Canadian Data Report of

Fisheries and Aquatic Sciences 1003

October 1996

REVIEW AND ASSESSMENT OF WATER QUALITY IN THE SKEENA RIVER WATERSHED, BRITISH COLUMBIA, 1995

by

Dawn Remington[1]

Habitat Management Sector
Habitat and Enhancement Branch
Department of Fisheries and Oceans
228 - 417 2nd Ave. West
Prince Rupert, B.C.
V8J 1G8

[1] REMINGTON ENVIRONMENTAL, RR 2, S59, C9, Smithers, B.C. V0J 2N0

Canadian Data Report of Fisheries and Aquatic Sciences

Data reports provide a medium for filing and archiving data compilations where little or no analysis is included. Such compilations commonly will have been prepared in support of other journal publications or reports. The subject matter of data reports reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Data reports are not intended for general distribution and the contents must not be referred to in other publications without prior written authorization from the issuing establishment. The correct citation appears above the abstract of each report. Data reports are abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-25 in this series were issued as Fisheries and Marine Service Data Records. Numbers 26-160 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Data Reports. The current series name was introduced with the publication of report number 161.

Data reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport statistique canadien des sciences halieutiques et aquatiques

Les rapports statistiques servent à classer et à archiver les compilations de données pour lesquelles il y a peu ou point d'analyse. Ces compilations auront d'ordinaire été préparées à l'appui d'autres publications ou rapports. Les sujets des rapports statistiques reflètent la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports statistiques ne sont pas destinés à une vaste distribution et leur contenu ne doit pas être mentionné dans une publication sans autorisation écrite préalable de l'établissement auteur. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports statistiques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 25 de cette série ont été publiés à titre de relevés statistiques, Services des pêches et de la mer. Les numéros 26 à 160 ont été publiés à titre de rapports statistiques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 161.

Les rapports statistiques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Data Report of

Fisheries and Aquatic Sciences 1003

October 1996

REVIEW AND ASSESSMENT OF WATER QUALITY IN THE SKEENA RIVER WATERSHED, BRITISH COLUMBIA, 1995

by

Dawn Remington[1]

Habitat Management Sector
Habitat and Enhancement Branch
Department of Fisheries and Oceans
228 - 417 2nd Ave. West
Prince Rupert, B.C.
V8J 1G8

[1] REMINGTON ENVIRONMENTAL, RR 2, S59, C9, Smithers, B.C. V0J 2N0

Cat. No. Fs 97-13/1003E ISSN 0706-6465

Correct citation for this publication:

Remington, D. 1996. Review and Assessment of Water Quality in the Skeena River Watershed, British Columbia, 1995. Can. Data Rep. Fish. Aquat. Sci. 1003: 328 p.

CONTENTS

List of Figures....................ix
List of Appendices....................x
Abstract and Résumé....................xi
Preface....................xii
1. INTRODUCTION AND OVERVIEW OF THE SKEENA RIVER WATERSHED.1
1.1 OBJECTIVES....................1
1.2 METHODS....................1
1.2.1 Major reaches of the Skeena River watershed....................1
1.2.2 Hydrology....................3
1.2.3 Land use history....................4
1.2.4 Water withdrawals....................5
1.2.5 Water quality and aquatic research....................5
1.2.6 Liquid waste discharges....................6
1.3 OVERVIEW OF THE SKEENA RIVER WATERSHED....................6
1.3.1 Physiography....................6
1.3.2 Land use history....................9
1.3.3 Water withdrawals....................11
1.3.4 Forestry/water quality research - regional studies....................12
1.3.5 Water quality and aquatic research - regional studies....................14
1.3.6 Linear developments traversing the watershed....................19
2. WATER QUALITY: HOW IS IT AFFECTED BY LAND USE ACTIVITIES AND HOW IS IT REGULATED IN BRITISH COLUMBIA?....................21
2.1 INTERACTION BETWEEN LAND USE ACTIVITIES AND WATER QUALITY....................21
2.1.1 Cumulative effects of small modifications to habitat....................21
2.1.2 Forestry and water quality....................21
2.1.3 Mining and water quality....................27
2.1.4 Agriculture and water quality....................29
2.1.5 Urban developments and water quality....................31
2.1.6 Linear developments and water quality....................32
2.2 WATER QUALITY MANAGEMENT IN BRITISH COLUMBIA....................34
2.2.1 BC water quality criteria and Canadian water quality guidelines....34
2.2.2 BC Waste Management Act and Pollution Control Objectives......34
2.2.3 BC Environmental Assessment Act 1995....................35
2.2.4 BC Wildlife Act classification of angling waters....................36
2.2.5 BC Land Development Guidelines....................37
2.2.6 BC Water Act and proposed Community Watershed Management Guidelines....................37
2.2.7 BC Fisheries/Forestry Guidelines, Forest Practices Code, Watershed Restoration Program and Land Use Planning....................38
2.2.8 Canadian Environmental Protection Act....................39
2.2.9 Canadian Fisheries Act....................40
2.2.10 Water Survey of Canada hydrometric network....................41

3. UPPER SKEENA RIVER TO BABINE RIVER CONFLUENCE 43
3.1 HYDROLOGY 43
3.2 LAND USE HISTORY 43
3.2.1 Settlements 43
3.2.2 British Columbia Railway and Omineca Resource Access Road 46
3.2.3 Forestry 46
3.2.4 Mining 47
3.3 WATER WITHDRAWALS 48
3.4 WATER QUALITY AND AQUATIC RESEARCH 48
3.4.1 Productivity of Skeena watershed sockeye nursery lakes, 1994 48
3.5 LIQUID WASTE DISCHARGES 49
3.6 SUMMARY AND REVIEW OF MONITORING NEEDS 49
3.6.1 Hydrometric data needs 50
3.6.2 Interaction of forestry and water quality 50
3.6.3 Interaction of mining and water quality 50
3.6.4 Monitoring needs 50
4. BABINE RIVER AND LAKE 51
4.1 HYDROLOGY 51
4.2 LAND USE HISTORY 54
4.2.1 Settlements 54
4.2.2 Sockeye enhancement facilities 54
4.2.3 Forestry 54
4.2.4 Mining 60
4.3 WATER WITHDRAWALS 61
4.4 WATER QUALITY AND AQUATIC RESEARCH 62
4.4.1 Historical limnological research for Babine Lake 62
4.4.2 Productivity of Skeena watershed sockeye nursery lakes, 1994 65
4.5 LIQUID WASTE DISCHARGES 66
4.5.1 Granisle Mine PE-1608 66
4.5.2 Noranda Minerals Inc. Bell Mine PE-1505 69
4.5.3 Village of Granisle - PE-1507 78
4.5.4 Fort Babine Enterprise Society PE-8046 80
4.5.5 Campbell's Babine Lodge PE-7180 81
4.5.6 Coyote Lodge and Marina PE-446 82
4.5.7 Tukii Lodge PE-8841 84
4.5.8 Minor discharges 85
4.6 SUMMARY AND REVIEW OF MONITORING NEEDS 86
4.6.1 Interaction of forestry and water quality 86
4.6.2 Interaction of mining and water quality 87
4.6.3 Datasets critical to the development of water and sediment quality objectives for the Babine watershed 93
5. SKEENA RIVER TO BULKLEY RIVER CONFLUENCE 95
5.1 HYDROLOGY 95
5.2 LAND USE HISTORY 95
5.2.1 Settlements 95

5.2.2 Agriculture ... 99
5.2.3 Forestry ... 100
5.3 WATER WITHDRAWALS ... 102
5.4 WATER QUALITY AND AQUATIC RESEARCH ... 103
5.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 ... 103
5.5 LIQUID WASTE DISCHARGES ... 105
5.5.1 Kispiox Band Council PE-11036 ... 105
5.5.2 Silver Standard Mine ... 107
5.5.3 Village of Hazelton PE-303 ... 109
5.6 SUMMARY AND REVIEW OF MONITORING NEEDS ... 111
5.6.1 Water quality assessment ... 111
5.6.2 Interaction of agriculture and water quality ... 111
5.6.3 Interaction of forestry and water quality ... 112
5.6.4 Interaction of mining and water quality ... 113
5.6.5 Interaction of urban developments and water quality ... 113
6. MORICE RIVER AND LAKE ... 115
6.1 HYDROLOGY ... 115
6.2 LAND USE HISTORY ... 115
6.2.1 Forestry ... 115
6.2.2 Mining ... 121
6.2.3 Kemano Completion Project ... 121
6.3 WATER WITHDRAWALS ... 121
6.4 WATER QUALITY AND AQUATIC RESEARCH ... 121
6.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 ... 121
6.5 LIQUID WASTE DISCHARGES ... 124
6.5.1 New Nadina Explorations Ltd. (Formerly Silver Queen Mine) ... 124
6.5.2 Northwood Pulp & Timber Ltd. PR-5394 ... 127
6.5.3 Minor discharges ... 128
6.6 SUMMARY AND REVIEW OF MONITORING NEEDS ... 128
6.6.1 Water quality assessment ... 128
6.6.2 Hydrometric data needs ... 128
6.6.3 Interaction of forestry and water quality ... 129
6.6.4 Interaction of mining and water quality ... 131
7. UPPER BULKLEY RIVER TO MORICE RIVER CONFLUENCE ... 133
7.1 HYDROLOGY ... 133
7.2 LAND USE HISTORY ... 133
7.2.1 Settlements ... 133
7.2.2 Agriculture ... 133
7.2.3 Forestry ... 137
7.2.4 Mining ... 138
7.3 WATER WITHDRAWALS ... 138
7.4 WATER QUALITY AND AQUATIC RESEARCH ... 139

7.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 139
7.4.2 Water quality assessment and objectives 142
7.5 LIQUID WASTE DISCHARGES 144
7.5.1 Equity Silver Mines PE-4475 144
7.5.2 District of Houston Sewage Treatment Plant PE-0287 156
7.5.3 Regional District of Bulkley Nechako (Knockholt) PR-8856 162
7.5.4 Regional District of Bulkley Nechako (Topley) PR-1791 163
7.5.5 Minor Discharges 164
7.6 SUMMARY AND REVIEW OF MONITORING NEEDS 165
7.6.1 Hydrometric data needs 165
7.6.2 Land use activities and nutrient/bacterial loading 165
7.6.3 Interaction of agriculture and water quality 166
7.6.4 Interaction of forestry and water quality 167
7.6.5 Interaction of mining and water quality 168
7.6.6 Interaction of urban developments and water quality 173
8. BULKLEY RIVER TO SKEENA RIVER CONFLUENCE 179
8.1 HYDROLOGY 179
8.2 LAND USE HISTORY 179
8.2.1 Settlements 179
8.2.2 Agriculture 185
8.2.3 Forestry 185
8.3 WATER WITHDRAWALS 188
8.3.1 Bulkley River 188
8.3.2 Canyon Creek 190
8.4 WATER QUALITY AND AQUATIC RESEARCH 190
8.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 190
8.4.2 Water quality assessment and objectives - Bulkley River 195
8.4.3 Water quality assessment and objectives-Kathlyn, Seymour, Round & Tyhee Lakes 195
8.5 LIQUID WASTE DISCHARGES 198
8.5.1 Village of Telkwa STP PE-12367 198
8.5.2 Manalta Coal Ltd. - Telkwa Coal 200
8.5.3 Regional District of Bulkley Nechako - Smithers/Telkwa Landfill PR-7687 (new) and PR-2270 (old) 202
8.5.4 Town of Smithers STP PE-0373 203
8.5.5 West Fraser Mills Ltd. PR-7867 205
8.5.6 Moricetown Sewage 206
8.5.7 Regional District of Kitimat-Stikine Hazelton Landfill PR-4399 207
8.5.8 District of New Hazelton PE-1556 207
8.5.9 REPAP Carnaby PR-7861 210
8.5.10 Hagwilget Indian Band PE-7460 211
8.5.11 Minor Discharges 213
8.5 SUMMARY AND REVIEW OF MONITORING NEEDS 214

8.5.1 Water quality assessment 214
8.5.2 Hydrometric data needs 215
8.5.3 Interaction of agriculture and water quality 216
8.5.4 Interaction of forestry and water quality 217
8.5.5 Interaction of mining and water quality 218
8.5.6 Interaction of urban developments and water quality 218
9. SKEENA RIVER TO KITSUMKALUM RIVER CONFLUENCE 225
9.1 HYDROLOGY 228
9.2 LAND USE HISTORY 228
9.2.1 Settlements 228
9.2.2 Agriculture 231
9.2.3 Forestry 231
9.2.4 Mining 234
9.3 WATER WITHDRAWALS 234
9.4 WATER QUALITY AND AQUATIC RESEARCH 235
9.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 235
9.4.2 Seasonal and long-term variations in water quality of British Columbia Rivers: Skeena River at Usk, BC 1984-1992 238
9.4.3 Productivity of Skeena watershed sockeye nursery lakes - 1994 239
9.5 LIQUID WASTE DISCHARGES 240
9.5.1 Gitsegukla Indian Band PE-7463 240
9.5.2 Silver Standard Resources Inc. PR-6681 (Duthie Mine) 241
9.5.3 City of Terrace PE-1594 243
9.5.4 City of Terrace PR-2809 246
9.5.5 Regional District of Kitimat Stikine Thornhill Landfill PR-4057 247
9.5.6 Regional District of Kitimat Stikine Queensway PE-12645 249
9.5.7 Minor discharges 252
9.6 SUMMARY AND REVIEW OF MONITORING NEEDS 253
9.6.1 Water quality assessment 253
9.6.2 Interaction of forestry and water quality 254
9.6.3 Interaction of mining and water quality 255
9.6.4 Interaction of urban developments and water quality 256
10. LAKELSE RIVER AND LAKE 261
10.1 HYDROLOGY 261
10.2 LAND USE HISTORY 261
10.2.1 Settlements 261
10.2.2 Forestry 263
10.3 WATER WITHDRAWALS 265
10.4 WATER QUALITY AND AQUATIC RESEARCH 266
10.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987 266
10.4.2 Water quality assessment and objectives 268
10.4.3 Productivity of Skeena watershed sockeye nursery lakes, 1994 270
10.5 LIQUID WASTE DISCHARGES 271

10.5.1 Mount Layton Hotsprings PE-7531 271
10.6 SUMMARY AND REVIEW OF MONITORING NEEDS 277
10.6.1 Water quality assessment 277
10.6.2 Interaction of forestry and water quality 277
10.6.3 Interaction of urban developments and water quality 278
11. LOWER SKEENA RIVER 281
11.1 HYDROLOGY 281
11.2 LAND USE HISTORY 285
11.2.1 Settlements 285
11.2.2 Forestry 285
11.3 WATER WITHDRAWALS 286
11.4 LIQUID WASTE DISCHARGES 287
11.4.1 Shames Mountain PE-11570 287
11.4.2 Minor Discharges 288
11.5 SUMMARY AND REVIEW OF MONITORING NEEDS 289
11.5.1 Interaction of forestry and water quality 289
12. OVERVIEW OF WATER QUALITY IN THE SKEENA WATERSHED WITH IDENTIFICATION OF DATASETS CRITICAL TO THE ASSESSMENT OF LONG-TERM/CUMULATIVE IMPACTS 291
12.1 WATER QUALITY IN THE SKEENA WATERSHED 291
12.2 LONG-TERM WATER QUALITY TREND MONITORING NEEDS 291
12.3 FORESTRY INTERACTION WITH WATER QUALITY 292
12.3.1 Short-term stream monitoring 292
12.3.2 Long-term stream monitoring 292
12.4 AGRICULTURAL INTERACTION WITH WATER QUALITY IN THE BULKLEY RIVER WATERSHED 293
12.4.1 Identification of sources of nutrients to the upper Bulkley River .293
12.4.2 Assessment of agricultural interaction with water quality 293
12.5 MUNICIPAL SEWAGE TREATMENT FACILITIES AND THEIR IMPACTS ON WATER QUALITY 294
12.5.1 Effluent and receiving environment monitoring 294
12.5.2 Assessment of potential acute and/or chronic toxicity within the mixing zones of sewage effluents 294
12.6 WATER AND SEDIMENT QUALITY OBJECTIVES FOR THE BUCK CREEK/GOOSLY LAKE AND FOXY CREEK/MAXAN CREEK/BULKLEY LAKE WATERSHEDS 295
12.6.1 Acute and chronic toxicity of treated ARD to stream and lake biota296
12.6.2 Sediment quality objectives 296
12.7 WATER AND SEDIMENT QUALITY OBJECTIVES FOR THE BABINE WATERSHED 297
12.7.1 Mass balance for copper and other metals 297
12.7.2 Acute and chronic toxicity of ARD to Babine Lake biota 298
12.7.3 Sediment quality objectives 298
13 REFERENCES 299

LIST OF FIGURES

Figure 1.1 Skeena River Watershed 2

Figure 3.1 Upper Skeena River to Babine River confluence 44

Figure 3.2 Discharge envelope Skeena River above Babine River 45

Figure 4.1 Babine River and Lake 52

Figure 4.2 Discharge envelope Babine River at Babine 53

Figure 4.3 Main elements of Bell and Granisle Mines 63

Figure 4.4 Schematic of proposed Bell Mine water collection areas and discharges 74

Figure 5.1 Skeena River to Bulkley River confluence 96

Figure 5.2 Discharge envelope Kispiox River near Hazelton 97

Figure 5.3 Discharge envelope Skeena River at Glen Vowell 98

Figure 6.1 Morice River and Lake 116

Figure 6.2 Discharge envelope Morice River [at outlet of Morice Lake] 117

Figure 7.1 Upper Bulkley River to Morice River confluence 134

Figure 7.2 Discharge envelope Buck Creek at mouth 135

Figure 7.3 Discharge envelope Bulkley River near Houston, ... 136

Figure 7.4 Main elements of Equity Silver Mine 145

Figure 8.1 Bulkley River to Skeena River confluence (hydrometric sites and licensed water withdrawals) 180

Figure 8.2 Bulkley River to Skeena River confluence (permitted waste discharges) 181

Figure 8.3 Discharge envelope Bulkley River at Quick 182

Figure 8.4 Discharge envelope Telkwa River below Tsai Creek 183

Figure 8.5 Discharge envelope Canyon Creek near Smithers 184

Figure 9.1 Skeena River to Kitsumkalum River Confluence 226

Figure 9.2 Skeena River at Terrace 227

Figure 9.3 Discharge envelope Skeena River at Usk 229

Figure 9.4 Discharge envelope Zymoetz River above OK Creek 230

Figure 10.1 Lakelse River and Lake........ 262

Figure 11.1 Lower Skeena River 282

Figure 11.2 Discharge envelope Zymagotitz River near Terrace........ 283

Figure 11.3 Discharge envelope Exchamsiks River near Terrace 284

LIST OF APPENDICES

Appendix 1 Table 1 BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines307

Appendix 1 Table 2 BC MOELP Criteria and CCREM Guidelines for Microbiological Indicators312

Glossary and Acronyms........ 313

ABSTRACT

Remington, D. 1996. Review and Assessment of Water Quality in the Skeena River Watershed, British Columbia, 1995. Can. Data Rep. Fish. Aquat. Sci. 1003: 328 p.

Historical water quality data presented for the Skeena River watershed are divided into nine subsequent sections, corresponding to the nine major watershed reaches. Each section is divided into 6 subsections: hydrology, land use history, water withdrawals, water quality and aquatic research, liquid waste discharges, and a summary and review of monitoring needs. Parameters and datasets which are critical in the assessment of long-term and/or cummulative impacts from proposed development are identified. Additional water quality information needs in critical geographical areas are described.

RÉSUMÉ

Remington, D. 1996. Review and Assessment of Water Quality in the Skeena River Watershed, British Columbia, 1995. Can. Data Rep. Fish. Aquat. Sci. 1003: 328 p.

Cette étude présente des données historiques sur la qualité des eaux dans le bassin de la rivière Skeena. Les données sont divisées en neuf sections correspondant aux principaux secteurs du bassin, chaque section étant elle-même divisé en six sous-sections: hydrologie, historique de l'aménagement du territoire, prélèvements d'eau, qualité de l'eau et recherche aquatique, rejets liquides et résumé des besoins en matière de surveillance. Les auteurs traitent également des paramètres et des données nécessaires à l'évaluation des impacts à long terme ou cumulatifs des travaux d'aménagement proposés. Ils décrivent en outre les besoins d'information en matière de qualité de l'eau concernant certaines zones critiques.

PREFACE

This project is supported by Fisheries and Oceans Contract No. 94-5192. Funding was provided through the Skeena/Kitimat Sustainable Fisheries Program. The goal of the program was to develop management strategies to protect weaker stocks while achieving sustainable fisheries, with the main focus on the Skeena River. This water quality project deals specifically with one of the habitat components of the Skeena River management process. The major goal of the project is to provide a concise overview of water quality issues in the Skeena watershed and to help focus habitat protection efforts. It entails the review and assessment of data documenting water quality in the Skeena River drainage. The need for additional water quality information critical to the assessment of cumulative impacts from proposed developments within the watershed is identified. Results of this assessment will help focus water quality assessment and monitoring efforts for a more effective habitat management program in the watershed.

This report would not have been possible without the generous cooperation of BC Environment Skeena Region in providing access to files, electronic databases and library. Many thanks go to Terry Roberts, Environmental Protection Regional Manager, Ian Sharpe and Phillip Ross, Environmental Protection Biologists. Paul Marquis and Lynne Williamson, Water Management and Dorothy Cardinal, Librarian, were also generous with their time. The assistance of Jeannette Lough in research of liquid waste discharges and John Howard in map preparation is greatly appreciated. Finally, special thanks go to the scientific authority Pierre Lemieux, DFO Habitat Management Unit, Skeena/Nass Area, who conceived and supervised this project.

1. INTRODUCTION AND OVERVIEW OF THE SKEENA RIVER WATERSHED

The Skeena River is the second largest river discharging to the sea on the coastline of British Columbia, draining an area of about 54,000 square kilometres (Figure 1.1). The Skeena River is second only to the Fraser, draining an area of about 219,000 square kilometres[1], in salmon production as well, with annual escapements exceeding 3 million fish. These fish form the basis of an internationally recognized sports fishery, an aboriginal food fishery, a saltwater recreational fishery, and a commercial fishery in Canadian and U.S. waters.

Although north-central British Columbia has a relatively low population density, there has been increasing anthropogenic pressure on the watershed from many sources. Water use sectors within the watershed include domestic, agricultural, municipal and industrial. Five major forest companies and many small business foresters harvest throughout the Skeena drainage. Agriculture is a major land use sector in the Bulkley valley. There are three decommissioning mines in the Skeena drainage and at least one additional mine in planning stages. Because of acid rock drainage, the three decommissioning mines may require site monitoring in perpetuity. There are numerous communities which discharge waste waters to the watershed. Although point source water quality data is available from various agencies, that has been little assessment of impacts from non-point sources or assessment of cumulative loading on water quality within the drainage.

1.1 OBJECTIVES

The objective of this report is 1) to provide an overview of water quality in the Skeena River drainage; 2) to assess municipal and industrial impacts on water quality; 3) to identify parameters and datasets which are critical in the assessment of long-term and/or cumulative impacts from proposed developments; 4) to identify additional water quality information needs in critical geographical areas; and 5) to identify additional water withdrawal information needs in order to assess possible impacts on in-stream flows.

1.2 METHODS

1.2.1 Major reaches of the Skeena River watershed

For the purposes of this review, the Skeena watershed has been divided into nine major reaches. These are shown in Table 1.1 along with the primary water uses and the major communities within each reach. In some instances British Columbia Ministry of Environment, Lands and Parks (MOELP) has approved water quality objectives for a specific reach. In preparing these objectives, the appropriate priority uses for the specific waterbody are chosen, which become the "designated" water uses to be protected by the objectives. Where water quality objectives have been approved for a reach, the designated water uses are shown in italics.

---

[1]Drainage area reduced by completion of Kenney Dam (October 1952).

