous at Station 10
6/26/97 – angling, 15 adults marked and released near Station 10
6/25/97 – drift net, fry caught at Station 10, 13-15 mm long
6/25/97 – visual, two adults at rock bluff 0.8 km below North Fork

8/12/96 – visual, fry near rock bluff 0.8 km below North Fork
8/11/96 – visual, fry in shallow eddies at mouth of Mainstem
7/15/96 – angling, seven adults marked and released near Station 10
6/19/96 – visual, one adult near Station 10

8/14/95 – angling, 11 adults marked and released, rock bluff 0.8 km below North Fork
8/11/95 – visual, fry (about 30) below North Fork
7/20/95 – visual, one adult near rock bluff 0.8 km below North Fork
7/17/95 – angling, two adults near rock bluff 0.8 km below North Fork
6/29/95 – angling, one adult just below North Fork

7/27/94 – visual, two adults just below North Fork