Figure 1.1 Skeena River watershed

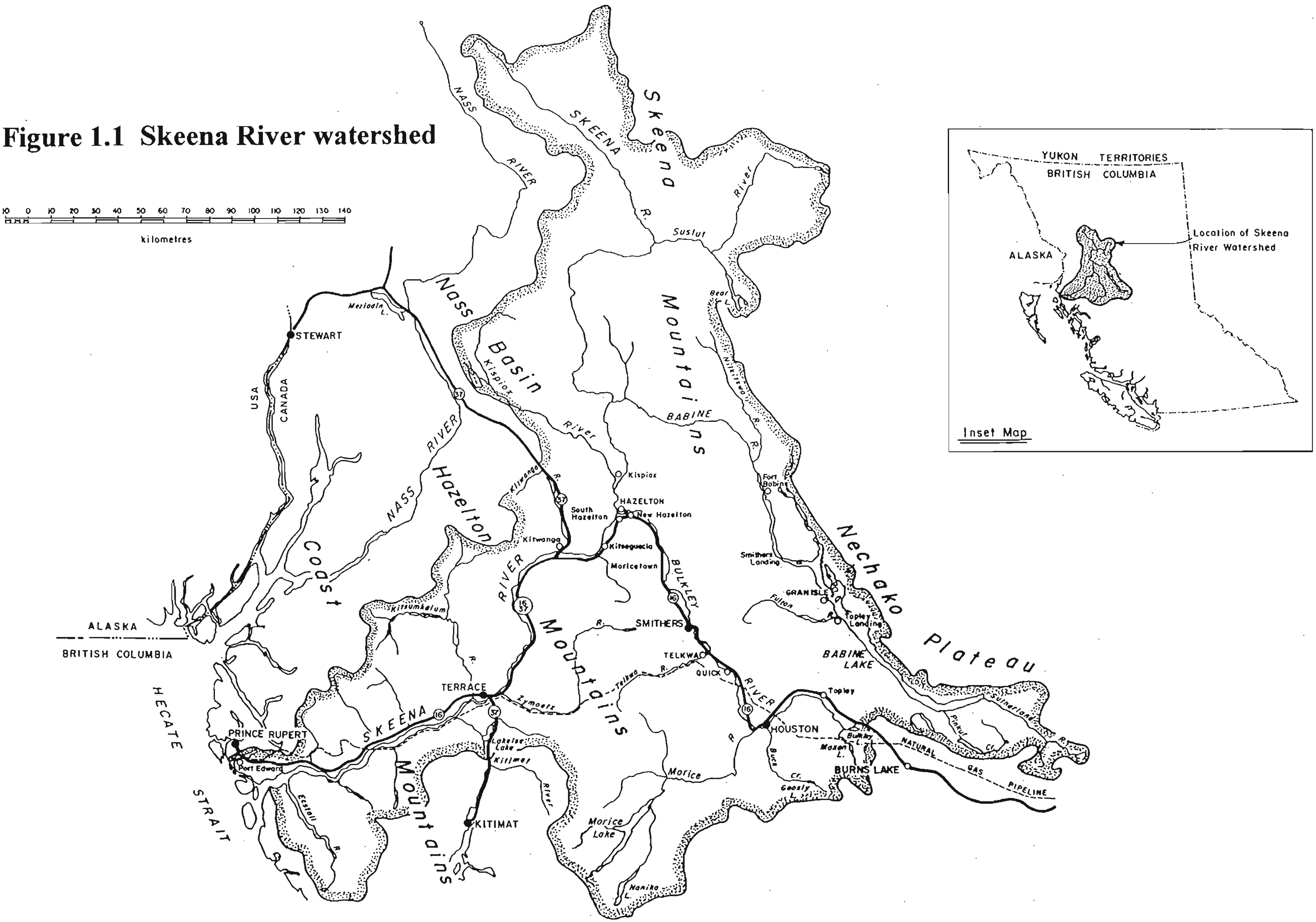


Table 1.1 Major reaches of the Skeena River watershed

Sec.	Major reaches	Water uses *(Designated)*	Communities
3	Upper Skeena River to Babine River confluence	aquatic life, wildlife, recreation, industrial use	
4	Babine River and Lake	drinking water, aquatic life, wildlife, recreation, industrial use	Babine, Smithers Landing, Granisle, Topley Landing
5	Skeena River to Bulkley River confluence	drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	Kispiox, Glen Vowell, Hazelton/Gitanmaax
6	Morice River and Lake	*drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use*	
7	Upper Bulkley River to Morice River confluence	*drinking water*, aquatic life, wildlife, recreation, livestock, irrigation, industrial use*	Topley, Houston
8	Bulkley River to Skeena River confluence	*drinking water**, aquatic life, wildlife, recreation, livestock, irrigation, industrial use*	Telkwa, Smithers, Moricetown, New Hazelton, Hagwilget
9	Skeena River to Kitsumkalum River confluence	drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	South Hazelton, Gitsegukla, Gitwangak, Kitwancool, Kitselas, Terrace, Kisumkalum
10	Lakelse River and Lake	*drinking water, aquatic life, recreation, irrigation*	Lakelse Lake
11	Lower Skeena River	drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	

* Drinking water designated use applies upstream of Houston only.

** Drinking water designated use applies upstream of Smithers only.

The first section of this report describes methods and gives an overview of the watershed. Section 2 discusses how water quality is affected by land use activities and describes the regulatory environment in British Columbia. Data presented in this report are divided into the nine subsequent sections, corresponding to each of the nine major watershed reaches. Each section is divided into 6 subsections: hydrology; land use history; water withdrawals; water quality and aquatic research; liquid waste discharges, and a summary and review of monitoring needs. Section 12 identifies datasets critical to the assessment of long-term and/or cumulative impacts, and identifies critical datasets and geographical areas for directed research. MOELP and CCREM water quality criteria and guidelines are found in Appendix 1. Glossary and acronyms are found in the final section.

1.2.2 Hydrology

For each major reach, the principal Environment Canada hydrometric stations are shown in the appropriate section. Environment Canada Water Survey summary monthly streamflow data are presented, as well as a chart depicting the streamflow envelope. Summary monthly streamflow data are also presented for selected tributaries.

In most jurisdictions in Canada and the United States, water withdrawals and minimum dilution requirements for liquid effluents are calculated using the average 7 consecutive day low flow on a 10 year return period (the low flow of at least one weeks duration which is predicted to occur once every 10 years). The average 7 day low flows are based on the 'climactic year', from freshet to freshet. In the Skeena watershed an extended low flow period generally occurs between January and April under ice cover. In dry years the low flow period in some smaller first order interior streams can occur in late summer (typically September). For this study, the average 7 day, 10 year low flow was calculated by the MOELP Flood Frequency Analysis Program software, FREQAN.

The location of MOELP Snow Survey Stations are mapped for each reach. Measurement of the water contained in the snowpack prior to the commencement of melt is a good indicator of subsequent streamflow and probability of flooding. For this reason, Snow Survey Stations have been established at selected locations and elevations on major and tributary basins After water equivalent measurements have been taken at the same sampling date for a number of years, a correlation is derived for a watershed by relating water equivalents and other applicable data to the subsequent streamflow. This relationship is used to forecast seasonal volume streamflow at freshet. The streamflow forecasts are published annually in March, April, May and June and are available from the Hydrology Branch, Water Management Division MOELP.

1.2.3 Land use history

1.2.3.1 Settlements

Population estimates for villages and municipal districts were provided by Statistics BC, and Regional District Official Community and Rural Settlement Plans. Population estimates for First Nations villages (on reserve) are from Indian and Northern Affairs Canada 1989 Indian Register (BC Ministry of Aboriginal Affairs 1992).

1.2.3.2 Agriculture

While there is a published profile of agriculture in the Smithers Agricultural District (Ministry of Agriculture and Food 1984), there is no breakdown by watershed. For this reason, the estimated farm and livestock numbers presented were provided by Dave Riendeau, District Agriculturist (personal communication). In the Skeena Region, most ranches utilize Crown lands for a four month summer grazing period. BC Crown Lands administers Crown grazing leases (grazing lands). The BC Forest Service administers the grazing through permits or licenses issued on an annual basis. Livestock numbers for each Forest District were provided by Skeena Region Forest Service (B. Drinkwater, unpublished data) and by Forest District Range officers.

1.2.3.3 Forestry

Likewise, there is no Ministry of Forests regional dataset of forestry operators and their areas of operation. The information presented as background on land use patterns is taken from discussion with Andrew Wheatley, Planning Forester, Prince Rupert Forest Region and Forest District officers. While there is presently no watershed based inventory of forestry activities such as percent of watershed harvested, kilometres of roads, etc., this information will become available through the watershed assessment program of the MOELP/MOF Watershed Restoration Program. Watershed assessments addressing water quality impacts of forestry activities (such as mass wasting, sedimentation and debris loading) of many key Skeena drainages are scheduled for completion in 1995 (Doug Johnston, MOELP Watershed Restoration Coordinator, personal communication).

1.2.3.4 Mining

Existing mines are permitted by MOELP and discussed under liquid waste discharges. Mining exploration activity is high in some areas of the Skeena watershed, and exploration programs which the Ministry of Energy, Mines and Petroleum Resources (MEMPR) refers to as 'major projects' are noted on the reach maps. Major projects are generally exploration sites at which diamond drilling is taking place but which have not proven reserves and have not applied for a Mine Development Certificate. Brief summary information (deposit type and exploration activity) is given for each project (P. Wojdak 1995, Skeena Region MEMPR files 1995).

1.2.4 Water withdrawals

Water withdrawals from each reach are summarized from the MOELP Water License Information System database (WILS). Because of the large number of individual water licenses, domestic and irrigation withdrawals are presented as summary data for each study reach. The larger licenses for waterworks and industrial use are cited individually and shown on the reach maps. Watersheds considered by MOELP Water Management to be Community Watersheds are noted. See section 2.2.5 for discussion of proposed Community Watershed Management Guidelines. The total licensed volume of water withdrawn is compared to the streamflow regime and to 7 day average 10 year low flow calculated for each reach and for selected gauged tributaries.

1.2.5 Water quality and aquatic research

MOELP Provisional Water Quality Objectives have been prepared for the Bulkley Basin (Nijman 1986), four Smithers lakes (Boyd and others 1985) and Lakelse Lake (McKean 1986). These documents are reviewed as well as subsequent objectives monitoring data published annually (MOELP 1989 - 1992).

Summary water quality data collected monthly by MOELP for the 5 year period, 1983 to 1988, from seven Skeena watershed drainages are reviewed (Wilkes and Lloyd 1990).

The Canada-BC Water Quality Monitoring Agreement, signed in 1985, provides for the coordination and integration of federal and provincial water quality monitoring activities in a cost-shared or work-shared manner. The main focus of the agreement has been on monitoring suitable for long-term trend assessment. The Skeena River at Usk is a water quality trend site under this agreement which is operated by Environment Canada. The Skeena River at Usk is also a UN Global Environmental Monitoring Station (GEMS). Seasonal and long-term variations in water quality at this site are examined in a recent Environment Canada report (Bhangu and Whitfield 1994).

DFO is currently determining the rearing capacity of a number of important Skeena River sockeye nursery lakes. The two main objectives of the 4 year project are 1) to determine the current status (numbers, diet and condition) of juvenile sockeye stocks, and 2) to determine the productivity of the lakes and the maximum number of sockeye they are capable of producing. Monthly limnological surveys were carried out from May-October 1994 on five lakes (Johanson, Sustut, Babine, Kitsumkalum and Lakelse). Other data collected include: other chemical variables such as particulate C and N; bacteria numbers; phyto- and zooplankton species composition, numbers, biomass, and productivity; and juvenile sockeye numbers, size, diet and distribution. Water quality data on the five lakes sampled in 1994 is presented (K. Shortreed, DFO, unpublished data).

Receiving environment sample site locations for the above reports are shown on the individual reach maps. General studies and reports from other sources are reviewed where applicable.

1.2.6 Liquid waste discharges

Liquid waste discharges under MOELP Waste Management Permit are reviewed for each reach. Major effluent discharges and associated receiving environment monitoring sites are shown on the reach maps. Lesser permitted discharges are summarized in tables at the end of each section. MOELP Environmental Protection Program (EPP) permit files and Technical Reports are the primary information source for this review. Other sources include municipal and industrial monitoring reports prepared by consultants, which are referenced individually.

1.3 OVERVIEW OF THE SKEENA RIVER WATERSHED

1.3.1 Physiography

The Skeena River watershed encompasses portions of four major physiographic units: 1) the Coastal Trough (Hecate Lowlands); 2) Kitimat Ranges of the Coast Mountains; 3) the Hazelton and Skeena Mountains; and 4) the Nechako Plateau (the most northern section of the large Interior Plateau). The following discussion of physiography and hydrology of the Skeena basin is summarized from Slaymaker (1972) and Clague (1984). Reference is also made to the MOELP Ecoregion Classification system adopted in 1985 to serve as a framework for recognizing small scale ecosystems in British Columbia (Demarchi 1993).

1.3.1.1 Coastal Trough

Coastal lowlands, such as the Hecate Lowland are low relief regions that are bordered by the sea and are below a few hundred metres in elevation. Only the islands of the Skeena estuary are within this physiographic region. The area occupied by the coastal lowlands in the Skeena basin is so small that it is of minor importance hydrologically.

1.3.1.2 Coast Mountains

The Coast Mountains, an unbroken mountain chain, extend along the mainland coast of British Columbia. About 28,500 square kilometres of the Coast Mountains physiographic region are in the Fraser basin, about 9000 square kilometres in the Skeena basin, and about 13,000 square kilometres in the Stikine basin. The three parts correspond approximately the three distinctive subregions of the Coast Mountains known respectively as the Pacific, Kitimat, and Boundary ranges. The Pacific and Boundary Ranges are characterized by peaks in the 3000-3400 metre range and by extensive glaciation. The peaks of the Kitimat Ranges, by contrast, range from 1800 to 2600 metres and there are no extensive ice fields. Because of their lower relief, the Kitimat Ranges allow considerable moisture to enter the interior of the province. For this reason it has been named the Coastal Gap Ecoregion.

The Kitimat Ranges were very heavily glaciated during the Pleistocene. As a result, mountain peaks and ridges are serrate and jagged and valley slopes are steep and typically U-shaped. The alpine zone consists of steep rock outcrops, cirque and valley glaciers. The steep valley side slopes consist of shallow mantles of colluvium overlying rock. These slopes are undergoing extensive modification by snow avalanches and gully erosion. The great relief and steep topography of the mountains combined with the heavy undergrowth below timberline makes the region difficult for ground travel. A broad active floodplain is found along the Skeena River.

A maritime climate exists along the western flanks of the Coast Mountains where temperatures are greatly moderated by the close proximity of the Pacific Ocean. These are areas where eastward moving maritime Polar air first encounters the land after a long trajectory over the Pacific Ocean. As this mild, moist air lifts to traverse the Coast Mountains, large quantities of moisture are precipitated over the west facing slopes. Typically, these are areas subject to cool, wet summers and mild, wet winters; the wettest period occurring between October and December. The air becomes progressively drier and relatively warmer as it passes up and over the western slopes of the Coast Mountains. Consequently, the eastern portions of the Coast Mountains are drier throughout the year, warmer during the summer months and cooler during the winter. A larger percentage of the annual precipitation occurs as snowfall although rainfall events will occur throughout the year.

The Kitsumkalum-Kitimat trough is a broad low-lying depression extending south from Nass Basin to the head of Douglas Channel at Kitimat. It cuts perpendicularly across the Skeena Valley at Terrace and separates the Coast Mountains from the Hazelton Mountains. The southern part of the trough is drained by the Kitimat River and the northern part by the Kitsumkalum, Cedar and Tseax rivers.

Although existing valleys cutting through the Coast Ranges probably predate the Pleistocene, patterns of stream flow are believed to have shifted in response to the growth and decay of ice sheets. Many valleys were enlarged and deepened by the glaciers that flowed down them (forming the classic U-shaped valleys). The lower parts of these valleys were scoured to such great depth that they were flooded by the sea at the close of glaciation, giving rise to fiords. Parts of some of these fiords have been isostatically uplifted and filled with sediment since the end of the Pleistocene; for example, the Skeena River west of Terrace flows in a valley that was a fiord at the close of the Pleistocene. An arm of the sea also occupied the southern Kitsumkalum-Kitimat Trough at the same time. This body of water was continuous with that in the Skeena valley fiord west of Terrace with the Skeena River discharging directly into it. The Skeena River at one or more times in the past probably flowed south down the trough from the vicinity of Terrace rather than west down the lower Skeena valley. At the close of the last glaciation, however, thick drift was deposited in the southern part of the trough, and the Skeena was forced to flow west towards Prince Rupert rather than south towards Kitimat. Kitsumkalum and Lakelse lakes were dammed by glaciomarine sediments during this period as well.

1.3.1.3 Hazelton and Skeena Mountains

The Hazelton and Skeena Mountains occupy 31,000 square kilometres in the Skeena basin. The Hazelton Mountains range from 1800 to 2700 metres and consist of sedimentary and volcanic rocks with some local granitic intrusives. The Skeena Mountains consist of folded sedimentary rocks in contrast to the Hazelton Mountains. The peaks and ridges have a serrate and jagged profile, the result of intense alpine glaciation. Remnant cirque glaciers still remain on north-facing slopes of the high ridges. The steep valley side slopes of both ranges consist of mantles of colluvium with some bedrock outcrops and minor amounts of shallow till. Valley bottoms are generally wide and drift-filled. Active floodplains (mixtures of sand, silt, gravel and organic sediments) occur along the Skeena, Zymoetz, and Morice Rivers. Raised marine deposits occur locally in the vicinity of Terrace. They consist of silt and clay (bottom sediments) and gravels (old beaches and deltas).

The Hazelton Mountains contain three major ranges known as Nass Ranges to the north of the Skeena River; the Kispiox Range rising out of the Nass Basin as an outlier from the main mass of the Hazelton Mountains (both within the Nass Ranges Ecoregion); and the Bulkley Ranges to the south (Bulkley Ranges Ecosection). Maritime air continues eastward over the Hazelton Mountains after traversing the Coast Mountains. The air is no longer being lifted by topographic barriers and the air flow is level to gently subsiding. Precipitation is reduced, winters colder and summers warmer than areas to the west. Local rainshadows occur at the lower elevations where deeply incised valleys lie east of major topographic features which obstruct the westerly flow of Pacific air. A particularly effective rainshadow occurs on the Skeena River near Kitwanga.

The Nass basin is an area of low, rolling relief resting below 760 metres which is bounded by the Coast, Skeena, and Hazelton mountains and is drained largely by the Nass River. In the Skeena watershed, the Nass basin occupies 3600 square kilometres and is drained by the Kitwanga and Kispiox Rivers. The basin is underlain by folded sedimentary rocks and conglomerate that have been sculptured into drumlin-like forms by Pleistocene ice. These forms tend in a southeasterly direction. The floor of the basin is dotted by hundred of small lakes which, together with the drainage pattern, display the underlying orientation of the bedrock.

The Nass basin (corresponding to MOELP's Nass Basin Ecoregion) is climatologically unique. Moist, mild Pacific air gains access to the area by way of Portland Inlet and the Nass River valley, greatly reducing the rainshadow effect at this location east of the Coast Mountains. As a consequence, this area is wetter than areas to the south and east. Winter temperatures are moderated by the Pacific air yet summer temperatures are considerably warmer than coastal areas. The dense coastal forest vegetation is evidence of the biotic response to greater humidity.

A zone of high precipitation extends along the western flanks of the Skeena Mountains where moist air, having passed through the Nass Basin is lifted. In winter, a large proportion of precipitation occurs as snowfall along this zone and snowdepths are greater than in other parts of the basin.

The Skeena Mountains lie to the north and east of the Bulkley River, and form the headwaters of the Skeena River drainage. The southern Skeena mountains are a complex series of mountain ranges that occur east of the Coast Mountains and Nass basin. These mountains appear to rise from the plateau surface in long, rounded ridges and eventually to peaks and high ridges with the serrated and jagged profile created by intense alpine glaciation. The zigzag course of the Skeena River, which cuts across the Babine Ranges in three places, was determined by ice barriers in adjoining valleys. The present drainage of Babine Lake northward into the Skeena River rather than through the old portage route across to Stuart Lake must also be the result of damming by ice or moraines.

The climate of the Skeena Mountains is more continental in nature because of a greater exposure to continental Polar and Arctic air masses than in areas to the southwest. However, precipitation and moderated temperature still result from the movement of maritime Polar air over the area. Annual precipitation decreases from southwest to northeast over the Skeena Mountains. Precipitation is more evenly distributed throughout the year and a large proportion of winter precipitation occurs as snowfall. MOELP divides this area into the Western Skeena Mountains Ecosection (moist climate) and Eastern Skeena Mountains Ecosection (drier, rain-shadow).

1.3.1.4 Nechako Plateau

The Nechako Plateau is the northernmost subdivision of the Interior Plateau, of which 10,000 square kilometres occur in the Skeena River basin. It is an area of low relief with great expanses of flat and gently rolling terrain. Glacial drift is widespread and extensively obscures the underlying bedrock. After the last major glaciation, ice downwasted and stagnated over the plateau. Meltwater deposited sand and gravel in a variety of fluvioglacial landforms such as kames, eskers and kame terraces. At some sites, particularly along the Bulkley River, meltwater was ponded by stagnant ice and glaciolacustrine silts were deposited. Active floodplains with associated organic sediments are found along the Bulkley, Morice, Telkwa and Fulton Rivers. MOELP divides this area into three Ecosections: the Babine Upland Ecosection (Babine Lake and watershed); the Bulkley Basin Ecosection (the upper Bulkley River to about Smithers); and the Nechako Plateau Ecosection (portions of the Morice River).

The Nechako Plateau is leeward of the Coast, Skeena and Hazelton mountains which results in relatively low precipitation and considerably reduced exposure to warm, moist Pacific air. The climate is semi-continental in nature, with cold winters and warm summers. There is only one important discharge peak per year and this is the late May-early June snowmelt peak.

1.3.2 Land use history

1.3.2.1 First Nations

For at least 12,000 years the Skeena watershed has been home to First Nations peoples who built a flourishing culture around the annual runs of salmon and eulachon and the harvest of wildlife. Extensive trading took place between coastal and interior tribes along the major river valleys. The Gitksan who live along the Skeena near Hazelton, the Nisga'a of the Nass and the Tsimshian of the lower Skeena and coastal islands all spoke Tsimshian dialect. Their main trading partners were the more nomadic Athapascan Carrier language tribes of the interior.

In 1990 the British Columbia government joined the federal government in commencing treaty negotiations to settle land claims in British Columbia. The first such tripartite treaty negotiation, that of the Nisga'a of the Nass River area, is scheduled for conclusion in 1996. The land claim areas of the different aboriginal groups within the Skeena watershed are overlapping and boundaries are in dispute. In general, the lands claimed by the different tribal councils center around the following areas:

- Tsimshian — Skeena River from coast to Terrace area
- Gitanyow — Kitwanga Lake and north
- Gitksan — Skeena River from Hazelton area to headwaters, Kispiox River
- Wet'suwet'en — Bulkley and Morice rivers
- Nat'oot'en — Babine Lake
- Sekanni-Carrier — Babine River and Sustut River

1.3.2.2 Settlements

The principal urban and transportation centers and their populations as of 1994 are: Smithers (5,476), Terrace (12,631) and Prince Rupert (17,350). (Prince Rupert is located just north of the Skeena estuary and is associated with short drainages which empty directly into the sea.) These communities are connected by highways and a railway. Major airports are located at all three communities. Kitimat (population 11,765) is the fourth major community in the region. Although outside the Skeena watershed, Kitimat is the second terminus of the transportation corridor and very important economically to the region.

1.3.2.3 Industry

Forestry, fishing, agriculture and mining are the main industries in the Skeena region. One or more sawmills are present in most large communities, and pulp and paper mills are located at Kitimat and in the Skeena estuary near Prince Rupert. Important commercial tree species in the area include western and mountain hemlock, amabilis and subalpine fir, western red cedar, yellow cedar, Sitka, white and Engelmann and hybrid spruce and lodgepole pine.

Several fish processing plants and canneries are located at Prince Rupert and nearby coastal villages. Catches of salmon and groundfish, including halibut, by fleets based in these towns provide a major source of income to the region. The tremendous natural salmon production of the Skeena watershed has been augmented by two Fisheries and Oceans sockeye salmon spawning facilities on Babine Lake.

The major agricultural activity in the Skeena watershed consists of beef production (44%), followed by dairy (26%) (Ministry of Agriculture and Food 1984). Most agricultural activity is concentrated in the Bulkley valley, but there is some cattle grazing in the Skeena valley near Hazelton and Kitwanga and in the Kispiox valley. Specialty crops such as potatoes and vegetables are grown on a small scale in the Terrace area and at a few other localities.

A major aluminum smelter (Alcan Aluminum Company of Canada Ltd.) is located at Kitimat. Built in the 1950's, this is one of the largest aluminum smelters in the world and is a major source of employment at Kitimat. The power for the electrolytic furnaces was derived from damming the Nechako River to change the Tweedsmuir Lake chain into the larger Nechako Reservoir. An outlet tunnel carries the water to Kemano Inlet, on the coast south of Kitimat, where power is generated for transmission to Kitimat. The Kemano Completion Project was proposed by Alcan in 1984 to further increase its power generation capacity at Kemano. The original proposal was 1) to divert additional flows from the Nechako River, and 2) to dam the Nanika River (Morice/Bulkley watershed) and divert approximately 62% of the mean annual flow from the Nanika River into the Nechako Reservoir. In 1987 Alcan and the federal and provincial governments came to an agreement which included the Nechako River portion of the project only. In 1994 British Columbia canceled the Kemano Completion Project altogether.

Smithers and Terrace are major service centers for mining and mineral exploration in the northwest of the province. Although there are no active mine operations in the area at this time, two large open-pit porphyry copper mines on Babine Lake (Granisle and Bell) and an open-pit silver-gold mine south of Houston (Equity Silver) are in decommissioning and closure phases. An open-pit coal mine proposal on the Telkwa River (Manalta Coal Ltd.) is under review by the provincial Mine Development Review Committee.

Considerable economic activity in the area centers on cargo transportation along the Bulkley and Skeena valleys. Deep-water ports at Kitimat and Prince Rupert are loci of barge, freighter and rail traffic. Port facilities at Prince Rupert include pulp and paper, grain, coal and bulk cargo terminals. Port facilities at Kitimat include pulp and paper, aluminum and petrochemicals, including the transshipment of methanol and MTBE (a gasoline additive) which arrive by rail, as well as methanol and ammonia produced in Kitimat.

A natural gas pipeline traverses the watershed from east to west: generally paralleling the Bulkley river to Telkwa and the Telkwa and Zymoetz Rivers to Terrace. At Terrace the pipeline divides, one branch following the Kitimat River to Kitimat, the other following the Skeena to Prince Rupert.

In addition to the primary industries cited above, tourism provides a substantial source of revenue to the region. There are small provincial parks within the main valleys. Salmon and steelhead fishing in the Skeena and tributaries attracts a large number of visitors each year. In recent years MOELP introduced the Classified Waters licensing system to protect unique fishing opportunities in the most popular fishing destinations in the province. Portions of the mainstem Skeena and numerous Skeena tributaries are Class I and II streams under MOELP regulations. Finally, Prince Rupert is a terminus for car and passenger ferries traveling to Alaska and the Queen Charlotte Islands.

1.3.3 Water withdrawals

Water supply generally exceeds demand in the Skeena watershed (Ministry of Environment 1983). There is currently some demand for water from small tributaries of the Bulkley River for irrigation, for example from Canyon Creek. Agricultural expansion in the Bulkley Valley would require increased withdrawals from these tributaries, many of which are not gauged.

Two Order in Council (OIC) reserves for future hydroelectric power generation were placed on the Skeena River and tributaries and the Morice River and tributaries in 1928 (OIC Reserve 372-

1928 and 514-1928 respectively). It is considered unlikely that this power generation will be required, but water use licenses for other purposes contain a clause noting the prior existence of these reserves.

In 1983 the Town of Smithers was granted an OIC reserve on the Bulkley River upstream of Smithers for protection of their waterworks (OIC 418-1983). This reserve was requested because Smithers draws some of its water supply from wells which are located near and charged by the Bulkley River. A clause noting the existence of this reserve is placed in water use licenses issued upstream of Smithers.

1.3.4 Forestry/water quality research - regional studies

1.3.4.1 Assessment of stream protection practices in the interior of the Prince Rupert Forest Region - 1986

An assessment of streamside treatments during logging in the interior of the Prince Rupert Forest Region (Bustard 1986*b* and Bustard and Wilford 1986) concluded that the larger, well-known fish streams had been recognized as important, and therefore usually received careful treatment during logging. Measures such as leave strips, or logging to the stream edge leaving leaners and deciduous vegetation, were usually effective in ensuring that most streams were protected. Windthrow in leave strips was identified as a key concern, for it can block fish movement and cause bank damage. Leave strips were usually found to be effective in providing stream protection provided they were either not exposed to storm winds or were wide enough that fringe blowdown did not become excessive. An alternative to leave strips in areas subject to windthrow are machine reserves which restrict equipment operation along the streambank but allow for the removal of much of the merchantable wood. At some sites, however, machine reserves may reduce streambank stability over the long term. The authors identified the need for site-specific logging treatments based on better fisheries inventories and habitat mapping for logging undertaken near side channels and wetlands of larger fish-bearing streams.

Close supervision of operations at sensitive sites was identified as critical for the protection of high value fish streams. When properly undertaken, high value sites can be logged with little impact on fish streams. On the other hand, if communication and close surveillance do not occur, streamside protection measures can fail, and specific examples were cited.

Observation of logging along small creeks suggested that protection of these systems varied much more than that of the larger systems. In many situations, small creeks were identified, and measures for their protection incorporated into the layout and harvesting operations, minimizing impacts from logging. In other cases, small fish creeks were yarded across and could be badly damaged. Small creeks that were winter-logged, especially they were not adequately marked, were the most vulnerable systems. Again, part of the difficulty was inadequate fisheries inventory to enable identification of important smaller streams.

Sedimentation from roads, and to a lesser extent from skid trails, landing, and fire guards, was identified as a major influence of interior logging operations on streams. The incorporation of measures to minimize erosion from road building and logging activities was highly variable. Timing logging operations to periods when there was adequate snow cover and restricting equipment types on critical sites were the measures in use to minimize soil erosion. Special measures for erosion control, such as the use of water bars and revegetation of disturbed sites, were typically not used except after problems had developed. Inactive forest roads were allowed to fall into disrepair and become sources of stream sedimentation. There was nearly a total absence of monitoring or evaluating of logging-induced sediment on streams in the interior districts. It was anticipated by the authors that soil erosion leading to increased stream sedimentation would become more prevalent as logging operations move to steeper mid- and high elevation sites.

The authors felt that bridge and culvert installations that allow for fish passage had improved considerably over previous years. Fish passage problems were seen at stream crossings where there was inadequate pre-logging inventory or where culverts were not maintained after logging.

Analyses of the rate and spatial distribution of logging in the interior districts suggested that harvesting operations had not altered the streamflow patterns of the larger systems (Wilford 1982 and 1985). It was noted however, that these analyses had not addressed small watersheds, especially those without permanent snowfields. The run-off patterns of the smaller systems may be altered by an earlier snowmelt or by the transition from old-growth forests to extensive clearcuts and thrifty regeneration.

1.3.4.2 Application and effectiveness of the Coastal Fisheries Forestry Guidelines in the Kalum and North Coast Forest Districts

Tripp and others (1993) conducted an assessment of the effectiveness of the Coastal Fisheries Forestry Guidelines (see section 2.2.6) in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts, as part of a coastwide audit. Results of a survey of 50 cut blocks, in the fall of 1992, showed there was considerable variation between forest districts and logging companies in compliance with either site specific stream prescriptions, or the more general Coastal Fisheries Forestry Guidelines.

Hill slope accounted for a large part of the variation - the steeper the slopes, the poorer the compliance and the more frequent the impacts. The steep blocks in the Kalum District (average block slope 35.1%) and North Coast districts (average block slope 40.3%) had 2.20 and 3.35 impacts per 100 ha, respectively. The Kalum and North Coast Districts had two and three times the number of impacts recorded per unit area in the QCI District and were also considerably high than the average recorded on Vancouver Island. In Class IV streams, the number of major/moderate alterations to the channel was approximately 2.2 times higher in both the Kalum and North Coast Districts than on Vancouver Island.

Amount of habitat lost in fish bearing Class I - III streams was 15.7% of the total habitat inspected on the North Coast. Stream areas affected in Class IV streams with moderate to high transport potentials were much higher (88.7%). Estimated reductions in stream stability were higher in Kalum (50.0%) and North Coast (71.4%) than in QCI or on Vancouver Island.

Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts, followed by bank scouring and channel scouring.

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO was 57.1% in Kalum and 86.2% in North Coast. Overall compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was assessed at 65% in Kalum and 53% in North Coast. The differences were significant, and consistent with the degree of impact observed in streams in each district, particularly fish-bearing streams. When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams in 214 out of the 217 cases (98.6%).

1.3.5 Water quality and aquatic research - regional studies

1.3.5.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly 1983 - 1987 from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Included in the study, but not summarized in this report, was the Kitimat River which drains into Douglas Channel.

The detailed data are archived on the MOELP System for Environmental Assessment and Management (SEAM) database. Summary data for each individual station are presented in the appropriate (reach) sections of this report.

Total suspended solids.— A comparison of non-filterable residue in the seven rivers 1983-1987 is found in Table 1.2. Non-filterable residue is also commonly referred to as total suspended solids or TSS. TSS is a measurement of the particulates such as silt, clay, organic matter and plankton which are held in suspension by turbulence and Brownian movement. A normal load of suspended particulates are derived from natural weathering and soil erosion during run-off. Fast flowing waters draining steep mountainous terrain such as the Skeena watershed typically carry heavy suspended solids loads during freshet. The presence of glaciers in the headwaters of a stream can contribute very fine glacial silt to the watershed which tends to remain in suspension.

Table 1.2 Comparison of non-filterable residue (TSS) in seven Skeena watershed rivers 1983-1987

Non-filterable	1983		1984		1985		1986		1987	
Residue (mg/L)	mean	max.	mean	max.	mean	max.	mean	max.	mean	max.
Upper Bulkley			11.8	59	10.6	57	29.1	132	10.3	46
Morice	15.8	105	6.8	26	37.8	149	12.8	66	4.6	19
Bulkley at Quick	27.8	103	11.8	91	8.9	37	18.8	81	6.5	20
Telkwa	31.9	175	18.2	124	7.5	37	58.4	316	8.0	18
Kispiox	24.3	153	16.5	94	14.5	67	10.8	43	9.8	68
Skeena at Usk	63.3	341	20.2	64	84.8	595	116.6	791	229.9	1840
Lakelse	6.8	19	11.1	79	10.3	59	9.8	67	6.1	12

Source: Wilkes and Lloyd 1990

In addition to natural sources of TSS, soil disturbance due to forestry, mining and agriculture may lead to increased suspended particulates in streams and rivers. Yellowhead Highway 16, many secondary roads, the railway and the natural gas pipelines in the Skeena watershed have long sections in close proximity to rivers, with large numbers of encroachments and crossings. In addition, sewage-treatment effluents and industrial wastes may directly discharge suspended solids to the watershed.

It is apparent from Table 1.2 that there is considerable annual and year to year variation in suspended sediment loading depending on the annual hydrological regime in each watershed, and in particular on depth of snowpack and rapidity of snowmelt. On average the Telkwa River carries a higher suspended sediment load than the other Skeena tributaries sampled.

By the time the Skeena River reaches the sampling station at Usk, it carries a particularly heavy suspended sediment load due to the steep mountainous terrain and higher precipitation on the windward slopes of the Hazelton Mountains. The sampling station Skeena River at Usk is identical to the Water Survey of Canada Hydrometric and Regional Suspended Sediment Station 08EF001.

The Lakelse River, which drains Lakelse Lake, is exceptional in having approximately half the TSS loading of the other major rivers sampled. Because it is lake headed, the Lakelse River remains relatively clear even during freshet.

Comparison of summary statistics.— Selected summary statistics for the seven Skeena watershed rivers are shown in Table 1.3. In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation of the true values.

When the 50th percentile was computed, the low values were included as "< MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

The colour of water (measured in True Colour Units) is usually attributable to the presence of natural mineral components such as iron and manganese, and from organic sources. Common organic sources include natural products from decaying vegetation such as humic substances, tannins, and lignins. Since humic substances are complex natural organic compounds that are resistant to microbial decay, they are ubiquitous in the environment and are a common source of natural water colour. All of the Skeena watershed stations are moderately coloured, probably due mainly to the presence of wetlands and swamps in the watersheds. The Morice River has the least natural colouration. The colouration of the upper Bulkley River may have been affected by the sewage treatment plant discharge 3.5 km upstream of the monitoring station.

Table 1.3 Comparison of selected water quality parameters for seven rivers in the Skeena watershed 1983-1987

	mean colour TCU	mean TSS[a] mg/L	mean hardness mg/L	mean TKN[b] mg/L	mean total P mg/L	mean total N mg/L	mean Cu mg/L	mean Pb mg/L	mean Zn mg/L
Upper Bulkley	25.1	15.1	57.3	0.33	0.16	0.35	0.003	0.003	0.012
Morice	7.3	16.6	32.0	0.09	0.02	0.12	0.002	0.002	0.015
Bulkley at Quick	23.5	13.4	26.5	0.14	0.02	0.20	0.005	0.003	0.009
Telkwa	22.2	23.9	43.0	0.09	0.03	0.15	0.004	0.003	0.014
Kispiox	11.1	13.2	39.3	0.12	0.02	0.18	0.005	0.001	0.015
Skeena at Usk	19.6	72.7	41.5	0.12	0.06	0.19	0.011	0.006	0.017
Lakelse	16.7	9.1	20.5	0.14	0.02	0.21	0.003	0.003	0.013

Source: Wilkes and Lloyd 1990

[a] Total Suspended Solids (Non-filterable Residue)

[b] Total Kjeldahl Nitrogen (a measure of both ammonia and organic nitrogen)

Hardness is principally determined by the sum of calcium and magnesium, and is normally expressed as an equivalent of calcium carbonate ($CaCO_3$). Water hardness relates to a water's capability to produce lather from soap. The harder the water, the more difficult it is to lather soap. A hardness less than 60 mg/L $CaCO_3$/L is considered soft and a hardness less than 30 is considered very soft (McNeely and others 1979). All of the Skeena watershed rivers have soft water, and the Lakelse River is considered to have very soft water.

Nutrients, as measured by Total Kjeldahl Nitrogen (TKN), total phosphorus (P) and total nitrogen (N) are generally low in the Skeena watershed with the exception of the upper Bulkley River. However, the monitoring site on the upper Bulkley River near Houston was located about 3.5 km downstream of the municipal sewage treatment plant. TKN (which is a measure of ammonia and organic nitrogen) and phosphorus concentrations would typically be elevated in a sewage discharge, and as expected, these nutrients were elevated at the upper Bulkley station. The District of Houston sewage treatment plant has subsequently been upgraded to improve wastewater treatment and to reduce phosphorus concentrations in the discharge (see section 7.5.2).

Copper (Cu), lead (Pb) and zinc (Zn) concentrations are within the ranges found in natural waters (McNeely and others 1979). Metal ions tend to be adsorbed onto suspended particulates. Thus the highest metals concentrations in the watershed are found in the mainstem Skeena at Usk, which is the station having by far the highest TSS loading.

Comparison with MOELP criteria.— Water quality criteria are policy guidelines for an acceptable range of conditions, or safe levels of contaminants, for particular water use classes (see section 2.2.10). A comparison of mean and 50th percentile concentrations with MOELP water quality criteria (Nagpal 1994) is shown in Table 1.4.

Table 1.4 Comparison of mean and 50th percentiles of selected parameters with MOELP criteria for the protection of aquatic life

	Criterion	Upper Bulkley		Morice		Bulkley at Quick		Telkwa	
		mean	50th %	mean	50th %	mean	50th %	mean	50th %
pH	6.5 - 9.0	7.6	7.6	7.3	7.3	7.3	7.4	7.5	7.5
Alkalinity mg CaCO3/L	>20	67.9	71.0	23.4	21.7	28.1	27.3	42.0	41.2
Ammonia mg N/L	6.55 - 27.7	0.087	0.024	0.008	<0.005	0.014	<0.005	0.010	<0.005
Metals mg/L									
Aluminum	0.1	0.077	0.040	0.053	0.020	0.059	0.030	0.067	0.040
Calcium		18.3	19.7	7.88	7.41	9.1	8.8	13.6	13.4
Chromium	0.002	0.015	<0.010	0.010	<0.010	0.010	<0.010	0.013	<0.010
Copper *	.0035 - 0.008	0.003	0.002	0.002	0.001	0.005	0.001	0.004	0.002
Manganese	0.1 - 1.0	0.087	0.070	0.040	<0.010	0.039	0.010	0.050	0.020
Molybdenum	2.0	0.010	<0.010	0.020	<0.010	0.020	<0.010	0.013	<0.010
Nickel	0.025 - 0.065	0.050	<0.050	0.050	<0.050	0.060	<0.050	0.050	<0.050
Lead *	0.008 - 0.052	0.003	<0.001	0.002	0.001	0.003	0.001	0.003	0.001
Zinc	0.03	0.013	<0.005	0.015	<0.005	0.009	<0.005	0.014	<0.005

Source: Wilkes and Lloyd 1990
* Criteria dependent on hardness

	Criterion	Kispiox		Skeena at Usk		Lakelse	
		mean	50th %	mean	50th %	mean	50th %
pH	6.5 - 9.0	7.5	7.4	7.4	7.6	7.1	7.1
Alkalinity mg CaCO3/L	>20	36.8	37.5	39.3	37.2	21.1	21.4
Ammonia mg N/L	6.55 - 27.7	0.013	<0.005	0.019	<0.005	0.044	0.010
Metals mg/L							
Aluminum	0.1	0.055	0.035	0.058	0.030	0.057	0.040
Calcium		12.7	12.3	14.7	13.6	6.88	6.83
Chromium	0.002	0.020	<0.010	0.007		0.013	<0.010
Copper *	.0035 - 0.008	0.005	0.002	0.011		0.003	0.001
Manganese	0.1 - 1.0	0.044	0.010	0.080	0.020	0.021	0.020
Molybdenum	2.0	0.011	<0.010	0.014	<0.010	0.017	<0.010
Nickel	0.025 - 0.065	0.050	<0.050	0.012		0.060	<0.050
Lead *	0.008 - 0.052	0.002	0.001	0.006		0.003	<0.001
Zinc	0.03	0.015	<0.005	0.017		0.013	<0.005

Source: Wilkes and Lloyd 1990
* Criteria dependent on hardness

Following are notes on the water quality criteria used in Table 1.4:

- The alkalinity criterion indicates the threshold for low sensitivity to acidic inputs. Values less than 20 mg $CaCO_3$/L indicate the waterbody is sensitive.

- Ammonia criteria levels vary with pH and temperature. Levels shown are for pH 6.5 - 8.0 and for temperature of 0 °C. The criterion is slightly lower when temperatures are higher.
- Metals criteria shown are for total metal ions, except for aluminum (Al), where the criterion is described as dissolved Al.
- Criteria for copper, nickel and lead depend on mean hardness. These are shown in Table 1.4 as a range covering all seven rivers; specific criteria are shown in Table 1.5.

Table 1.5 MOELP water quality criteria for copper nickel and lead (depending on hardness)

	mean total hardness mg/L	criteria for Cu	Ni	Pb
Upper Bulkley	70.67	0.0086	0.065	0.0525
Morice	25.11	0.0044	0.025	0.0141
Bulkley at Quick	28.92	0.0047	0.025	0.0168
Telkwa	44.35	0.0062	0.025	0.0290
Kispiox	39.56	0.0057	0.025	0.0251
Skeena at Usk	47.83	0.0065	0.025	0.0319
Lakelse	20.60	0.0039	0.025	0.0109

Source: Wilkes and Lloyd 1990

In general these data indicate that the water quality in the Skeena watershed is very good. The water is soft with generally low nutrient levels. High suspended solids loads are observed during spring freshet, which is not surprising given the runoff from snowpack which accumulates in mountainous terrain at this latitude.

1.3.5.2 Productivity of Skeena watershed sockeye nursery lakes - 1994

DFO is currently determining the rearing capacity of a number of important Skeena River sockeye nursery lakes (K. Shortreed, Memorandum April 27, 1995). The two main objectives of the project are 1) to determine the current status (numbers, diet and condition) of juvenile sockeye stocks, and 2) determine the productivity of the lakes and the maximum number of sockeye they are capable of producing.

Monthly limnological surveys were carried out from May-October 1994 on five lakes (Johanson, Sustut, Babine, Kitsumkalum and Lakelse). Data were collected from one mid-lake site on all lakes except Babine, where four locations were sampled down the length of the lake. Other data collected include: other chemical variables such as particulate C and N; bacteria numbers; phyto- and zooplankton species composition, numbers, biomass and productivity; and juvenile sockeye numbers, size, diet and distribution.

Table 1.6 provides a comparison of water quality and productivity of the five Skeena sockeye nursery lakes in 1994 (mean epilimnetic concentrations for June, July, August and October sampling dates) (K. Shortreed, DFO, unpublished data). Limnological data indicate that all the lakes in this study are oligotrophic. Note in Table 1.6 that the total phosphorus concentrations in Kitsumkalum Lake are very high. This is believed to be due to the lake's high turbidity (phosphorus tends to adsorb to particulate matter) and should not be interpreted as an indication of eutrophication. Because of its high turbidity and fast flushing rate, Kitsumkalum Lake is highly oligotrophic. Babine Lake is the most productive lake in the study and is about 4X more productive than Kitsumkalum Lake, the least productive of the five lakes. Based on time-weighted photosynthetic rates, Johanson, Lakelse and Sustut Lakes are 50%, 42%, and 33%, respectively, less productive than Babine Lake.

Table 1.6 Water quality and productivity comparison of selected Skeena sockeye nursery lakes, 1994

Lake	Temp °C	pH	Secchi depth m	Euphotic zone depth m	TDS mg/L	Total alkalinity mg CaCO3/L	Total P ug P/L	Nitrate ug N/L	Total Chlorophyll ug/L	Photosynthetic rate mg C/m2/d
Johanson	7.7	7.14	10.0	21.5	53	19.70	3.2	1.8	0.97	83.8
Sustut	10.3	7.26	9.3	14.9	52	26.60	6.4	0.8	1.44	109.1
Babine	12.5	7.43	5.5	7.1	61	36.81	5.4	36.6	1.79	139.3
Kitsumkalum	10.5	7.13	0.8	3.5	28	15.19	15.7	38.8	0.57	38.7
Lakelse	15.4	7.32	4.3	7.4	45	21.84	5.6	11.5	1.38	89.4

Source: K. Shortreed, unpublished data.

1.3.6 Linear developments traversing the watershed

The Canadian National Railway, Highway 16, most secondary roads, and the Pacific Natural Gas pipeline are examples of linear developments in the Skeena watershed which have long sections in close proximity to rivers. Highways, railways and pipelines often interfere with river channels and the associated flood plains through encroachments, temporary or permanent diversions, and channelization. Pipelines are generally buried under the streambed. In addition to short term sediment transport during construction, the potential for future channel degradation is a major consideration.

1.3.6.1 Pacific Natural Gas - natural gas pipeline

The Pacific Natural Gas (PNG) pipeline traverses the Skeena watershed east to west as shown in Figure 1.1: through the Bulkley drainage to Telkwa; west up the Telkwa River; through the Telkwa Pass and; down the Zymoetz River to Terrace. At Terrace the pipeline divides into two branches; one branch passes near Lakelse Lake and south to Kitimat, and one branch more or less follows the Skeena west to Prince Rupert and Port Edward. In addition to hundreds of smaller stream crossings, it crosses the Bulkley River twice, the Telkwa and Zymoetz Rivers numerous times, and the Skeena River once. The PNG pipeline through the Zymoetz watershed has suffered numerous washouts and forced relocations since construction, and twinning of the pipeline is presently being carried out.

1.3.6.2 Pac-Rim liquefied natural gas project

In early 1995 PAC-RIM LNG Inc. submitted a prospectus to the BC Energy Project Review Process for the construction of 490 km pipeline connecting natural gas supplies from northeastern BC to a proposed liquefied natural gas (LNG) facility on the coast (at either Kitimat or Prince Rupert). Proposed is a 500 million cubic foot per day LNG facility, capable of producing 3.5 million tonnes of LNG per year, requiring a dedicated fleet of 5 LNG tanker ships to transport the LNG to Pacific Rim markets. The pipeline will be 24" or 30" diameter and constructed generally along the existing PNG pipeline right-of-way.

In addition to concerns relating to the plantsite and process, MOELP and DFO have raised concerns with the pipeline construction, particularly with the large number of stream crossings. If the project is approved, environmental design and impact management along the proposed pipeline right-of-way will be required, as well as the presence of an Environmental Monitor on site during construction.

Application for Project Approval Certificate (PAC-RIM LNG Inc. 1995), submitted to the BC Environmental Assessment Office in August 1995, provided a some detail as to the potential water quality impacts. Potential problem areas, in which hydrological events (i.e., flooding) might affect pipeline security are the Telkwa River, upper Zymoetz and Clore Rivers, and possibly some of the Skeena River tributaries where they enter the Skeena. In localized areas, channel shifting, deep scour and bank undercutting are possible occurrences.

The proposed pipeline route generally parallels the existing PNG right of way through the upper Bulkley drainage to Telkwa. From Telkwa, the proposed pipeline would generally follow the existing PNG right of way west along the Telkwa River, through the Telkwa Pass (elevation 900 m), down along Limonite Creek to the Zymoetz River valley. A deviation in route alignment has been proposed at this point. The proposed route alignment will deviate from the existing PNG routing by following the Zymoetz River valley to the Clore River, and thence along Trapline Creek to Williams Creek and on to the plateau lands just south of Terrace, thus avoiding the populated areas in the vicinity of Terrace.

If it is determined that the proposed LNG plant will be located in Prince Rupert, the pipeline route between Terrace and Prince Rupert will be the subject of detailed route evaluation. The existing PNG pipeline follows the south side of the Skeena to Salvus, crosses the Skeena and follows the valleys of the Kasiks and Khyex Rivers before rejoining the Skeena. The route then follows Lamach Creek northwest to the vicinity of the south end of the Work Channel before proceeding to Ridley Island and Prince Rupert. Portions of the routing between Terrace and Prince Rupert traverse environmentally-sensitive areas, difficult terrain and constrained working areas, therefore deviations from the existing right of way can be expected based on route assessments.

2. WATER QUALITY: HOW IS IT AFFECTED BY LAND USE ACTIVITIES AND HOW IS IT REGULATED IN BRITISH COLUMBIA?

2.1 INTERACTION BETWEEN LAND USE ACTIVITIES AND WATER QUALITY

2.1.1 Cumulative effects of small modifications to habitat

Accumulation of localized or small impacts can result in regional and global changes in fisheries. These accumulations of effects, often from unrelated human actions, pose a serious threat to fisheries (Burns 1991, American Fisheries Society position statement). World-wide declines in fish abundance have been documented for species that have been historically of major economic and social significance. Time trends resulting from multiple effects on salmon populations have resulted in declines over much of the globe (Netboy 1980). Pollution and physical side effects, from operations such as mineral extraction and power plants, can have an overall negative effect on fisheries productivity (Anonymous 1981). Effects of small man-caused temperature changes can potentially result in oceanic change in the Pacific Ocean and loss of fishing capacity (McBean and others 1992). Such effects are of international concern (Ruvio and others 1971).

Regional trends also cause concern for fisheries. Recently widespread increases in nitrate, chloride, arsenic and cadmium in rivers of the United States have been related to man's activities (Smith and others 1987). These trends are the result of apparently unrelated activities. Although the activities themselves may differ widely, the environmental alterations they produce may be similar.

The effects of increased sedimentation on spawning gravels, for example, will be the same whether the sediment resulted from road construction, a pipeline crossing, logging, mining or livestock grazing. The same is true for other variables such as water temperature, quantity and distribution of instream cover, channel morphology and dissolved oxygen concentration. Sedimentation and nutrient delivery, causing lowered dissolved oxygen concentration and eutrophication of streams and lakes, can be a consequence of municipal, agricultural and mining effluents as well. Cumulative losses of even one element of fish habitat can extend over long time periods. Loss of habitat elements such as large woody debris can have effects for 80 to 160 years (Sedell and Froggatt 1984; Sedell and Swanson 1984).

2.1.2 Forestry and water quality

2.1.2.1 Importance of small streams

Chamberlin and others (1991) discuss the interactions between timber harvesting, silviculture and watershed processes. Anadromous salmonids occupy a wide variety of streams that range in size from tiny headwater tributaries (first-order streams) to the mainstream Skeena River. Most spawning and rearing in forested watersheds however, takes place in second- to fourth-order streams. Small streams are responsible for a high proportion of salmonid production in a basin, and they influence the quality of habitat in larger tributaries downstream. They are also the streams most easily altered by forest management activities.

Vegetative crown cover is often complete over first- through third-order streams. Because small streams depend largely on litter fall for organic energy input, any manipulation of the canopy or riparian vegetation will influence the stream's energy supply. Likewise, road building or other activities that increase sediment supplies or modify local runoff may have greater effects on smaller streams than they would on larger tributaries.

Although larger streams generally have a greater capacity to buffer the effects of changes to the riparian zone, salmonid fry often preferentially inhabit the lower-velocity margins and side channels of large streams. Forest harvesting and other land-use impacts can accumulate over time to cause substantial changes in stream-edge environments, even along very large rivers (Sedell and Froggatt 1984).

2.1.2.2 Hydrologic change

Harvesting activities such as road building, falling, yarding and burning can affect streamflow by altering the water balance or by affecting the rate at which water moves from hillsides to stream channels. Road systems, skid trails, and landings accelerate slope runoff, concentrate drainage below them, and can increase soil water content.

Regional differences in runoff patterns, ranging from rain-dominated coastal systems to snow-melt-dominated systems in the interior, make it difficult to generalize about the hydrologic effects of forest management. From a fisheries perspective, the maintenance of side channels is a primary habitat protection goal in rain-dominated coastal systems. In interior snow-dominated watersheds, management practices to augment low late-summer rearing flows are encouraged.

In the rain-dominated Carnation Creek catchment on the west coast of Vancouver Island, clear-cutting 90% of a 12 ha catchment resulted in increases water yield in 6 of the 7 years of monitoring, increased autumn flows, and 78% higher summer low flows. Over the entire catchment studied (about 1000 ha), road construction and clear-cutting modified runoff patterns by increasing groundwater levels, peak flows, and water yields and decreasing the number of days of low flows in the stream (Hartman and Scrivener 1990).

In interior regions where snowfall is a significant component of the hydrological cycle, clear-cutting causes increased snow deposition in the openings and advances the timing and rate of snowmelt. The effect lasts several decades until stand aerodynamics approach those of the surrounding forest. Where rain on snow events cause naturally high spring runoff, the effect of clear-cutting can be pronounced.

2.1.2.3 Temperature change

The principal aquatic consequences of timber felling and yarding are changed rates of sediment and nutrient delivery, and altered levels of temperature and dissolved oxygen. The value of maintaining a buffer strip of streamside vegetation to ameliorate the direct effects of logging activities has been well documented (Meehan 1991).

When riparian vegetation is removed, summer water temperatures generally increase in direct proportion to the amount of increased sunlight on the water surface. Planned openings along cold coastal streams might enhance fish productivity if other habitat requirements are maintained. In this as in other habitat manipulations, however, caution is required because modest changes in water temperature can change the time required for salmonid eggs to develop and hatch. In northern areas, removal of over-stream cover may lower winter stream temperatures because a net outward energy flow may result, causing slower egg development, deeper surface ice, and bottom-ice formation on gravels.

Increases in stream temperature were a result of clear-cutting in the coastal Carnation Creek investigation (Hartman and Scrivener 1990). For the chum salmon population, egg-to-fry survival, fry size, and adult returns were reduced and more variable following logging. Possibly as a result of higher stream temperatures, the fry emigrated earlier to the ocean. Smaller fry going to sea early experienced a lower survival after entry into the marine environment. This is believed to be one of several reasons that much lower numbers returned to spawn in the creek at the end of their life cycle than had been observed prior to clear-cutting.

Summer maximum water temperatures increased up to 9 °C following clear-cutting in the study streams of the interior Slim Creek watershed (Brownlee and Shepherd 1975). In a clearcut tributary where high sedimentation was not sustained after logging, because of coarser soils, the temperature increase was thought to be beneficial to rearing salmonids (Slaney and others 1977*a*). The authors note that such an increase would be unfavorable and perhaps lethal in a small, warm outlet stream of a lake at the same latitude.

2.1.2.4 Sedimentation

Poorly designed roads and skid trails are persistent sources of sediment, but so are open slopes whose soils have been exposed by yarding, mass movements, scarification or intense fire. Not all hillside sediment reaches the stream channel, but roads and ditches form important pathways. The quality of management planning strongly influences sediment production from forest-harvesting activity, as illustrated by the study of Reinhart and others (1963). Sediment production varied over 3 orders of magnitude according to the degree of planning and care with which the skidder logging was conducted. In cold climates, removal of insulating vegetation promotes formation of ice lenses in and frost heaving of soils, facilitating soil movement during spring thaws (Slaney and others 1977*a*).

In addition to disturbing surface soil, activities near the stream bank may destabilize channel margins, releasing sands that settle in and clog the streambed gravels. Sedimentation due to the breakdown of streambanks is among the most persistent results of riparian harvesting, and it is among the most difficult to avoid when streamside felling or skidding and cross-stream yarding occur.

The Carnation Creek watershed study (Hartman and Scrivener 1990) found that the annual densities of coho fry that emerged declined during the 17-year study period. The decrease in fry emergence suggested influences of erosion related to logging practices. Mean annual coho fry emergence from 1972 to 1986 approached 30,000 fry. The highest fry emergences occurred during the pre-logging period (1972-1976) and the lowest following logging (1977-1986). Survival of eggs to emergence during pre-logging years was 28.8%. After logging, the 1977-1986 time interval, survival was reduced to 10.9%. Lower percentages of coho eggs surviving to fry was correlated with the reduction in mean particle size of spawning gravel.

The results of the Slim Creek watershed study in the central interior (Slaney and others 1977*a* and *b*) suggested that the main impact of the logging operations in the area came from a substantial (5- to 10-fold) increase in sediment levels in the logged watershed. The main sediment source area was a pocket of silty loam soil located on a road cut near the stream. Skid trails were secondary sediment sources. A riparian buffer strip helped to reduce sediment from overland flow but did not reduce sediment transported through small drainages transecting the strip. Sediment levels in the smaller, steeper gradient tributary streams recovered rapidly to pre-logging levels. Experimental results suggested that the sediment loading and subsequent deposition in the larger, lower gradient systems downstream would result in poorer survival of the eggs to fry stage. Observations showed that intragravel silt formed a barrier that would restrict emerging fry. As well, it was estimated that there was some loss of overwintering habitat for juvenile fish because of sediment filling spaces in the substrate.

2.1.2.5 Dissolved oxygen

Clogging of surface gravels by fine inorganic sediments can restrict intergravel flow enough to lower dissolved oxygen concentrations. Lowered intergravel dissolved oxygen concentrations were associated with reduced salmonid egg survival in heavily sedimented streams in the Slim Creek watershed (Slaney and others 1977*b*). This problem usually occurs only when large or persistent volumes of sediment emanate from active road system, mass soil movements, bank slumps or destabilized upstream channels.

During extremely low flows, dissolved oxygen concentrations naturally decline in streams. In summer, high temperatures both accelerate respiration and lower the solubility of oxygen. In winter, ice cover may prevent diffusion of oxygen from air to water. Harvest activities that impose large oxygen demands on streams exacerbate the normal stresses that low flows place on fish.

2.1.2.6 Nutrients

Nutrient concentrations (for example N, P, K, Ca) in streams may increase after logging, but usually by moderate amounts and for short periods. Likewise, 5- to 10-fold increases in nutrient releases after slash burning have shown rapid returns to earlier levels. The mobilization of nutrients is tempered by their adsorption onto soil particles and by their uptake by microorganisms that decompose stream detritus.

2.1.2.7 Channel forms and geomorphic processes

Forest harvesting can affect alluvial streams by weakening channel banks, removing the source of large woody debris, altering the frequency of channel-modifying flows, and changing sediment supply. Both the removal of bank vegetation and increased sediment supply cause channels to become wider and shallower with fewer pools and more riffles. Streams in which structural elements such as embedded logs (large woody debris) have been removed have lost stored sediment to downstream reaches and have generally degraded. When there are fewer “steps” in the stream’s profile, more energy is released to move sediment, resulting in a simpler, higher-gradient channel with poorer salmonid habitat.

The loss of stable instream large woody debris (also called large organic debris) by direct removal, debris torrents, or gradual attrition as streamside forests are converted to managed stands of smaller trees will likely contribute to loss of sediment storage sites, fewer and shallower scour pools, and less effective cover for rearing fish. The negative fisheries impacts of logging-caused changes to channel morphology and large woody debris supply were thoroughly documented both in the coastal Carnation Creek studies (Hartman and Scrivener 1990) and the central interior Slim Creek studies (Slaney and others 1977*a*, *b* and *c*).

2.1.2.8 Water transportation and storage of logs

Water storage and transportation of logs and railway ties was common in the Bulkley and Skeena valleys in the early 1900's. River "log drives" took place on Dungate and Buck Creeks (Houston), the Kitsumkalum River (Terrace) and probably others. Bulkley Lake, Babine Lake and probably many others were used for storage and sorting of logs (Mould 1976). Many rivers in the region were probably used for log transportation and storage at one time or another.

Log driving.— At first, all timber within easy access of a stream was cut and floated down the adjacent river. The more distant timber required the use of splash dams, built of log cribbing, to store water and then release a flushed flow (Sedell and others 1991). Streams had to be "improved" before a log drive could begin. Sloughs, swamps, and back channels were blocked off with log cribbing to keep the logs in the main channel, and boulders, leaning trees, sunken logs, or other obstructions were blasted out or otherwise removed. Small, low-gradient streams often were substantially widened and straightened during log driving, resulting in loss of habitat complexity and destruction of salmonid spawning and rearing areas.

Canada Department of Fisheries (1964; cited in Sedell and others 1991) reported that channeling on the Kitsumkalum River did not stabilize the river bed because as the flow was directed from one place, it scoured others. During log driving on this river (now discontinued), the logging company continually made requests for further river improvements and, in some instances, had to repair or rebuild previous work. Despite construction to facilitate log driving, stranding of logs remained a major problem.

Lake storage and transport.— The previous practice of log storage, sorting and transport by floating log booms in Babine Lake was replaced by dry-land storage and barge transportation following an environmental evaluation by the Westwater Research Centre (Hall 1987) which documented deleterious effects on water quality. In addition to physical alterations to habitat, accumulation of wood and bark debris, alteration of light levels, and increases in turbidity resulted. Chemical disturbances included changes in water quality, decomposition of woody debris, leaching of potentially toxic chemicals from wood, and deoxygenation of water and substrate.

The use of watercourses for transportation and storage of logs has been phased out in the region, with the exception of log booming leases on the lower Skeena River in the vicinity of the Scotia River. Documentation of the long-term changes in channel morphometry and sediment transport which have occurred as a result of the Kitsumkalum River "training" for log driving purposes was identified as a research need in a recent Environment Canada BC-Yukon Sediment Issues Workshop (Miles 1991).

2.1.2.9 Chemical applications

Chemical applications to forest lands are reviewed by Norris and others (1991). Chemicals which are used on forests can be grouped into three categories; pesticides, fertilizers, and fire retardants. The most important process by which chemicals enter streams is direct application, but drift from nearby treatment areas is also important. Mobilization of residues in ephemeral stream channels during the first storms after application is sometimes important.

Vision®.— In the Prince Rupert Forest Region, herbicides for the control of deciduous brush species are the only pesticides currently in use, and the current amount of use is considered low (Lou Tromp, MOF Silviculture, personal communication). The estimated number of hectares receiving herbicide treatment with the isopropylamine salt of glyphosate (Vision®) in the Prince Rupert Region in 1995 was about 700 hectares (Lakes Forest District ±400 ha, Bulkley Forest District ±300 ha). In 1994 about 170 hectares were treated with Vision® in the region, mostly north of Babine Lake. A 10 m pesticide free zone along any watercourse is a requirement for herbicide application.

In general, glyphosate is highly soluble in water but very immobile in soil, being rapidly adsorbed by soil particles, and subject to some degree of microbial degradation. The herbicides Roundup® and Vision® contain the same concentration of glyphosate and the toxicity data for the two formulations are identical (CCREM 1989). Toxicity studies indicate that technical-grade glyphosate, the active ingredient in Roundup®, was less toxic than Roundup® or the proprietary surfactant used in its formulation. The maximum acceptable concentration CCREM (1987) drinking water guideline for glyphosate is 280 μg/L. The concentration of glyphosate in streams and lakes should not exceed 65 μg/L for the protection of freshwater aquatic life (CCREM 1989).

Studies of glyphosate in the surface waters of the Carnation Creek watershed (Feng and others 1986) involved the direct overspray of two tributaries. Direct overspray with Roundup® at 2.0-2.1 kg/ha, resulted in maximum glyphosate concentrations in a tributary of >160 μg/L at 2 hours postspray. This concentration rapidly dropped to 54.4 and then 36.5 μg/L at 6.4 and 15.4 hours postspray, respectively. Considerable differences in glyphosate concentrations between the tributaries was observed, due to such variables as water surface area and overhanging riparian vegetation. The first rainfall event after spraying caused glyphosate concentrations in one oversprayed tributary to increase from below 0.5 to 144 μg/L at 27 hours postspray. These high values were thought to result from glyphosate washing off the riparian vegetation along the tributary. This experiment clearly demonstrated that direct overspray of streams can result in glyphosate concentrations greater than the CCREM guidelines for aquatic life.

A Carnation Creek tributary protected by a 10-m buffer strip contained a concentration of 0.75 μg/L at 1 hour postspray due to spray drift. This concentration decreased to <0.1 μg/L between 2 and 7.5 hours postspray. A second peak concentration of 2.47 μg/L occurred at 10 hours postspray, which then decreased below 0.1 μg/L at 16 hours postspray. This delayed response was thought to have resulted from the slow, subsurface flow of the tributary between the area receiving the spray drift and the sampling point. The tributary protected by a 10-m buffer strip also showed a minor increase in glyphosate to 0.64 μg/L during the first 1/2 hour of rainfall. Glyphosate was not detected in this tributary (<0.1 μg/L) at 47 hours postspray. This experiment demonstrates that substantial protection can be provided by a 10 m pesticide-free buffer strip.

Research needs.— Relatively little has been done on the bioaccumulation of glyphosate, primarily because its physiochemical properties are such that bioaccumulation is not expected to be substantial (Norris and others 1991). However the authors emphasize there is an acute lack of data on glyphosate and other herbicides.

MSMA.— A second chemical, MSMA (a pentavalent organaic arsenical herbicide) has been applied by individual stem injection for precommercial thinning and to aid in control of certain bark beetles in the Prince Rupert Forest Region. This mode of application provides very limited opportunity for MSMA to enter the aquatic environment.

Fertilizers.— Nitrogen (N), as urea, is the element most commonly applied as a forest fertilizer in the northwestern USA. As long as there is no direct application of urea to streams, it is readily incorporated by vegetation or adsorbed by humic substances in forest soils. No broadcast application of fertilizers currently occurs in the Prince Rupert Region, although there may be some experimental use in the future (J. Pinkerton, MOF Silviculture, personal communication). Fertilization in the region is presently limited to the placement of a small fertilizer packet in the soil with individual conifer seedlings at the time of planting.

Fire retardants.— Modern chemical fire retardants are complex mixtures (Norris and others 1991). The most abundant constituent (responsible for the fire-retarding action) is diammonium phosphate (Phos-Chek products), ammonium sulfate (Fire-Trol 100), or ammonium polyphosphate (other Fire-Trol products). The principal toxic ingredient of the chemical fire retardants currently in use is believed to be an ammonium salt (in the form of un-ionized ammonia, NH_3, the formation of which is temperature and pH dependent). One analysis, however, suggested that photolysis of the ferrocyanide (a corrosion inhibitor) in several Fire-Trol retardant formulations may yield sufficient cyanide to be the primary toxicant in these products.

As fires sweep across streams and rivers, direct entry of fire retardants into streams is possible. An extensive study of an ammonium-based fire retardant was conducted in forest streams in Oregon, Idaho, and California. The retardant was applied directly across streams producing detectable changes in water chemistry for distances as far as 1,000 m downstream. The principal chemicals that were elevated in the stream within the first 24 h after application were ammonium-nitrogen (range 0.01 to 100 mg/L) and total phosphorus. Ammonia is potentially toxic to aquatic species and phosphorus may contribute to downstream eutrophication. A second, non-toxic effect of fire retardants entering streams and lakes is nutrient enrichment (N and P). Most fire-retardant drops occur in watersheds well drained by streams, but if retardants are used in or around basins with oligotrophic lakes, bogs or swamps, their eutrophic effects may be prolonged.

2.1.3 Mining and water quality

2.1.3.1 Acid rock drainage

Some of the effects of mining on water quality and fisheries habitat are obvious. Road building and removal of surface vegetation may disturb or divert water courses and contribute to sedimentation. Other influences may be less obvious. One of the most persistent results of mining in certain rock types is acid rock drainage (ARD). ARD may occur from active or abandoned underground mines, open pit mine faces and pit workings, waste rock dumps, tailings deposits and ore stockpiles.

ARD is drainage that occurs as a result of natural oxidation of sulphide minerals contained in rock which exposed to air and water (SRK 1990). When sulphur bearing rocks are mined for their metals, broken up and exposed to oxygen and water, they generate sulphuric acid. The acid lowers the pH of water leaching through the rock pile, and dissolves metals into solution. Below a pH of 3.5, conditions are right for sulphur oxidizing bacteria such as *Thiobaccillus ferrooxidans* to greatly accelerate the rate of reaction. Typically pH drops farther to 2.0 to 2.5, and more metals are leached from the rock due to the more corrosive nature of the drainage.

The rate of this reaction is important. If it occurs very slowly, with production of acidity spread over a wide time interval, the effect on the environment may be unimportant. However, rapid acid generation, with production of low pH, metal-laden drainage waters can seriously affect downstream water quality. Many metals (including arsenic, cadmium, chromium, copper and iron) are highly toxic to aquatic resources. Whether a particular mine will produce ARD is not easily predicted, as physical characteristics of the rock may resist weathering and the presence of neutralizing, or acid consuming, minerals can buffer the process. Acid generation can potentially go on for hundreds of thousands of years, or until all available sulphide minerals are used up. Ore bodies mined in Norway in the 1700s are still generating ARD.

The basic methods for controlling ARD are the exclusion of water and oxygen with impermeable covers or the deposition of wastes under water. Blending of wastes with acid consuming materials is also a control method when alkaline materials are locally available in sufficient quantities. The most common control method used by the mining industry today is the collection and chemical treatment of all the drainages at the minesite to reduce acidity and precipitate metals.

2.1.3.2 The Equity example

Several mines in the Skeena drainage are known to be generating ARD; Equity Silver Mine, Bell Mine, Granisle Mine and others. A brief history of ARD generation at the Equity Silver Mine south of Houston is given below to illustrate this phenomenon. A detailed review of the Equity permit and monitoring is found in section 7.5.1.

Pre-mining environmental impact assessment at the Equity Silver Mine south of Houston failed to seriously address the possibility of an ARD problem (Wilkes 1985). The 5600 tonne per day open pit copper-silver-gold operation went into production in 1980. The property straddles the high ground between two small drainages. The tailings pond lies in the Foxy Creek drainage (tributary to Maxan Creek) and the waste rock is dumped in an area at the headwaters of Bessemer Creek, tributary to Buck Creek (Figure 7.4). Within a few years, elevated levels of acidity, copper, zinc and iron were discovered in seepages from the tailings pond, waste rock dump and waste rock used as plant site and mine road foundation materials. The company had to start excavating a system of deep trenches around the site to collect the drainage. Later a lime treatment plant was added to neutralize acid and remove metals prior to discharging treated water to Bessemer and Foxy creeks.

In 1986 it was estimated that 800,000 m^3 of ARD was produced per year from the mine site, with mean concentration 88 mg/L copper, 58 mg/L zinc, 16 mg/L arsenic, 775 mg/L iron and a pH of 2 (Rhebergen 1986). Bioassay results indicated a 1:11,000 dilution ratio would be required to protect water quality and fisheries in the Bulkley River. To illustrate the volume and toxicity of ARD produced, worst case predictions were prepared using ARD flow data and chemical analyses from the minesite and Water Survey of Canada hydrometric data. These predictions indicated the potential for rainbow trout acute toxicity to occur in Buck Creek, Maxan Creek and the Bulkley River above Houston for most of the year. And, if uncontrolled release of ARD were to occur, the entire length of the Bulkley River could be toxic 215 km downstream to Hazelton during winter low flows. This, of course, is just an illustration of the potential seriousness of the problem, and has never been allowed to happen.

Mining ceased in early 1994 due to lack of economic ore. The company has since undertaken major site reclamation, including applying a till cover over 82 million tonnes of waste rock and flooding 32 million tonnes of tailings. The company has posted a large reclamation bond in order to insure long-term ARD collection and treatment.

2.1.4 Agriculture and water quality

2.1.4.1 Runoff from winter feedlots, barnyards and other high use areas

A typical beef cattle operation in the region consists of summer range or grazing areas located on Crown land and confined winter feedlots, barns and feed storage areas located on private land. The dairy operations are based almost entirely on private lands and tend to have a smaller number of cattle kept in high density pastures, confined winter feedlots, barns and milkhouses.

Most farms use wood waste or straw as bedding material in the barn. The manure and soiled bedding which accumulate in high-use areas are generally stored outdoors for later use as fertilizer. Both feed storage (particularly silage) and sawdust storage may release leachates. The risk of direct overland runoff of manure and leachate into watercourses is greatest during spring snowmelt and during periods of high precipitation. Where cattle have direct access to watercourses for drinking, which is common in the region, the direct deposition of manure in or near the watercourse will occur. The runoff of manure and leachate from agricultural areas may affect water quality by direct toxic effects of ammonia and nitrates, by creating oxygen demand and by the addition of pathogens and nutrients.

Ammonia.— Ammonia, which comes from manure, urine or fertilizer, is highly toxic to fish. Runoff from uncovered manure piles or from over-fertilized crop land can have a high ammonia concentration. In fields and in water, ammonia is quickly converted to nitrate form, which is highly water-soluble. Nitrate does not attach to soil particles and so is easily leached from the soil. Once past the root zone, nitrates can continue moving downwards to the groundwater and into drinking water supplies. Allowable nitrate levels in drinking water are below 10 mg/L.

BOD.— Oxygen demand is measured by BOD (biochemical oxygen demand) or COD (chemical oxygen demand). When waste enters a water body, its decomposition requires oxygen. This removes oxygen that would otherwise be available for fish and other aquatic life. The BOD of dairy cattle manure is about 30 times higher than human waste. Wasted feed and silage juices can have BODs three to five times higher than manure (BC Ministry of Agriculture, Fisheries and Food 1993).

Pathogens.— All animal wastes contain microorganisms, such as bacteria, viruses and parasites. Some organisms in waste may be pathogenic (disease-causing) either to animals of the same species or of different species. More than 100 diseases are transmissible between animals and humans. Unsafe drinking water supplies occur when pathogens contaminate surface or ground water.

Nutrients.— Although nitrogen, phosphorus and other nutrients are all necessary for aquatic plant growth, phosphorus is generally the "limiting nutrient"; the nutrient which is in short supply and, if added, will result in prolific plant growth and eutrophication. Orthophosphate is the dissolved biologically available form of phosphorus which is limiting in streams and rivers. In lakes, total phosphorus is generally the critical limiting nutrient and its addition can cause nuisance algae blooms and the proliferation of aquatic macrophytes. The subsequent die-off of algae and aquatic plants the following winter can result in oxygen depletion and fish kills. The former practice of winter feeding up to 600 cattle on the ice of Round Lake (D. Riendeau, personal communication) may have contributed to the eutrophication of this lake.

Cook and others (1986) summarized the relationships expected between various types of land use and the phosphorus concentrations expected in streams draining watersheds containing these different land uses. The total phosphorus and orthophosphate concentrations from 904 "nonpoint source-type" watersheds distributed throughout the United States are shown in Table 2.1. These data are not directly comparable to typical phosphorus concentrations in the Skeena watershed, which are much lower (generally <3 µg/L orthophosphate). However, these data do illustrate the increase in phosphorus loading generally associated with agricultural activities in a watershed.

Table 2.1 Land use vs. mean total phosphorus and mean orthophosphate stream concentrations

	Total Phosphorus µg/L	Orthophosphate µg/L
≥90% Forest	18	9
≥50% Forest	34	14
≥50% Range Remainder predominantly forest	57	18
≥50% Agriculture Remainder predominantly forest	85	37
≥90% Agriculture	161	71

Source: Cook and others 1986

2.1.4.2 Livestock grazing

The density of livestock utilizing Crown grazing lands in the region is considered to be low compared to other regions in the province (B. Drinkwater, MOF, personal communication). The literature demonstrates that improper livestock grazing can degrade streams, riparian environments, and fish populations (Meehan 1991). On uplands, soil can be compacted and the vegetative composition changed, thus increasing runoff and erosion. Closer to the stream, streambank vegetation and stability may decline when livestock concentrate near water. The combination of upland erosion, loss of riparian canopies, and breakdown of streambanks can lower local water tables and cause streams to become wider but more shallow, warmer in summer but colder in winter, and poorer in instream structure but richer in nutrients and bacterial populations.

2.1.4.3 Fertilizer and pesticide use

Fertilizer and pesticide use is considered to be low in the Skeena Region when compared to row-crop farming areas (D. Riendeau, District Agriculturist, personal communication). Run-off due to improper application of fertilizer or over-fertilization can contribute to nutrient loading and eutrophication of streams and lakes. The principle pesticide in use in the area is Roundup®, which is applied in conjunction with the zero-till cultivation system. See section 2.1.2.9 for further discussion of aquatic toxicity of Roundup®.

2.1.4.4 Irrigation

Although most agricultural operations in the region hold water use licenses for irrigation, the actual volume of water utilized by this sector is unknown. The allocation of water use licenses for irrigation in the Skeena watershed is complicated by the fact that very few small tributaries are gauged. Excessive water removal from streams for irrigation can contribute to increased water temperatures and inadequate in-stream flows for fish.

2.1.5 Urban developments and water quality

2.1.5.1 Community sewage discharges

There are 12 villages or municipalities discharging treated sewage into the Skeena watershed, as well as number of smaller permitted discharges from resorts and industries. The smaller communities generally rely on one or more facultative lagoons for sewage treatment, while the larger communities have one or more aerated lagoons. Disinfection of effluent prior to discharge is generally not practiced. Municipal sewage presents a potential threat to receiving waters of oxygen depletion, solids settling, release of pathogenic organisms, enrichment (eutrophication) of streams and lakes, and toxicity.

BOD.— Sewage wastes have a high biological oxygen demand (BOD), which has the effect of depleting water of oxygen due to microbial respiration during the consumption of organic materials in the wastes. Many salmonid species require a minimum of 4 to 6 mg/L oxygen as a minimum to survive. Raw wastewater typically has between 300 to 800 mg/L BOD, but septage solids may have 25,000 mg/L BOD or more (Hellawell 1986).

TSS.— Solids, as measured by total suspended solids (TSS) include both microorganisms and debris solids. They may carry a considerable fraction of the total content of other contaminants including metals, organic toxicants, BOD and adsorbed pathogens. Once discharged, solids may settle out and smother the stream bed.

Pathogens.— Many sewage transmitted diseases are not of significance in British Columbia since the disease incidence is very low (Warrington 1988). However undisinfected sewage waste can contaminate surface waters with disease-causing bacteria, viruses, protozoa and worms.

Nutrients.— Sewage contains nutrients, primarily as phosphorus and nitrogen. In streams and lakes these can enhance the growth algae and favor certain algal species. The resulting bloom can rapidly choke out other species and when the populations collapse, result in oxygen depletion.

Toxicity.— Toxicity associated with sewage plant discharges during the winter is often attributable to ammonia (MISA 1990). During winter operation, high ammonia levels result from reduced nitrification at lower wastewater temperatures. Ammonia is particularly toxic to fish. The toxicity is dependent on pH and temperature as molecular speciation is critical to creating the toxic effect. In addition, in plants using chlorine disinfection, residual chlorine and compounds created by the use of chlorine, such as trihalomethanes, may also cause toxicity. Finally, if there are unregulated industrial discharges into a community wastewater treatment system, any number of other organic and inorganic toxicants may be present.

2.1.5.2 Solid waste disposal sites

Landfills operated by the Bulkley-Nechako and Kitimat-Stikine Regional Districts are the most common method of solid waste disposal in the Skeena watershed. When landfill waste is contacted by infiltrating precipitation, run-off or ground water, a contaminated liquid, known as landfill leachate is produced. Landfill leachate has the potential to affect ground water and surface water quality, downgradient of the landfill. A subsurface leachate plume could affect residential wells or affect aquatic life in springs downgradient of the landfill. Leachate springs and overland flows can enter streams affecting surface water quality and aquatic life.

Leachate quantity depends on: the amount of infiltration (climate); size of the landfill; disposal of liquid wastes in the landfill; location of the landfill (in low lying areas such as flood plains and wetlands which are seasonally flooded); and on the quality of the final cover which is placed over the wastes.

Leachate quality depends on: the types of wastes; age of the landfill (younger landfills tend to have high BOD concentrations, old landfills tend to have higher ammonia concentrations); amount of infiltration (wet climates tend to dilute leachates); and depth of wastes (the deeper the wastes the stronger the leachate tends to be).

2.1.6 Linear developments and water quality

2.1.6.1 Railways and highways

The first major linear development through the Skeena watershed was the construction of the Grand Trunk Pacific Railway (now the Canadian National Railway), which occurred between 1907 and 1914. The Skeena River portion of the rail line was a major undertaking. It is estimated that ten million pounds of explosive were used in blasting rock canyon walls between Prince Rupert and Kitselas Canyon, at Terrace (Large 1957). Later, Highway 16 was completed, more or less paralleling the rail line through the Bulkley and Skeena valleys. The recent upgrading of Highway 16 between Prince Rupert and Terrace has involved extensive encroachments into the Skeena River.

Along the floodplains of the Bulkley and Skeena rivers, numerous side channels have been cut off at their upstream end from the main river channel by the rail line or Highway 16. Side channels are often very important rearing habitat for juvenile salmonids, particularly coho. In some instances the side channels have been culverted, but culverts are often the target sites for beaver dams.

Channelization and installation of culverts which block fish passage are also seen at numerous locations along the rail line and highway. Stream channelization is common upstream of highway bridge crossings throughout the region (for example, Buck Creek at Houston, the Zymoetz and Shames rivers near Terrace). Stream channelization reduces overall stream length and therefore eliminates productive fish habitat. Remaining stream environments are often devoid of niches suitable for endemic species and thus overall species diversity is diminished. Sedimentation, loss of riparian cover, and hydrologic changes often result. These effects can be of very long duration (Hooten and Reid 1975).

An example is found at New Hazelton where both Waterfall and Station creeks have had a history of habitat alterations related to railroad and highway construction (and to development of New Hazelton's water supply and sewage disposal systems). Waterfall Creek has been channelized upstream of the CN Rail line for approximately 1.2 km before joining Station Creek and passing under the tracks. Coho salmon passage into Station Creek is blocked by a poorly installed Highway 16 culvert about 1.4 km from the Bulkley River. About 5 km of potential coho rearing habitat is located upstream of the highway and has been made inaccessible by the culvert (Bustard 1986). Recently New Hazelton elementary students have released coho smolts into Waterfall Creek and have approached Ministry of Highways to renovate the culvert design.

2.1.6.2 Pipelines

The Pacific Northern Gas (PNG) natural gas pipeline route traverses the Bulkley valley as far as Smithers/Telkwa, then follows the Telkwa and Zymoetz Rivers to Terrace, where it divides, with one branch following the Skeena to Prince Rupert, and the other branch continuing south to Kitimat. Pipeline crossings generally are buried under the stream bed, which can cause habitat loss and siltation during construction. Potential future channel degradation or realignment is a major design consideration. The PNG pipeline through the Zymoetz watershed has suffered numerous wash-outs and forced relocations since construction. Twinning of the PNG pipeline is presently being carried out. A second natural gas pipeline has been proposed for approximately the same route to supply a proposed liquefied natural gas facility on the coast (see section 1.3.6.2).

2.2 WATER QUALITY MANAGEMENT IN BRITISH COLUMBIA

2.2.1 BC water quality criteria and Canadian water quality guidelines

The MOELP Water Quality Branch is developing province-wide water quality criteria for use in assessing water quality data and preparing site-specific water quality objectives. Water quality criteria are policy guidelines concerning the acceptable range of conditions for particular water use classes. Water quality criteria are developed for five use classes: drinking, public water supply and food processing (for raw sources prior to treatment); recreation and aesthetics; aquatic life and wildlife; agriculture (livestock watering and irrigation); and industrial uses. Water quality criteria are safe levels of contaminants for the protection of a given water use. They are intended to be used as a water quality data-screening tool. If the data do not exceed the criteria, problems are unlikely. If the data lie outside the criteria, then a detailed assessment of the data and the criteria should be done to determine the extent of the problem.

The Canadian Water Quality Guidelines were developed in order to harmonize water quality criteria and guidelines used by governments throughout Canada. The Canadian Council of Resource and Environment Ministers (CCREM) originally published the guidelines in March, 1987 and they are updated periodically. Selected MOELP water quality criteria (Nagpal 1994) and Canadian water quality guidelines (CCREM 1987 and updates) are found in Appendix 1, Tables 1 and 2.

2.2.1.1 BC water quality objectives and monitoring

Water quality objectives are environmental quality conditions set as targets for specific water bodies based on three main factors: 1) the designated use(s) for the water; 2) the water quality criteria that have been adopted for the most sensitive designated use; and 3) the local conditions, including the actual measured water quality in the area. For a specific drainage the appropriate priority uses for the water are chosen. This becomes the designated use to be protected by the objectives. Objectives are chosen for that waterbody based on criteria or guidelines, taking local circumstances into account. Objectives can be chosen above or below the criteria depending on the situation, and what is at risk. The objectives are policy guidelines for decision-makers who issue Water Licenses for water use and Waste Management Permits for waste disposal. Water quality objectives are not themselves legally enforceable. The instrument for enforcement is the Permit, License or Order issued by the regulatory authority.

MOELP conducts an objectives-related provincial ambient monitoring program to determine the degree of attainment of the objectives which have been approved for various waterbodies. In many cases, this requires five samples at weekly intervals in a 30-day period at a specified time of year. An annual report is produced on the attainment of objectives, starting with monitoring data for 1986.

2.2.2 BC Waste Management Act and Pollution Control Objectives

MOELP Environmental Protection Program (EPP) is the lead agency in the regulation of waste discharges under the authority of the *Waste Management Act* and the *Litter Act*. Waste dischargers are required to have a Waste Management Permit which specifies the location, time, quantity, type and characteristics of waste permitted to be discharged, and may include conditions that must be maintained in the receiving environment. Characteristics of wastes may be described as concentrations of known contaminants or in terms of toxicity to specific organisms, typically rainbow trout.

The EPP is guided in part by legislated Pollution Control Objectives established for five broad classes of waste dischargers:

Food-processing, Agriculturally Oriented, and Other Miscellaneous Industries;
The Forest Products Industry;
The Mining, Smelting and Related Industries;
The Chemical and Petroleum Industries; and
Municipal Type Waste Discharges.

The *Waste Management Act* is amended from time to time, for example, with the addition of regulations to deal with specific industries, such as the Agricultural Waste Control Regulation, and the Code of Agricultural Practice for Waste Management. Producers who conform to the Code are exempt from holding a Waste Management permit.

2.2.2.1 Initial dilution zone

The water quality objectives (if available for a given watershed) and/or the water quality criteria serve as guidelines. The objectives do not apply within the initial dilution zone (IDZ), which is the initial portion of the larger effluent mixing zone. The areal extent of the initial dilution zone is defined on a site-specific basis, and is normally relatively small (for example, up to 100 metres from the point of discharge, but not exceeding 25 to 50 percent of the width of the water body). The water quality in the IDZ may be outside the objectives or criteria and sub-lethal effects may occur, but the condition should not be acutely toxic or conducive to other objectionable effects. Federal regulatory agencies take a different approach to toxicity within the IDZ (see section 2.2.9.2).

2.2.2.2 Acute lethal toxicity of liquid effluents

Effluent toxicity is regulated by the Province through permits which limit 1) specific identified toxic substances, and 2) toxicity to fish and other organisms. For example, the Pollution Control Objectives for Municipal Waste Discharges require a 100% effluent 96 hour LC50 non toxic discharge (for specified discharges). The Lethal Concentration (LC) is described as the toxicant concentration estimated to produce death in a specified proportion of test organisms in a specific time of observation. The 96 hr LC50 is the concentration killing 50% of exposed organisms, usually rainbow trout underyearlings, within 96 hours. Standardized laboratory bioassay procedures to determine acute lethal toxicity of effluents to fish have been published (MOELP 1982).

2.2.3 BC Environmental Assessment Act 1995

For many years, the multi-agency Northwest Mine Development Review Committee (MDRC) reviewed both development plans and the decommissioning and closure plans for mines in the Skeena Region. Water quality impact assessments of mining effluents prior to Mine Development Certification were an important consideration under the MDRC process.

In June 1995, a new *Environmental Assessment Act*, establishing a single multi-agency review process for all major projects, including mining, was proclaimed. Under the Act, major project proposals will be assessed in the following sectors: industrial (e.g. chemical production facilities), waste management, mining, food processing, energy, transportation, water management, and tourism.

In the case of mine proposals, the new Environmental Assessment Office (EAO) has replaced but operates similarly to the Mine Development Review Committee. Under the EAO there is enhanced participation by local government, First Nations and the public. In addition the new process introduces specific time-lines for activities within each stage of the process.

Meanwhile, the provincial and federal governments continue to work on a harmonization agreement for projects which are subject to both the *Canadian Environmental Assessment Act* and the provincial legislation. The primary objective of such an agreement is to ensure that federal and provincial environmental assessment requirements for all major projects in British Columbia are met through a single environmental assessment process.

2.2.4 BC Wildlife Act classification of angling waters

The *Wildlife Amendment Act*, 1989, enabled the designation of Class I and II angling waters. Classified waters are listed in the fishing regulations in recognition of the extremely high sports fishing values of these waters, including not only the existence of special fish (for example record-sized steelhead) but also a highly desirable fishing experience. In the Class I water, this experience contains an additional element of "wilderness" or "pristine" value.

2.2.4.1 Class I waters

Class I waters contain extremely valuable wilderness fishing opportunities where both guided and non-guided use is controlled (by special licenses which limit the number of allowable fishing days). Intensive interagency planning is usually required to carefully integrate commercial activity in order to preserve the natural character of the river. Class I waters are often difficult to access, and this is viewed as a desirable characteristic of a wilderness fishing experience. Vehicles and roads are generally restricted within the riverine corridor. The corridor's width will vary, but is, in most cases, no less than 1 km in width. Access outside the riverine corridor will be managed through a Coordinated Access Management Plan to limit industrial traffic to specified times and locations, and to direct recreational traffic to appropriate parking or camping locations.

2.2.4.2 Class II waters

Class II waters are described as containing "high natural values", often in attractive natural setting, where MOELP regulations will focus on managing guided (and perhaps non-resident) fishing, but where the number of resident anglers will not be restricted and will be allowed to grow over time. Integrated habitat management and interagency planning will be required to preserve the high natural values of Class II waters, but the objective of maintaining an unmodified landscape experience may not always be met. In contrast to Class I water, Class II water may be accessed at numerous locations. However, sensitive location of industrial roads and operations should attempt to minimize intrusive noise, dust and visual blight.

2.2.4.3 Fishability

Fishability is the term describing those factors which enable fishermen to successfully catch fish. The water must not be too filled with debris for casting or boating and, most importantly, must be clear enough for fish to see a lure or fly. When the turbidity of the water column exceeds this standard, the river is "out" and the fishing is over. Turbidity is caused by suspended sediment which may be introduced by natural events such as storms or glacial melt, but is often accelerated or initiated by logging and other land use activities. In essentially all non-glaciated, undisturbed watersheds, natural turbidity is very low during the mid to late summer fishing season. This especially true in lake headed streams, which often produce high value fisheries.

The amount of sedimentation required to result in a deleterious effect on fish habitat has been extensively researched, and measures to control it are well documented. However, turbidity sufficient to restrict the fishability of a stream can be caused by much smaller amounts and much finer particle sizes. Both Class I and Class II waters require more attention to water turbidity than would be required for habitat maintenance alone. In addition, because of the downstream transport of sediment, all upstream tributaries of Class I and II waters may be sources for fine sediments which may impact water many kilometres downstream.

2.2.5 BC Land Development Guidelines

The Land Development Guidelines for the Protection of Aquatic Habitat (Chilibeck 1992) were jointly developed by the DFO and MOELP to ensure that the quantity and quality of fish habitat are preserved and maintained at the productive level that existed prior to land development activities. The guidelines explain the regulatory environment, outline the steps and information required to prepare a land development impact assessment, and provide specific guidelines and examples for: leave strips along streams, erosion and sediment control and site planning, storm-water management, instream work, and fish passage and culverts.

Fisheries Sensitive Zones are defined as the instream aquatic habitats, as well as the out-of-stream habitat features such as side channels, wetlands and riparian areas necessary for the protection of aquatic habitat. Area and fish species-specific timing windows for operating within the Fisheries Sensitive Zones are described.

2.2.6 BC Water Act and proposed Community Watershed Management Guidelines

The MOELP Water Management Division regulates the use of water in the province under the *Water Act*, licensing the withdrawal of water from lakes and streams for such uses as domestic use, community waterworks, mining, agriculture (including irrigation), industry, and power generation. There are two large Order in Council (OIC) reserves for future hydroelectric power generation on the Skeena and Morice Rivers, as well as a reserve granted to the Town of Smithers on the Bulkley River upstream of Smithers for protection of their waterworks. In addition, Skeena Water Management Branch holds Crown land Section 12 Map Reserves over the watersheds of 16 creeks and three lakes in the Skeena basin which are Community Watersheds. Community Watersheds are the source of domestic water to numerous homes through a community waterworks or water utility.

More than 12,000 watersheds in British Columbia have some form of licensed withdrawal of water for domestic use, through municipal or community waterworks systems and through individual landowners extracting water directly from a stream or lake. In addition, many of these watersheds have long term commitments to a variety of land-uses, including timber harvesting, grazing, farming, recreation, and mining, which can affect the quality of drinking water in these watersheds, specifically due to sediment, pathogens and toxic chemicals. In addition, resource use in watersheds in combination with increasing population can lead to seasonal water supply problems, and/or to inadequate water flows for fish.

For these reasons water management guidelines that would outline procedures and operational standards for resource development in community watersheds have been proposed. If approved, the guidelines will define standards for resource development planning, risk assessment, operations, and monitoring of resource use within community watersheds. Once adopted, they will be enforced on Crown land through provincial resource management regulations, such as the *Water Act*, the Forest Practices Code and the Agricultural Practices Code.

2.2.7 BC Fisheries/Forestry Guidelines, Forest Practices Code, Watershed Restoration Program and Land Use Planning

2.2.7.1 Fisheries/Forestry Guidelines

Province-wide concern for the effects of clearcut logging on salmon streams led to the establishment of a referral system and later to the Coastal Forest Planning Guidelines, Protection Clauses, and guidelines for the construction of forest haul roads. In the late 1960's, resource managers recognized that for the guidelines to work, detailed local information about the effects of forest practices on streams would be required.

In 1970, in response to this need, the 17-year Carnation Creek Watershed Study (Hartman and Scrivener 1990) was initiated. The research findings underscored the need to revisit the coastal forestry guidelines. The first Coastal Fish/Forestry Guidelines were published in 1987, and have since been revised three times. The Guidelines identify practices to reduce erosion and sediment production. The Watershed Workbook (Wilford 1987) is a tool to address watershed level or cumulative effects issues surrounding stream channel integrity. In the early 1990's, the scope of guideline development expanded geographically to include the entire province and jurisdictionally to include silviculture and well as harvesting, and the effects of forest practice on wildlife, biodiversity and community watersheds.

2.2.7.2 Forest Practices Code

In 1992, the development of the Forest Practices Code (FPC) was initiated, and the regulations came into effect in June 1995. The FPC consists of eighteen regulations covering all aspects of BC forestry. A total of 68 guidebooks have been completed or are in production, which describe how the regulations will be implemented. The Interior and Coastal Watershed Assessment Procedures and Channel/Gully Assessment Procedures are guidebooks focused specifically on cumulative effects to water quality and stream channel habitat such as hydrologic change and suspended sediment loading. FPC requires that watershed assessments be completed for all community watersheds and for all watersheds with high value fisheries that are jointly requested by MOELP and MOF. The Community Watershed Guidebook will describe forest practices to protect the quality and quantity of water in rivers and streams which are the drinking water source for municipalities and other organized community groups.

2.2.7.3 Watershed Restoration Program

The Watershed Restoration Program was initiated, in part, to help bridge historical forest harvesting practices and the new standards established by the Forest Practices Code. The program, which was initiated in 1994, is designed to accelerate the recovery of damaged watersheds. During the first few years, inventory specialists will identify watersheds that were adversely impacted prior to the introduction of the Coastal Fisheries/Forestry Guidelines and the Forest Practices Code and prescribe restorative measures. These measures will include stabilizing hillslopes, rehabilitating roads and restoring streams. During the next few years, as watersheds are inventoried under this program, a great deal of insight will be gained into the cumulative effect of past forestry activities on water quality in the Skeena watershed.

2.2.7.4 Land Use Planning

Forestry and land-use planning in the province have evolved in recent years in order to resolve increased conflicts between forestry and integrated resource management (for example, management for fisheries, wildlife, biodiversity or tourism). One of the main changes is the increased inclusion of local and stakeholder representation in the planning process. Local Resource Use Plans (LRUPs), Integrated Resource Management Plans (IRMPs) and Total Resource Plans (TRPs) are intended to resolve local or watershed level land use issues.

At the sub-regional level are Land and Resource Management Plans (LRMPs), which define specific land allocation and resource management objectives for an area (usually a Timber Supply Area). Tree farm licenses, found only on the coast, will also be incorporated into LRMPs. Development Plans, Silvicultural Prescriptions, and Access Management Plans define the site-specific activity that will occur during the term of the plan. Field operations are monitored in order to ensure compliance with the resource plans. Monitoring and enforcement have been strengthened under the Forest Practices Code. LRMPs must be approved by Cabinet (the ministers of Forests, of Energy, Mines and Petroleum Resources, of Environment, Lands and Parks, and other government ministries, as appropriate).

One of the first attempts at land use planning involving public as well as industry stakeholders was in the Kispiox Forest District, initiated in 1989. Public, industry and local government representatives worked with government resource managers to prepare the land use recommendations. The participants developed resource management strategies, objectives and guidelines for sub-units of the planning area, which were presented to Cabinet in 1994 (Consensus Management Direction for the Kispiox Forest District). This document is currently being revised into the format of an LRMP, reflecting forestry planning guidelines developed under the Forest Practices Code. LRMPs are presently under development in all the remaining forest districts in the Skeena watershed except the North Coast Forest District.

2.2.8 Canadian Environmental Protection Act

The *Canadian Environmental Protection Act* (CEPA) 1985 is administered by both the Minister of the Environment and the Minister of National Health and Welfare. Under the Act, the Minister of the Environment may establish environmental quality monitoring systems and research programs and formulate pollution control plans. The minister is also required to establish environmental quality objectives and guidelines, limits for the amounts of substances that may be released, and environmental codes of practice. The Minister of National Health and Welfare is directed to undertake the same task with respect to the elements of the environment that may affect the life and health of Canadians. Part II of CEPA regulates toxic substances, that is, substances which may endanger the environment or human health.

The *Environmental Assessment and Review Process Guidelines Order* outlines the administrative procedure for assessing the environmental consequences of certain federal activities. The procedure is applicable to any federal department or agency activities that might have significantly adverse environmental effects; to which the federal government makes a financial contribution; that may have environmental effect on areas of federal responsibility; or which are located on lands administered by the federal government. The Federal Environmental Assessment Review Office (FEARO) coordinates and administers the system.

2.2.9 Canadian Fisheries Act

2.2.9.1 Fisheries Act

The *Fisheries Act*, 1985, prevents any person from depositing or permitting the deposit of a "deleterious substance" of any type in any water frequented by fish, except as authorized. The *Fisheries Act* also makes it an offense for any person to carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat. In meeting its goal of protecting fish habitat, the Department of Fisheries and Oceans (DFO) applies the principle of NO NET LOSS to new works and undertakings to ensure that habitat productive capacity is maintained. The free passage of both ascending and descending migratory fish is protected under the act. Regulations under the act also deal with the quality of the water and contaminant standards applicable to certain industries (for example, pulp and paper and chlor-alkali mercury plants, petroleum refineries, metal mining, and others).

2.2.9.2 Toxicity within the IDZ

The issue of toxicity within the initial dilution zone (see section 2.2.1.1) is a general concern to DFO, because in some situations valuable fish habitat may exist within the mixing zone below an effluent discharge. In contrast to the Provincial regulations, Federal authorities under jurisdiction of the *Fisheries Act* consider any kill of test fish in an effluent to be an introduction of a "deleterious substance" into a receiving water and thus an offense under the Fisheries Act. The federal position holds that the usual toxicity criteria expressed as the 96 hour LC50 is of limited value. Values below the LC50 level are toxic to 50% or the organisms and the concentration at which the first death occurs may be well below this level. At yet lower concentrations, effects may be chronic though not acute. Chronic toxicity effects of reduced biological efficiency or reproductive failure may be significant in the long run. Consequently, federal officials would prefer that no toxicity exist in an IDZ. Provincial officials feel that the IDZ concept allowing river dilution and assimilation within a small volume is a valid one, otherwise discharges would need to be of receiving water quality at "end of pipe". The issue remains unresolved primarily because of the costs involved in meeting the higher objective of no toxicity in the IDZ.

2.2.10 Water Survey of Canada hydrometric network

Long-term hydrometric data is necessary for assessing the potential impact of stresses on water quality and for understanding climate variability/climate change. Water Survey of Canada (WSC) has operated a network of hydrometric gauge stations on streams within the Skeena watershed, beginning with the first station at Quick in 1930. Many of these stations have been jointly funded based on Federal-Provincial cost-sharing agreements. A suspended sediment monitoring program has operated in conjunction with the hydrometric stations at two sites: the Bulkley River at Quick and the Skeena River as Usk.

In 1995 WSC undertook a rationalization and reduction of the hydrometric network. The National Water Rationalization Team (1995) applies a business approach to monitoring by 1) reducing the number of WSC funded stations and 2) adopting new funding principles for working with partners and clients, based on the true cost of operating specific stations. Funding for a total of 14 stations in the Skeena watershed is uncertain (Table 2.2) and thus the stations may be discontinued.

Table 2.2 Skeena watershed hydrometric stations under review March 1995

Station No.	Station Name	Operation
08EG011	Zymagotitz River near Terrace	M1
08EE003	Bulkley River near Houston	D
08EE014	Canyon Creek near Smithers	D
08EC001	Babine River at Babine	R
08EC003	Babine Lake at Topley Landing	R
08EC004	Pinkut Creek near Tintagel	R
08ED001	Nanika River at outlet of Kidprice Lake	R
08ED002	Morice River near Houston (at outlet of Morice Lake)	R
08EE012	Simpson Creek at the mouth	R
08EE013	Buck Creek at the mouth	R
08EE020	Telkwa River below Tsai Creek	R
08EE025	Two Mile Creek in District Lot 4834	R
08EF005	Zymoetz River above OK Creek	R
08EG017	Deep Creek above reservoir	R
08EB005	Skeena River above Babine River	U

M1 - Station operation suspended (Mothballed) April 1, 1995 and decommissioned later if no funding is found

D - Station will be circulated for funding support. May be Decommissioned in 1996 or 1997

R - Stations which Require funding support or may be subject to discontinuation

U - Stations for which Federal or Provincial funding is Uncertain and may be subject to discontinuation. Further examination required.

3. UPPER SKEENA RIVER TO BABINE RIVER CONFLUENCE

The Skeena River heads in the rugged Skeena Mountains of north central British Columbia and follows an irregular path southward to its junction with the Babine River (Figure 3.1). The headwaters of the Skeena are bordered on the north by Spatsizi Plateau Wilderness Park and on the east by Tatlatui Park. A major tributary of the upper Skeena is the Sustut River, which drains three sockeye nursery lakes; Bear, Sustut and Johanson Lakes.

The Sustut River has been identified by MOELP as a Class I stream having extremely valuable wilderness fishing opportunities. (See section 2.2.4 for an explanation of classified waters.) In addition, the Sustut Valley has been designated by MOELP as a study area by the Protected Areas Strategy. Depletion of steelhead stocks particularly in the upper reaches of the Sustut River has led to a recent closure of the area to sport fishing. The upper Sustut steelhead stock has been identified for its management concern (Bustard 1992) and has been adopted as an important index stock of Skeena River summer-run steelhead.

3.1 HYDROLOGY

The drainage area of the upper Skeena is approximately 12,400 km^2. Environment Canada hydrometric gauge station 08EB005 is located on the upper Skeena just above its confluence with the Babine River. Monthly mean, maximum and minimum discharge for the period 1970-1993 are shown in Table 3.1 and Figure 3.2. Low, stable flows are recorded during late winter under heavy snowpack in the Skeena Mountains. Maximum freshet discharges occur in mid-June with high elevation snowmelt. A second, much lower discharge peak can occur in October of some years due to heavy autumn rainfall.

Environment Canada is undertaking a review of the hydrometric network, and has placed this station on a list of stations for which Federal or Provincial funding is uncertain and which may be subject to discontinuation. Further examination is required for need and/or operations costs.

3.2 LAND USE HISTORY

3.2.1 Settlements

Kuldo, a principal winter village of the Gitksan First Nation, was located near the mouth of Kuldo Creek at the time of first contact. Kuldo has been deserted since about 1939, the people and their descendants having joined villages downriver (Sturtevant 1990).

The Sekanni-Carrier First Nations from the Babine Lake area also utilized the eastern portion of the watershed, with a settlement at Bear Lake. An active trade route followed the Skeena and Sustut Rivers to Bear Lake before crossing into the interior. The Hudson's Bay Company erected Fort Connolly at the north end of Bear Lake in 1826 to facilitate trading in furs and supplies from the coast (Large 1957). The old trade routes were eventually abandoned with construction of the Canadian National railway in 1914.

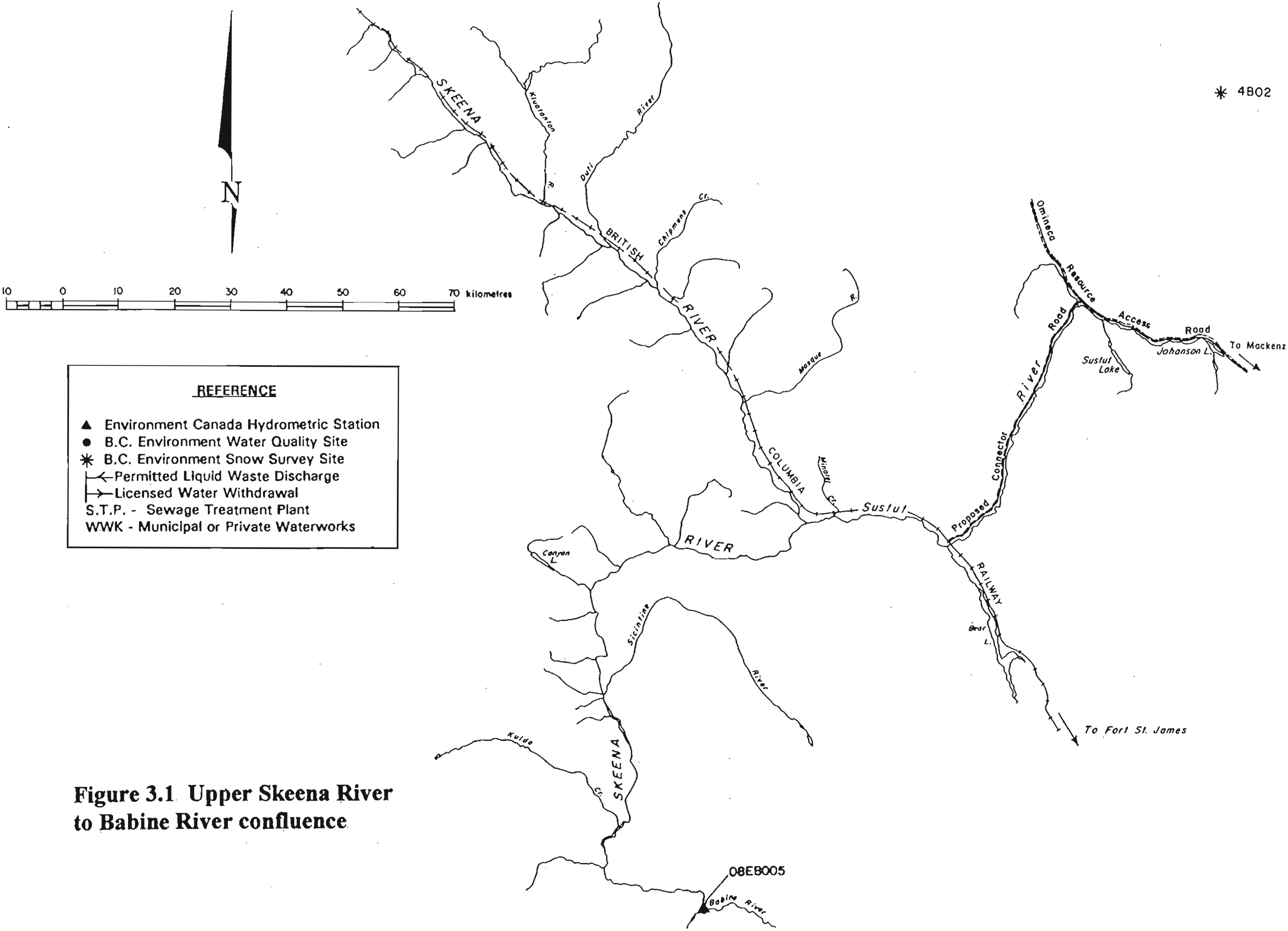


Figure 3.1 Upper Skeena River to Babine River confluence

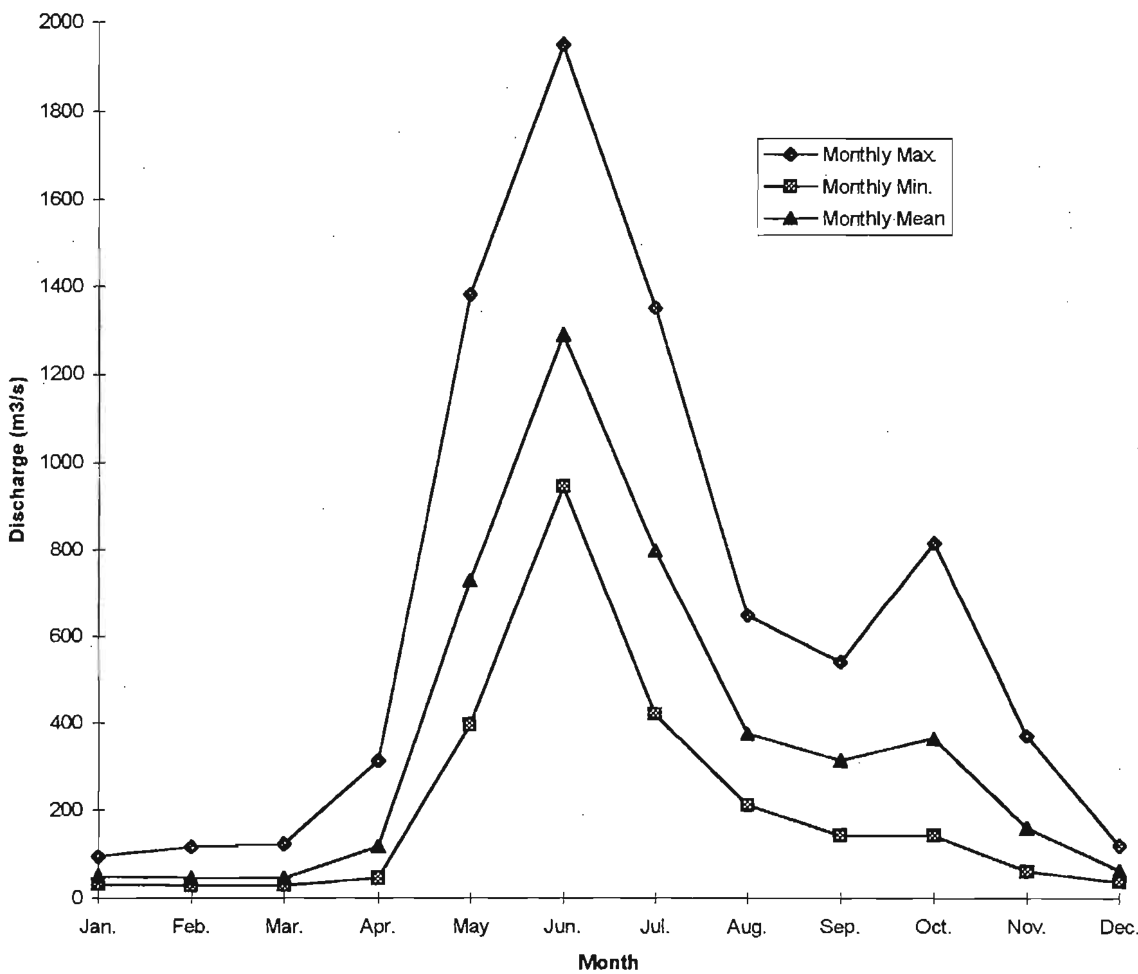
Table 3.1 Monthly discharge summary Skeena River above Babine River, Station 08EB005

Latitude:	55 42 58 N
Longitude:	127 41 05 W
Drainage Area Gross:	12 400 km2
Period of Record	1970 - 1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	93.7	115	122	313	1380	1950	1350	647	541	816	370	119
Monthly Min.	31.5	27.5	27.6	44.3	396	946	420	210	142	142	59.8	36.6
Monthly Mean	48.8	44.7	45.6	116	731	1290	799	375	313	364	159	63.9

Average 7-day, 10-year low flow is 24.7 m3/s with 95% confidence limits of 23.0 and 27.2.

Figure 3.2 Discharge envelope Skeena River above Babine River, 1970-1993



3.2.2 British Columbia Railway and Omineca Resource Access Road

In the 1970's the province began construction of the British Columbia Railway (BCR) Dease Lake extension intended to connect Fort St. James with Dease Lake to the north. The railway had been completed paralleling the Bear, lower Sustut, and upper Skeena Rivers as far north as Chipmunk Creek, on the upper Skeena, when the project was abandoned as uneconomic a few years later. The abandoned BC Railway line has recently been reconstructed from Fort St. James to the vicinity of the Mosque River for timber extraction.

During the 1980's a mining exploration road now called the Omineca Resource Access Road (ORAR) was pushed in from the south-east to mineral properties in the vicinity of Tutade Lake. This opened up seasonal vehicle access to the Johanson Lake/Johanson Creek area. In September 1993 an application for Mine Development Certificate was received for the Kemess South gold-copper project near Tutade Lake, proposing to construct a mine access road along the north side of the Sustut River connecting the ORAR with the BCR at Sloane (see section 3.2.4).

3.2.3 Forestry

Following the abandonment of the BC Rail Dease Lake Extension, the upper Skeena remained unimpacted by industrialization. In the past five years, access routes by road and rail for timber extraction have extended into the upper Skeena watershed. The upper Skeena River lies within two Forest Districts; the Sustut and the upper Skeena River watershed north of about Canyon Creek is within the Fort St. James Forest District, the remainder of the Skeena watershed is within the Kispiox Forest District.

In 1988 two temporary Forest Licenses were awarded for harvest in the Sustut River area to Prince George companies. Rustad Brothers was granted a license in the Bear Lake/Bear River area and Takla Track and Timber was granted a license on the lower Sustut River drainage. The purposes was to address mountain pine beetle outbreaks and to reactivate the BC Rail line. Wood is moved by spur roads to haulouts on the BCR, for shipment to Fort St. James and Prince George.

In 1995 Skeena Cellulose Carnaby extended the forestry road along the west side of the Skeena from Hazelton north past Kuldo Creek and constructed a major bridge crossing on the Skeena. The Damsumlo Bridge will provide access to timber on the east side of the Skeena and into the Sicintine River drainage for the first time. Additionally, a bridge crossing of the Babine River near its confluence with the Skeena to access timber north of the Babine is being sought by Isolite Stege Forest Products of South Hazelton (M. Todd, Kispiox Forest District, personal communication).

3.2.3.1 Kispiox LRMP

A land and resource management planning process was initiated for the Kispiox Timber Supply Area in 1989. The Kispiox process occurred prior to, and concurrent with, the development of legislation and policy regarding regional land use, resource and environmental management planning. The lengthy planning process involving the public and government agencies produced a Consensus Management Direction (MOF 1994). The plan specifies broad resource/environmental management objectives and strategies, including forest practices, for the area surrounding the Hazeltons. The Consensus Management Direction is currently being revised into an Land and Resource Management Plan, reflecting recent forestry planning guidelines.

The upper Skeena drainage, including the Kispiox, Bulkley and Babine Rivers and their tributaries, were identified as containing significant fisheries habitat. Therefore general management prescriptions for the protection of water quality and fisheries habitat were applied throughout the TSA. On average, a 22% clear-cut equivalency rule will limit the rate of harvest by watershed. Prescriptions for riparian zone width and management will be determined on a site specific basis. The objective of riparian zone management will be to protect large woody debris sources, to ensure bank stability, to protect water quality and wildlife habitat.

Monitoring.— A monitoring committee will be established consisting of five people from the general public and one representative from each of agencies. The committee will evaluate field results through GIS analysis and maps provided by the resource agencies and licensees and will participate in field trips.

3.2.3.2 Sustut LRUP

The Sustut Local Resource Use Plan (LRUP) was initiated in 1988 and a Draft Consensus Report completed in 1994 (MOF 1994) to address conflicts between timber harvesting and the high fish and wildlife values of the area. The Sustut LRUP area is bordered by and includes the Slamgeesh River drainage to the west, the Mosque river to the north, the Squingula River to the south and the Asitika River drainage to the east. An accelerated harvest is planned in areas of heavy mountain pine beetle infestation. Access to the Sustut is only by rail. Spur roads will move wood into loadouts along the BC Rail line.

A Preservation Zone is established in the Sustut River valley bottom designed to protect critical wildlife habitat and maintain visual qualities and characteristics that make the Sustut a Class I sport fishing river. The remainder of the area is broken up into watershed sub-units and the key resource values and management objectives are identified for each unit. A Forest Ecosystem Network (FEN) is proposed consisting of 12 reserve areas and 25 connecting linkages. The purpose of the FEN is to maintain stream ecology, riparian habitat and wilderness characteristics and to maintain natural forest ecosystems in the LRUP area, although no specific management prescriptions are given.

Monitoring.— There is no reference to monitoring in the LRUP document. A broader planning process, an LRMP, is under development for the Fort St. James Forest District, which encompasses the Sustut LRUP area as well as the remainder of the upper Skeena watershed.

3.2.4 Mining

3.2.4.1 Sloane Connector Road

The Kemess South copper-gold mine proposed near Tutade Lake is in the Findlay River watershed. A connector road paralleling the Sustut River from the ORAR to the BC Rail siding at Sloane is proposed in the mine development plan in order to supply the mine and ship concentrate via rail. The application for Mine Development Certificate is currently undergoing review by the BC Environmental Assessment Office. Issues of concern identified by MOELP and DFO concerning the road proposal are summarized below:

- The upper Sustut and Johanson Creek are important steelhead as well as coho and chinook salmon habitat. Water quality in the Sustut system must be maintained through rigorous attention to avoidance of easily eroded soils and unstable slopes as detected through geotechnical assessment of the road corridor and sediment yield hazard mapping.
- To minimize impacts, it is essential that an Environmental Monitor, responsible to a MOELP/DFO committee, be in place during route selection and construction.
- A detailed sediment monitoring and management program is required. The Sustut watershed is highly erodible with pockets of glacial lacustrine deposits which can yield high sediment loads when disturbed (P. Lemieux, DFO, personal communication).
- Realignment of the proposed road to the north at its junction with the ORAR is necessary in order to avoid habitat degradation and access impacts to steelhead spawning and rearing waters.
- The proposed Sloane siding for ore transfer is within the wilderness Preservation Zone prescribed in the Sustut LRUP. In addition, the Sustut valley has been identified as an area of interest for consideration by PAS.
- Appropriate compensatory measures to offset the anticipated impacts from construction of the Sloane Connector Road would include the closure and rehabilitation of an equivalent length of the ORAR.

3.3 WATER WITHDRAWALS

There are only two licensed water withdrawals (Table 3.2) from the upper Skeena watershed, both in the Sustut drainage: the Takla Forestry camp at Minaret Creek and a sport-fishing lodge on the Sustut River. Flow data is not available for Minaret Creek or the Sustut River. These water withdrawals would be inconsequential to the Skeena River at the gauge station near the confluence of the Babine, where the average February discharge is 27.5 m^3/s. The 7 day average 10 year low flow is 24.7 m^3/s for this site.

Table 3.2 Licensed water withdrawals upper Skeena River to Babine River confluence

Uses: Forestry camp, sports-fishing lodge (2 licences)		
GD	m3/d	m3/s
4000	18.2	0.0002

3.4 WATER QUALITY AND AQUATIC RESEARCH

3.4.1 Productivity of Skeena watershed sockeye nursery lakes, 1994

Monthly limnological surveys were carried out by DFO on Sustut and Johanson Lakes during June-October 1994 as part of a survey of selected Skeena sockeye salmon nursery lakes. A complete description of the ongoing research is found in section 1.3.5.2. Preliminary water quality data from this project are found in Table 3.3.

Table 3.3 Johanson and Sustut Lakes water quality and productivity May - October 1994 (mean epilimnetic concentrations)

Date	Temp °C	pH	Secchi depth m	Euphotic zone depth m	TDS mg/L	Total alkalinity mg CaCO3/L	Total P ug P/L	Nitrate ug N/L	Total Chlorophyll ug/L	Photosyn-thetic rate mg C/m2/d
					Johanson Lake					
18-Jun-94	5.9	7.12	9.0	22.2	39	19.78	2.3	1.7	0.98	88.3
15-Jul-94	8.4	7.14	10.5	18.6	37	19.03	3.6	1.2	0.89	70.1
19-Aug-94	10.1	7.27	10.5	22.8	47	19.52	3.1	2.4	1.01	60.0
3-Oct-94	6.5	7.01	10.0	22.2	87	20.46	3.8	2.0	0.98	121.7
					Sustut Lake					
18-Jun-94	8.8	7.28	8.0	13.8	51	27.77	5.6	0.7	1.69	114.7
15-Jul-94	11.1	6.88	8.5	14.1	48	21.25	5.7	0.5	0.97	81.8
19-Aug-94	14.1	7.55	11.5	15.9	57	28.01	7.0	0.9	1.70	134.0
3-Oct-94	7.1	7.32	9.0	15.6	51	29.38	7.1	0.9	1.40	105.8

Johanson Lake is a cold (maximum temperature 10.1 °C in August), clear mountain lake, with neutral pH and low dissolved solids. Alkalinity, a measure of the pH buffering capacity of water, is low to moderate. Nutrient concentrations, phytoplankton biomass (as chlorophyll *a*) and primary productivity (photosynthetic rate) are well within the general trophic classification of oligotrophic (Wetzel 1983).

Lower in elevation, Sustut Lake is somewhat warmer (maximum August temperature of 14.1 °C). Secchi and euphotic zone depths in Sustut Lake are shallower than Johanson, which may be due the erosion of suspended sediments from the surrounding watershed. Total phosphorus concentrations (generally the determiner of algal productivity in lakes) and primary productivity are slightly higher in Sustut compared with Johanson Lake.

3.5 LIQUID WASTE DISCHARGES

There are no permitted liquid waste discharges in this reach.

3.6 SUMMARY AND REVIEW OF MONITORING NEEDS

The upper Skeena River is the most remote headwaters reach in the watershed. There likely may have been some impacts on water quality in the upper Skeena watershed due to sedimentation caused by the construction of the BC Rail Dease Lake Extension and the Omineca Resource Access Road in the 1970's and 1980's. However, the headwaters of the Skeena have otherwise remained largely in a wilderness state and with pristine water quality until the recent introduction of industrial forestry and mining activities.

3.6.1 Hydrometric data needs

The WSC hydrometric station which has been serving this reach of the Skeena is under examination for need for the data and/or operations costs. With the expansion of roads and forestry operations into a largely undeveloped wilderness watershed, there is a need for ongoing hydrometric data from this station.

3.6.2 Interaction of forestry and water quality

In 1988 two Timber Licenses were awarded in the Sustut River drainage based upon rehabilitation of the abandoned BC Rail line and the construction of spur roads and loadouts along the upper Skeena River. Because of mountain pine beetle infestation, accelerated timber harvesting is now taking place in the Bear River and lower Sustut River watersheds. Forestry road construction and harvesting activities are entering the upper Skeena watershed from the south for the first time as well, with the construction of a bridge crossing of the Skeena near Kuldo Creek in 1995. Logging in the Sicintine drainage will follow.

3.6.3 *Interaction of mining and water quality*

A road paralleling the Sustut River connecting the ORAR and the BC Rail line has been proposed by the proponents of the Kemess South Mine. Road building along the proposed route is predicted to be difficult because of pockets of highly erodible glacial-lacustrine sediments, steep slopes, and difficult stream crossings along the proposed route.

3.6.4 Monitoring needs

3.6.4.1 Sediment yield monitoring

Water quality in the Sustut system can only be maintained through rigorous attention to avoidance of easily eroded soils and unstable slopes as detected through geotechnical assessment of road corridors and sediment yield hazard mapping. In order to adequately assess impacts, a detailed sediment monitoring program should be implemented.

3.6.4.2 Access management

A second requirement is that an access management plan be in place before and during road building and logging activities in order to protect both water quality and the wilderness qualities which make the Sustut a Class I River and a proposed PAS study area. Integral to the mine and road proposal should be a long-term access management plan for both the Sloane Connector Road and the ORAR within the Sustut watershed.

3.6.4.3 Long-term stream monitoring

The need for long-term stream monitoring in forest ecosystems in the Skeena watershed is discussed in detail in section 12. The upper Skeena presents an unusual opportunity for long-term monitoring of forestry and mining activities, in that forestry and mining activities will be occurring in many pristine drainages for the first time.

4. BABINE RIVER AND LAKE

Babine Lake is the largest natural lake in the province of British Columbia (Figure 4.1). It lies within the gently rolling Nechako Plateau physiographic region. The lake is a long (150 km), narrow body of water located at an elevation of 780 m. It has a surface area of 490 km^2, mean depth of 55 m, and a maximum depth of 186 m. The lake is divided into the north arm (45 km), main basin (65 km), south basin (45 km), and Morrison Arm (13.4 km). The Babine Lake watershed has an area of approximately 6,500 km^2. Four main tributaries, the Fulton, Morrison, Pinkut, and Sutherland Rivers drain 53 percent of the watershed. The rest of the watershed is drained by numerous small creeks, some with intermittent flows. Peak discharge from the tributaries occurs in May or June with the Fulton River contributing approximately half of the annual discharge to the lake. Babine Lake is usually ice-covered from late October to early May.

A short stretch of river joins the outlet on the north arm of Babine Lake with Nilkitkwa Lake (12 km). The Babine River flows northward from the Nilkitkwa Lake outlet before angling westward through the rugged Skeena Mountains to join the Skeena River. Major tributaries to the Babine River are the Nilkitkwa River, Nichyeskwa Creek, Shelagyote River and the Shedin River. The Babine River contributes approximately 15% of the mean annual flow to the Skeena at their junction (Levy and Hall 1985). The Babine River is recognized as a world class wilderness river for steelhead sport fishing and is classified as one of only six Class 1 angling streams in the province (see section 2.2.4). The Babine River corridor has been recommended to BC's Protected Areas Strategy as a candidate wilderness area.

4.1 HYDROLOGY

Several hydrometric gauge stations are located within the Babine drainage (Figure 4.1). Station 08EC001 Babine River at Babine (the lake outlet) was chosen for summary because it had the greatest number of records (period of record 49 years). A second station, Station 08EC0013, is located not far downstream of the first, on the Babine River at the outlet of Nilkitkwa Lake (period of record 20 years). A lake level recorder is located at Topley Landing (Station 08EC003). Active hydrometric stations are located on Pinkut Creek (Station 08EC004) and on the Morrison River at the outlet of Morrison Lake (Station 08EC008). Three stations on the Fulton River drainage have been discontinued.

WSC is undertaking a review and reduction of the hydrometric network. Three Babine watershed hydrometric stations may be subject to discontinuation if funding support from other agencies is not found; specifically Stations 08EC001, 08EC003 and 08EC004.

Monthly mean, maximum and minimum discharge for Station 08EC001, Babine River at Babine are shown in Table 4.1 and Figure 4.2. The annual low flows occur in February to April, with freshet occurring in May-June of most years. The 7 day average 10 year low flow for the Babine River at Babine Station 08EC001 is 7.53 m^3/s with 95% confidence limits of 4.39 and 10.50 m^3/s. The lowest recorded 7 day average flow for this station is 3.9 m^3/s, which occurred in 1951.

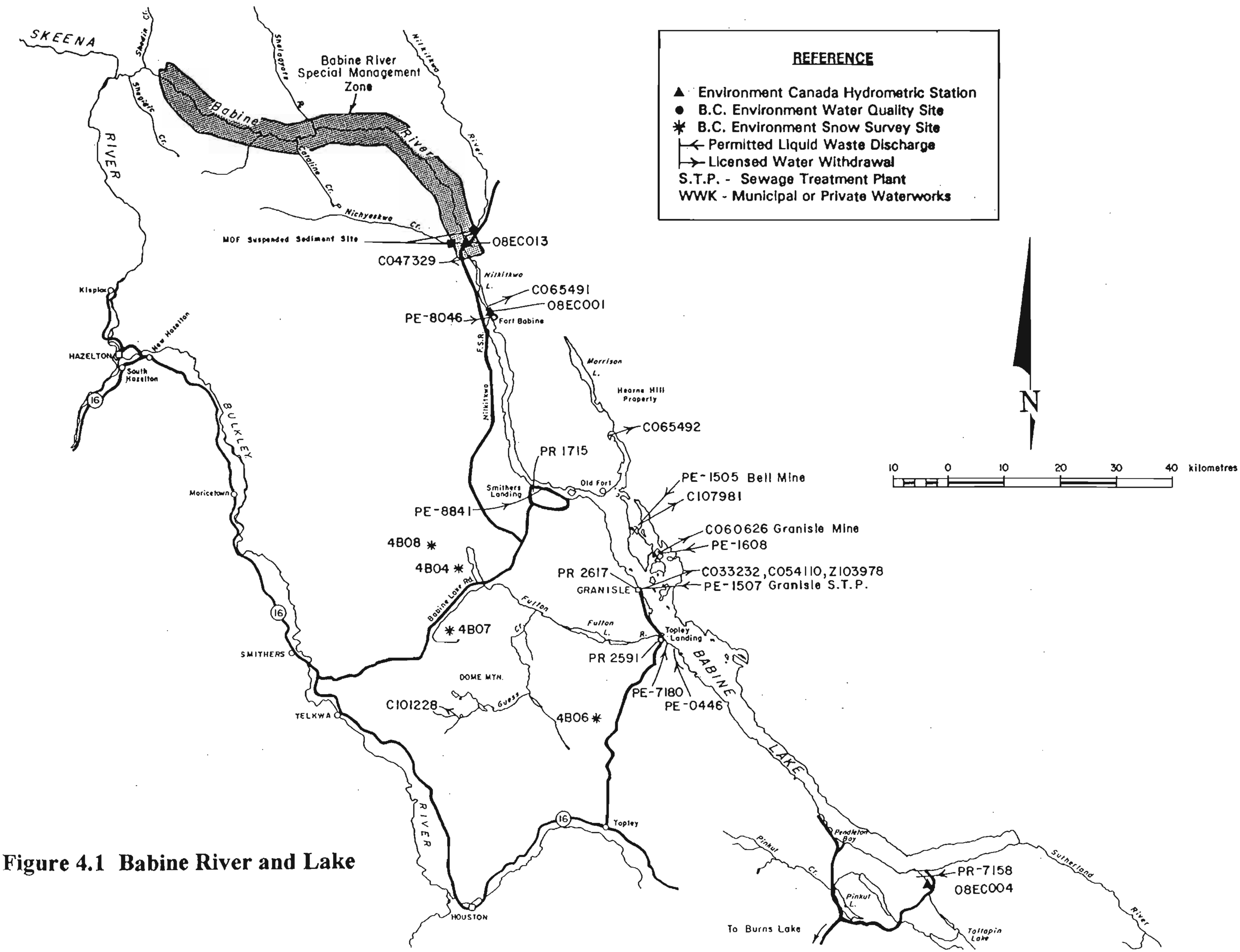


Figure 4.1 Babine River and Lake

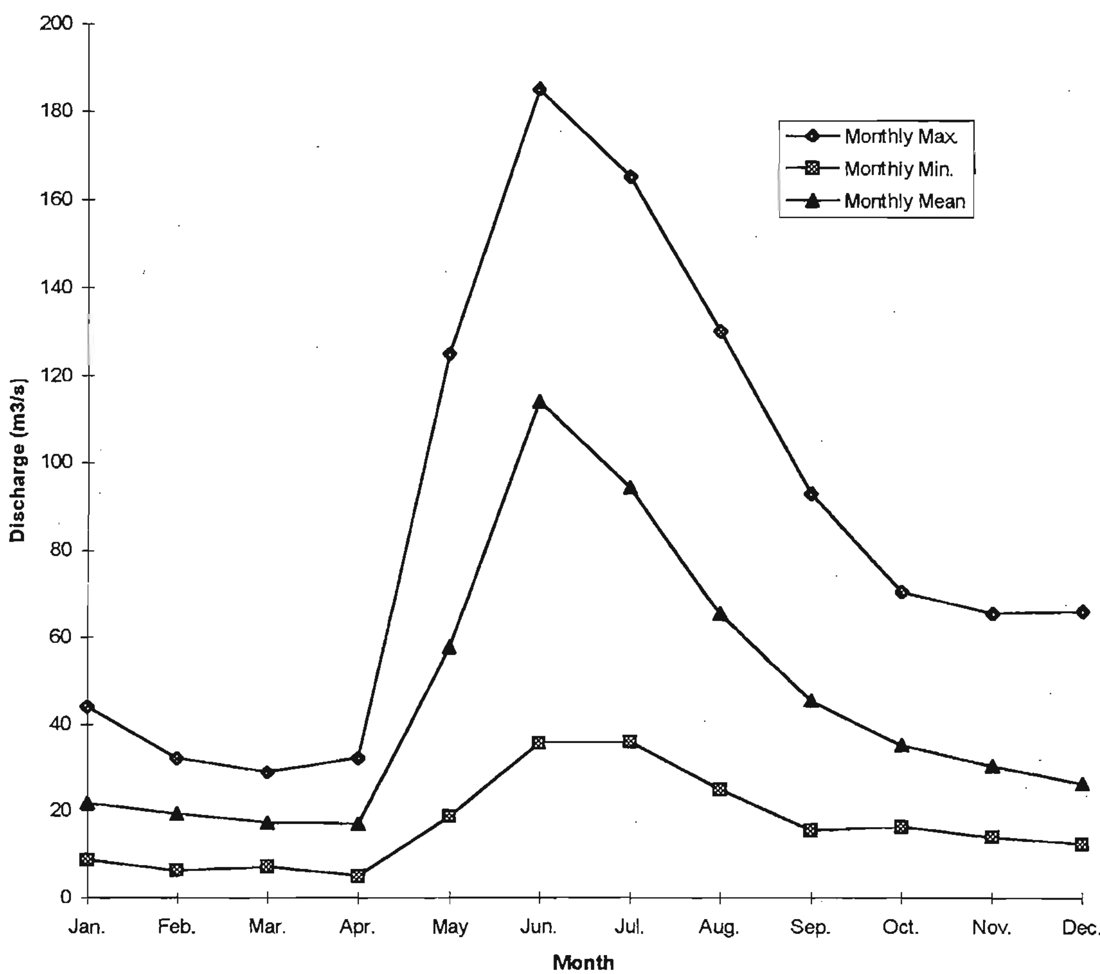
Table 4.1 Monthly discharge summary Babine River at Babine, Station 08EC001

Latitude: 55 19 25 N
Longitude: 126 37 40 W
Drainage Area Gross: 6 480 km2
Period of Record 1929-1930, 1944-1985

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	44.1	32.1	28.8	32.2	125	185	165	130	92.9	70.7	65.4	66.0
Monthly Min.	8.63	6.23	6.99	4.95	18.6	35.7	35.9	24.7	15.3	16.2	13.8	12.2
Monthly Mean	21.7	19.2	17.2	16.9	57.7	114	94.2	65.5	45.4	35.1	30.2	26.1

Average 7-day, 10-year low flow is 7.53 m3/s with 95% confidence limits of 4.39 and 10.5. (1945-1985)

Figure 4.2 Discharge envelope Babine River at Babine



4.2 LAND USE HISTORY

4.2.1 Settlements

At least four separate villages belonging to people of the Nat'oot'en First Nation (Carrier language group) were present on Babine Lake at first contact. The Gitksan village of Kisgegas was located near the confluence of the Babine River with the Skeena at this time. Kisgegas has been deserted since approximately 1949, its inhabitants having moved to Kispiox and Hazelton (Sturtevant 1990).

In the 1870's a pack trail crossing the Babine Range was a route to the Omineca gold fields via Babine Lake. In 1822 the Hudson's Bay Company constructed Fort Kilmaurs (now called Old Fort) between the Morrison and North arms of Babine Lake, which was also supplied by the Suskwa Pass trail. The site was chosen mainly because of the dependable and good fishing grounds at the start of the Babine River (Large 1957). The fort was later relocated to the east shore of the lake near its outlet.

This is the site of the present Nat'oot'en village of Fort Babine. The population of the Fort Babine Band is estimated to be 1357, however some band members live in Burns Lake. A smaller First Nations settlement is also found at Topley Landing.

The Granisle Copper Mine went into production in 1966 and the Township of Granisle was started, which became the main community of the lake. The Noranda-Bell Copper Mine went into production in 1971 and soon the expanded Granisle was incorporated into a Village. With the closure of the Bell mine the population of the village plummeted. The village is now endeavoring to develop a tourist trade and as a retirement community. The estimated population of Granisle was 646 in 1994.

Numerous recreational cottage leases line the shore of Babine Lake, mainly on the west side. There are several commercial sport fishing operations on the lake providing cabins, boat rentals and guided fishing (Regional District of Bulkley-Nechako 1980).

4.2.2 Sockeye enhancement facilities

Three artificial spawning channels (two in the Fulton River, completed in 1965 and 1971 and one in Pinkut Creek completed in 1968) have been established by the DFO to enhance sockeye stocks. In recent years, the catches of adult sockeye in the Skeena fishery have averaged about 0.75 million fish, with these Babine enhancement facilities producing a third of that catch (Levy and Hall 1985).

4.2.3 Forestry

In the mid-1930's a trail from Topley on the CNR line to Topley Landing on Babine Lake was upgraded to supply the fur trade and mining explorations in the area. By 1950 the logging industry had developed on Babine Lake with portable sawmills. By 1960 a permanent sawmill had been built at Michell Bay near Topley Landing. The sawmill at Michell Bay closed down and a new logging road to connect Michell Bay with Houston was constructed in the early 1970's.

4.2.3.1 Impact assessment of log handling in Babine Lake - 1983-1986

In the early 1980's a mountain pine beetle infestation occurred in the Morrison Arm region of Babine Lake. MOF decided that the area should be logged as soon as possible, by Houston Forest Products, in order to salvage the timber and arrest further spread. The logging plan called for the cut timber to be stored in the water before being transported in bundle-booms across the lake for processing in Houston. Since Babine Lake supports major fisheries, in particular for sockeye salmon, DFO and MOELP required that a study be undertaken of the log storage and transportation impacts on the fisheries.

Logs were dumped, bundled and stored in Morrison Arm throughout the winter by keeping the area open with an aerator. After ice-out, in early May, the bundles were towed in large booms down the arm and across the lake to the dewatering site south of Topley Landing. There the logs were stored in an open exposed bay before dewatering and transport by truck to Houston. In 1983 Northwood Pulp and Timber Ltd. was the only other company operating on the lake and it had been harvesting logs on the east side of the lake since 1971. Both their dump and dewatering sites were in shallow and fairly exposed bays of the main basin of the lake. An open channel was maintained across the lake all winter with a bubbler system to facilitate transportation of bundled logs. A number of historic log dump sites existed on Babine Lake and the largest of these, the old Mercury Logging dump, was located in the North Arm of the lake opposite Fort Babine.

The UBC Westwater Research Centre (Hall and others 1987) undertook a three year research program consisting of pre-impact environmental assessment, paired comparison of water quality conditions and fish utilization at several active and historical log handling sites, and a post-impact assessment of the log transportation sites after two years of forestry development. Conclusions of this study are summarized below:

- Log storage and handling in shallow, poorly mixed waters of the Morrison Arm dump site resulted in high BOD, and thus low oxygen levels, and a build-up of organic leachates, especially when the water rapidly stratified in the spring. A high number of filamentous bacteria developed where log leachates are available. High leachate concentrations and shading restricted the growth of phytoplankton.
- Log dumping and handling resulted in the deposition of wood and bark debris in shallow areas, especially those protected from the wind. A gelatinous slime developed on stored logs which had a high microbial activity and an oxygen demand similar to sewage sludge. This material sloughed from the logs and settled on the sediments smothering benthic invertebrates and depressing oxygen concentrations at the sediment/water interface.
- In Babine Lake, most benthos occurred in littoral areas, and relatively low numbers of organisms were obtained from deep sites. The benthic monitoring studies documented rapid and drastic reductions in benthic organisms, probably caused by the deposition of wood debris and gelatinous slime material. Population decreases may have been due to either physical impacts (smothering) or chemical impacts (sediment oxygen depletion). Log storage impacts on benthos were not found at historical storage sites, suggesting that recovery was complete within a 20 year period. Analysis of fish feeding habits suggested that several species fed partially (rainbow trout and cyprinids) or entirely (lake whitefish) on benthic invertebrates.

These fish species were therefore indirectly susceptible to log storage impacts on the benthos, at least during the active operating period of a log storage facility.

- Zooplankton populations were reduced in stratified surface waters of log handling sites where water circulation was restricted, resulting in increases in temperature, oxygen depletion and leachate build-up. At field concentrations, sublethal leachate effects on zooplankton were not detected by bioassays, but at elevated leachate concentrations reproductive rates did decline. Lowered reproductive rates may explain the reduction in zooplankton populations seen in experimental enclosures. Reduced zooplankton populations at log handling sites were reflected in reduced fry stomach fullness and numbers of prey in stomach contents of sockeye fry.
- Dissolved oxygen concentrations in the epilimnion of the Morrison Arm log dump were drastically reduced as a result of log storage, resulting in avoidance by juvenile sockeye. Although caged sockeye suffered 100% mortality in 15 minutes in the deoxygenated water, no obvious fish kills were observed. There was no avoidance of areas where logs were stored but where water exchange prevented water quality deterioration. There were increases in cyprinids and catostomids and decreases in resident salmonids at the log dump site where debris accumulated and destroyed the benthic invertebrate population and where low oxygen concentrations were measured in the epilimnetic waters. Changes in benthic invertebrates could indirectly affect the growth and survival of juvenile sockeye through impacts on their feeding success in the littoral habitat, but the spatial extent of these impacts was relatively small.
- The authors concluded that the degraded water quality at log handling sites deleteriously affected the food supply and feeding patterns of juvenile sockeye salmon fry. Fry avoidance of oxygen-depleted waters at the Morrison Arm log dump indicates a mechanism whereby the toxic effects of leachates and the reduced food supplies could be avoided. However, increased predation risk and/or energy expenditure as a result of avoidance behavior might increase the mortality rate of fry passing by log storage areas. The vulnerability of the wild Morrison River sockeye stock, in particular, was noted.

This and other similar research findings resulted in a gradual change in forestry practices from the former water-based log handling method to the present method of dryland storage and sorting, with transportation of loaded logging trucks by barge across the lake. A bubbler system now operates during winter to allow barge passage.

4.2.3.2 Stream protection practices

The Babine Lake and River watershed lies within four Timber Supply Areas: 1) the western two-thirds of the Babine River watershed are in the Kispiox TSA with timber transported to Hazelton; 2) the eastern one-third of the Babine River watershed (including the lower Nichyeskwa and all of the Nilkitkwa watersheds) are in the Bulkley TSA with timber transported to Smithers; 3) the drainages entering the northern half of Babine Lake, including Morrison Lake, are in the Morice TSA with timber transported to Houston; and 4) drainages into the southern half of Babine Lake are in the Lakes TSA with timber transported to Burns Lake.

Bulkley TSA.— Stream protection practices in the interior of the Prince Rupert Forest Region (Bustard and Wilford 1986) are reviewed in section 1.3.4. Bustard (1986*b*) conducted an assessment of stream protection practices in the Bulkley, Morice and Lakes TSAs using a combination of interviews and field inspections. He found that recent harvesting priorities had been directed at salvaging blowdown and beetle infested timber in the upper Fulton River area. The lack of site specific inventory in the upper Fulton watershed had made decisions concerning streamside treatment more difficult. Some areas have numerous small creeks transecting cutblocks, and one forester indicated that there were very few small creeks that did not get debris in them during logging operations. In a number of cases stream clean-ups had been required following falling or skidding in a small stream during winter logging.

Field inspections in the upper Fulton River indicated that the streamside treatments along the larger well-known fish streams were generally quite adequate. However one concern was that smaller side channels adjacent to the main river were logged across and their importance to fisheries may not be recognized. Treatment of the smaller fish streams was inconsistent. For example, some small streams were being both logged across and in some instances skidded down to landings, resulting in a loss of fish production capabilities due to stream blockage and diversion, bank damage and channel instability.

Road building and lack of road maintenance, particularly in the vicinity of culvert and bridge crossing, were identified as the main sources of sediment to streams. Extensive erosion resulting from logging operations in the McKendrick Pass area was noted and high sediment loads were reaching McKendrick Creek (a tributary to the upper Fulton).

The rate of cut in the Fulton drainage had been examined as well. Concerns in this watershed are for possible water quality effects (including nutrients) on the spawning channel downstream.

Morice TSA.— Bustard states that there are more sensitive fisheries sites in active logging areas in the Morice TSA than in other interior districts in the region. Potential water temperature changes following logging are considered an important problem in the lake-headed systems such as Morrison Creek, since this system already experiences high summer water temperatures.

There has been a shift away from total reserves along streams due to windthrow problems in the reserves that had been left. For example, a total reserve left on a tributary of Morrison Creek had suffered significant windthrow. Forest companies have gone back into these strips to remove the blowdown in subsequent years, and there is a concern that blowdown was serving as a breeding area for spruce bark beetle. As in other districts in the interior, there had been a shift towards the use of machine reserves. A machine reserve is a system of selective cutting along a stream in which leaning commercial trees and immatures are left within a stated distance of the stream and equipment operation is minimized in this strip.

Field examinations showed that careful measures to prevent erosion and streambank damage that were carried out at the streamside (measures that were usually quite effective in achieving objectives) were often offset by a lack of erosion control measures on roads, skid trails or fire guards. Road related erosion appeared to be most prevalent in the Morrison Creek area. The soils in this area are poorly-drained and difficult to work. The logging and road development has been concentrated in a highly sensitive area of low gradient streams, including several that drain directly into Morrison Creek.

Lakes TSA.— Major fisheries values in the active logging areas are located in sockeye and coho tributaries to Babine Lake such as Pierre, Twain, and Pinkut creeks. Bustard found that, in general, reserves of up to 50 m had generally been left along significant salmon spawning tributaries, depending on topography. DFO staff indicated that high water temperatures in some of the smaller tributaries to Babine Lake might be a concern, particularly in the low gradient swamp and lake-headed systems.

Lakeside logging is also a concern in the district. Historically, leave strips along lakes had suffered windthrow. Usually a 20 m machine-free reserve was requested along lakes, although there were examples where logging had been taken to the lakeshore with no reserve.

Field inspection revealed several examples of the difficulties involved in management prescriptions for streamside logging of tributary streams. At the first site, timber in a leave strip in a stable bedrock-controlled gully had blown down, and in some locations the upturned roots and fallen trees had blocked the stream channel. This setting was a fish stream but several miles upstream of the section used by salmon spawners.

At a second site, a large gully was winter-logged and wood was skidded to a landing part way down the gully and then trucked down a winter road located in the gully. This setting was several miles upstream from fish habitat. Post-treatment examination indicated that this treatment would not be appropriate in fish-bearing waters. The stream had cut a new channel throughout much of the gully, largely because of blockages caused by small debris. The new channel was unstable and would probably take years to stabilize.

A third example was a stream adjacent to the Pinkut Creek watershed with a resident fish population 1 km below the logging setting. Timber in the gully was directionally-felled and top-skidded out of the gully. Any wood that fell into the stream channel was left. Inspection of the stream channel indicated that they were virtually undisturbed by the operations.

In general, most soils in this portion of the watershed tend to be coarse-textured tills that make for relatively problem-free road building. However, several instances of gullying and lack of maintenance at culvert crossings which could lead to wash-outs of secondary roads in the future were cited.

4.2.3.3 Forestry planning

Babine River Corridor LRUP.— In 1988, plans were made to bridge the Babine River and increase access into the area for timber harvesting which conflicted with high fish and wildlife values, recreation and tourism. A planning process was established along with a steering committee and a technical advisory committee consisting of representatives from the forest industry, federal and provincial ministries, and conservation and tourism stakeholders. Their report outlined three land management and three access route alternatives for the river. In 1992, after considering the results of the public review and two open houses, a public review summary was released.

An assessment of the public comments resulted in the development of a LRUP and a Coordinated Access Management Plan for the Babine River watershed downstream of Nilkitkwa Lake. After more information was gathered, including grizzly bear habitat, recreational uses, and present sediment levels in Babine River tributaries, a draft Babine River Interim LRUP was released for public review in 1993. After further public review and revisions, the final plan became official in June 1994. The land management option chosen attempts to maintain wilderness qualities along the river by recommending a 14,000 hectare Babine River Corridor as a candidate wilderness area to PAS. In addition, a special management zone borders the corridor, while customary forest development is allowed outside the special management zone.

Monitoring.— One of the recommendations of the Babine River Corridor LRUP was the implementation of long term monitoring of forestry impacts on suspended sediment loadings in the upper Babine watershed. As a result, the Prince Rupert Forest Region Research Section has recently installed three automatic suspended sediment samplers (OBS meters): two on the Nilkitkwa River, one near the mouth and one at the road crossing approximately 50 km upstream; and one on the Nichyeskwa River near the mouth (Figure 4.1). Monitoring results from these samplers are not yet available, but this is planned to be a multi-year research study (Dave Maloney, Prince Rupert Forest Region, personal communication).

The Babine LRUP monitoring committee is collecting information on recreational visitor use of the area, compliance of forestry activities with the LRUP management prescriptions, and sedimentation in the Babine River and its tributaries (Hillcrest Recreation Consulting 1995, Quanstrom 1995). The monitoring program identified two road locations which were contributing sediment to streams during rainfall events and immediate remedial action was undertaken (D. Maloney, Prince Rupert Forest Region, personal communication). Preliminary recommendations resulting from the monitoring program were in three different areas: road construction, road maintenance and shutdown.

Kispiox LRMP.— Road access into western portions of the Babine watershed from the south-west (from the Hazeltons) is advancing. The Shedin Creek and Shelagyote River watersheds north of the Babine River remain unroaded, however a bridge crossing of the Babine near its confluence with the Skeena is in planning stages.

Section 3.2.3 discusses the Kispiox Forest District LRMP process, which has been ongoing since 1989. In June 1995, the Kispiox Consensus Management Direction received was approved by provincial cabinet. The Consensus Management Direction is currently being revised into an LRMP, reflecting recent forestry planning guidelines. The Kispiox LRMP states that management prescriptions for the Kispiox portion of the Babine planning area are to be followed as outlined in the Babine River Corridor LRUP.

Bulkley LRMP.— Active road development and logging is advancing into the Nilkitkwa, Nichyeskwa, and Babine River watersheds from the south-east as well. A bridge crossing of the Babine River is located near the end of Nilkitkwa Lake. Development into this area proceeded in 1994 with about 60 km of road constructed by REPAP Skeena Cellulose Inc. and West Fraser's Pacific Inland Resources of Smithers.

The Bulkley Valley Community Resources Board, formed in 1993, has reached a Consensus Management Direction for an LRMP for the Bulkley district, but is conducting an additional socio-economic study prior to release of the plan. The Community Resources Board had previously announced its agreement to following the Babine LRUP for management of the Babine River and its tributaries while noting that because the LRUP is a lower level plan, it is subordinate to the LRMP. At this time, the BV Community Resources Board has indicated agreement with full Protected Area status for the Babine Wilderness Corridor.

Morice LRMP.— The Morice TSA portion of the Babine watershed encompasses all of the drainages into Babine Lake south of Nilkitkwa Lake, including the Morrison Creek watershed (which drains into Morrison Arm). Most of the drainages flowing into the north half of Babine Lake have been developed for forestry since an industrial road was constructed in the early 1970's connecting Houston to Michell Bay near Topley Landing. There are presently two main companies operating in the drainages to the north half of Babine Lake: Northwood Pulp and Timber, and Houston Forest Products, both with sawmills located in Houston. A process to develop an LRMP for the Morice TSA is underway.

Lakes TSA.— The Lakes TSA occupies the southern half of the Babine Lake watershed, including Pinkut Creek and the Sutherland River. Road access is from Burns Lake north to Pendleton Bay. Babine Forest Products Company is the main operator in these drainages. Babine Forest Products operates a sawmill about 25 km east of Burns Lake. Because of fisheries and wildlife habitat concerns, the decision was made to access timber on the east side of Babine Lake by truck-barge crossing, rather than by road construction through the Sutherland River valley (see Sutherland Valley LRUP below). Decker Lake Forest Products, with a mill located about 20 kilometres west of Burns Lake currently has harvesting operations in the Pinkut Creek drainage.

Sutherland Valley LRUP.— The Sutherland River drainage, at the south end of Babine Lake, has very high fisheries and wildlife values and is an area of interest for PAS. For these reasons, a forestry access road proposed to cross the Sutherland River was opposed by MOELP, DFO, and other resource users. In 1992 a summer barge crossing of Babine Lake was approved as the access route to timber on the east side of the lake. Subsequently, the Sutherland Valley LRUP was completed and the watershed has been designated as a Special Management Area and, for the next 10 years, as a no-harvest area.

Lakes LRMP.— A process to develop a LRMP has been underway in the Lakes District since late 1993. A Lakes Resource Council of 21 people representing various community perspectives was formed in April 1994 to assist with planning. The Resource Council will make recommendations on approximately 216,000 hectares of the Lakes Timber Supply Area which were identified as candidate areas for protected area status in 1994. One of these areas is the Sutherland Valley deferral area.

4.2.4 Mining

Mining exploration has historically been active in the Babine Lake area. Exploration at the Hearne Hill copper/gold property east of Morrison Arm in 1995 will involve diamond drilling and geophysics. Access to this property is via existing logging roads.

Large scale copper mining began in the mid 1960's when Granisle Copper Ltd. operated an open pit mine on an island complex in Hagan Arm. Noranda Mines Ltd. bought out Granisle mines in 1980, and the mine closed in 1982 because of low copper prices. In late 1972, the Bell Copper Division of Noranda Mines opened a second mine on the Newman Peninsula a short distance from the Granisle property. The Bell mine also closed in 1982 but reopened in 1985. It is now also decommissioning, and closure plans for both mines are under review (see sections 4.5.1 and 4.5.2 for further discussion).

4.3 WATER WITHDRAWALS

A summary of licensed water withdrawals for Babine Lake and for its tributary streams is found in Table 4.2. The largest licensed water withdrawal is waterworks for the Village of Granisle (681 m^3/d). There are no water licenses on the Babine River. The total licensed water withdrawal from Babine Lake is 938.7 m^3/d (0.0109 m^3/s). The 7 day average 10 year low flow at the outlet of the lake is 7.53 m^3/s. The volume of water withdrawals from the lake itself appears insignificant. Water withdrawals from input streams cannot be evaluated without discharge data.

Table 4.2 Licensed water withdrawals Babine River and Lake

Input streams							
Domestic			Work camps & waterworks				
GD	m3/d	m3/s	License	Licensee	GD	m3/d	m3/s
(3 licenses)			C047329	Min. of Forests	2000	9.1	1.05E-04
2000	9.1	1.05E-04		Nilkitwa Forest Camp			
			C101228	Habsburg Resources Inc.	14000	63.6	7.37E-04
				Dome Mine			
Babine Lake							
Domestic			Work camps & waterworks				
GD	m3/d	m3/s	License	Licensee	GD	m3/d	m3/s
(1 license)			C060626	Maclaren Forest Products Inc.	12000	54.6	6.31E-04
1500	6.8	7.89E-05		Granisle Mine			
			C107981	Maclaren Forest Products Inc.	7500	34.1	3.95E-04
				Bell Mine			
			C065492	Houston Forest Products Co.	2500	11.4	1.32E-04
				Work Camp			
				Lake Babine Indian Band			
			C065491	Waterworks Babine I.R.	15000	68.2	7.89E-04
					GY	m3/d	m3/s
			C033232	Village of Granisle	18250000		
			C054110	Village of Granisle	36500000		
				total	54750000	681.9	7.89E-03

4.4 WATER QUALITY AND AQUATIC RESEARCH

4.4.1 Historical limnological research for Babine Lake

4.4.1.1 Water quality

A detailed review of limnology and sockeye salmon ecology of Babine Lake was prepared by Levy and Hall (1987). Rescan (1992*a*) also provides a review of historical environmental data of Babine Lake. A number of studies have been undertaken as the result of the high fisheries importance of this sockeye rearing lake, and the presence of two open pit copper mines on the lake (shown in Figures 4.1 and 4.3). Unfortunately, much of the early water quality data for metals is not entirely useful as baseline or background information since the minimum detectable concentrations (MDCs) in the 1960s and 1970s were too high. MDCs used in these studies were also often higher than the water quality criteria and guidelines for metals which are in use today.

Stockner and Shortreed (1976) state that Babine Lake is a dystrophic, oligotrophic lake. A dystrophic lake is one whose waters are stained by terrestrial organic matter entering the system from the surrounding drainage basin. An oligotrophic lake is characterized by waters that are low in nutrients, particularly phosphorus, and generally have low phytoplankton productivity.

The colour of Babine Lake water ranged between 10 and 28 mg Pt/L with different parts of the lake showing some seasonal variation. Differences in colour were correlated with proximity to major inflow streams which receive water from bogs and marshy areas in their watershed (for example Fulton and Morrison Rivers). The pH of Babine Lake waters was slightly basic (mean = 7.65). The alkalinity (range 36.2-37.0 mg/L $CaCO_3$) indicates that the waterbody has moderate pH buffering capacity. The lake generally has a very low level of suspended solids. Nutrient levels were generally low with the levels of some, particularly dissolved and total phosphorus, being at or below the detection limit.

In 1974 Stockner and Shortreed (1976) found concentrations of trace metals were generally low, being near or below the detection limit for cadmium, iron, lead and molybdenum. Metals levels in surface waters in the vicinity of Bell and Granisle mines were not significantly different from levels found at other stations in the Main Arm of the lake, with the exception that copper levels were higher (mean = 4.2 µg/L) than in the main body of the lake (mean = 2.3 µg/L). The water quality criterion for protection of aquatic life for copper, based on an average hardness of 37.4 mg/L $CaCO_3$, is 2 µg/L 30-day average and 5 µg/L maximum.

Subsequent follow-up studies in 1975 and 1976 (Stockner and Shortreed 1978) indicated that mean copper concentrations averaged across all Main Arm stations were slightly higher in 1975 (5 µg/L) and in 1976 (4.9 µg/L) than in 1974 (2.3 µg/L). Corresponding values for copper in the water near the Bell and Granisle minesites in 1975 and 1976 were 5.7 µg/L and 4.3 µg/L respectively. These values are about the same as those observed in 1974 (4.3 µg/L) and are within the range of values reported for the Main Arm of the lake for the same period.

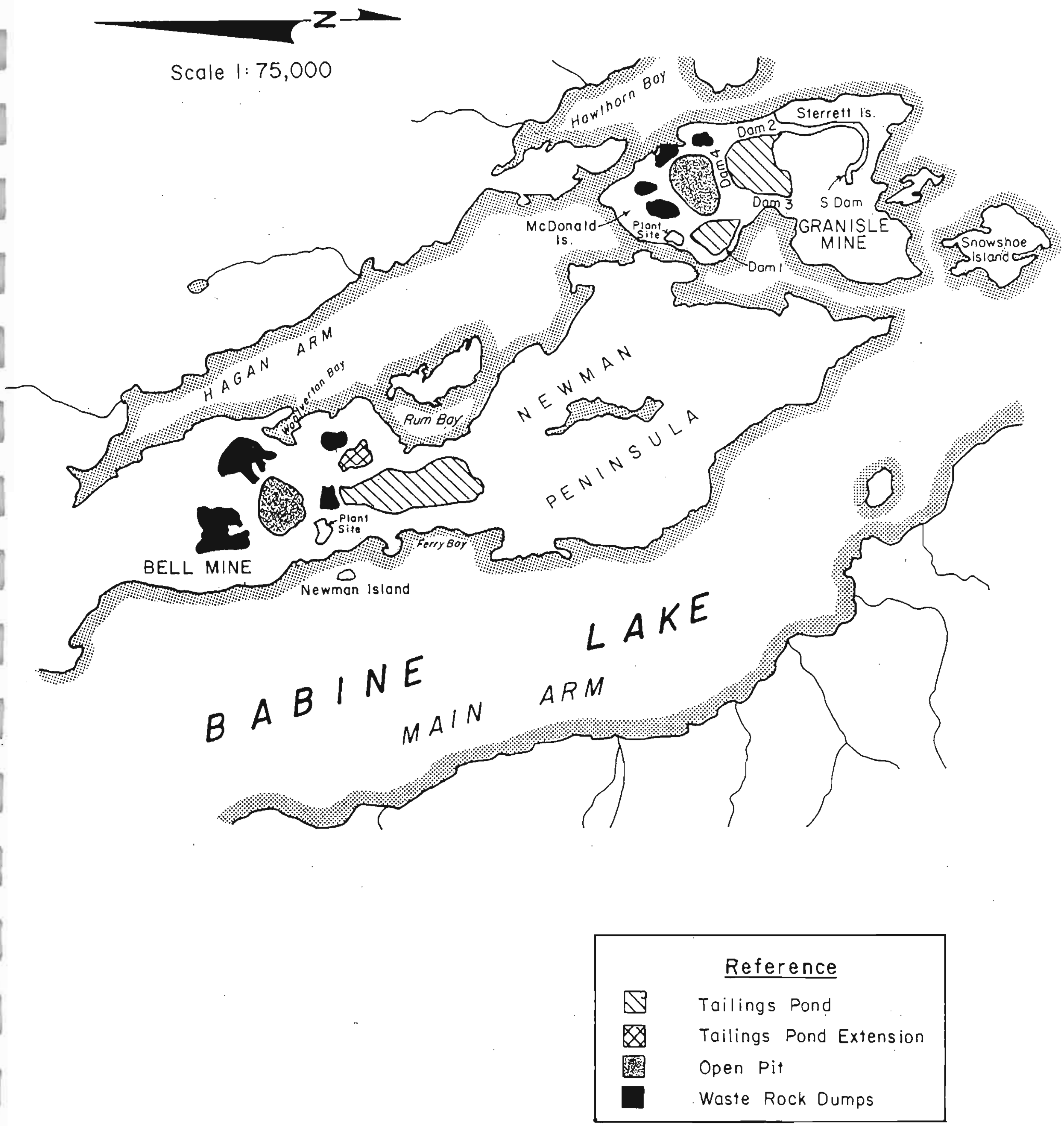


Figure 4.3 Main elements of Bell and Granisle Mines

Water quality monitoring in Hagan Arm in 1974 (Hallam 1975) found that concentrations of copper, iron and zinc were significantly higher in Hagan Arm than at sites near Granisle mine and Main Lake stations. Hallam reported average copper concentrations of 14 µg/L, zinc 34 µg/L and iron 200 µg/L for Hagan Arm.

Chau and Wong (1975) showed that Babine Lake waters have a high copper complexing capacity. This means that the organic matter in the lake waters has a high affinity for adsorbing copper ions. They found that the copper in water samples taken from the vicinity of the two mines was tightly bound to organic complexing molecules. They estimated that the copper complexing capacity of Babine Lake waters was about 100 µg/L.

Noranda Bell Mine conducted a monitoring program during January 1983 to monitor the effects of the discharge of tailings pond supernatant to Rum Bay in Hagan Arm. The data indicate that in general during the period of discharge, dissolved copper, sulphate and conductivity values were elevated throughout Rum Bay relative to the period when no discharge occurred.

In 1983-1984, the Environmental Protection Service (EPS) conducted a detailed study on the water quality of Babine Lake (both mid-lake and in close proximity to the Bell and Granisle mines) and in Hagan Arm (Godin and others 1985). The study concluded that alkalinity, conductivity, copper and zinc values in Rum Bay and Hagan Arm were higher than in the Main Lake.

A comparison of the data gathered in 1984 with the earlier data reported by Stockner and Shortreed (1976) and Hallam (1975) indicates that the water quality in Babine Lake in 1984 was not significantly different from that in 1974. However, slight but noticeable changes were evident in the water quality in the vicinity of the two mines, where conductivity, total residue, calcium and copper concentration were high in 1984 (41 µg/L near Bell and 7 µg/L near Granisle). Mean copper concentrations in Rum Bay and Hagan Arm were 13 µg/L.

EPS conducted monitoring again in 1990 (Godin and others 1992), which found similar copper values to those found in 1984. Copper concentrations at the Main Arm station averaged 5 µg/L, Hagan Arm 12.3 µg/L, Rum Bay 11 µg/L and a station east of Granisle Mine averaged 8.2 µg/L.

4.4.1.2 Sediment quality

In 1972, Stockner and Smith (1974, cited in Rescan 1992*a*) sampled sediments at ten sites in Babine Lake. Average sediment copper concentration north of the Fulton River was 66 µg/g, and south of the Fulton River was 34 µg/g. Surface layers of sediment from the core collected in Hagan Arm, approximately 300 m from the Granisle mine, contained high copper (230 µg/g) at 1 - 1.5 cm below the surface, which was attributed to mining activity. Sediments above this layer showed normal copper concentrations.

Hatfield (1989) conducted a study on sediments of Babine Lake and Hagan Arm. The data indicate that lake sediments at several locations in the nearshore zone on both the east and west side of Newman Peninsula contain much higher levels of copper relative to copper concentrations found by Stockner and Smith for the north half of the lake. Bottom sediments in other parts of

Hagan Arm, such as the deepest part of the basin around Granisle Mine, also exhibited elevated copper concentrations.

Sediment samples were also analyzed by Godin and others (1992), who found copper concentrations tended to be much higher in the top centimetre of sample. The maximum value was 1410 µg/g from Granisle Bay near an ARD seepage. Sediments collected in Rum Bay and Hagan Arm were not anomalous except for elevated copper. Sequential extractions were conducted on sediments from three stations near the mines (Hagan Arm, Rum Bay and Granisle Bay). Sequential extraction gives an indication of the biological availability of a metal. The amount present in the exchangeable and carbonate fractions is considered more easily taken up by organisms. The three sediment samples evaluated by sequential extractions to determine the bioavailability of heavy metals present were also tested for chronic effects to aquatic insects using the *Chironomus tentans* emergence test. *C. tentans* is a representative of the group of insects known as midges, which have a wide distribution during their larval stages of development in freshwater sediments, and are therefore a useful bioassay test species. It was found that deep sub-basin stations in the Main Arm, Rum Bay and Hagan Arm showed chronic toxicity, indicated by delayed fly emergence, while the sample from near an acid mine seep at Granisle Bay showed acute toxicity. At this station, high levels of exchangeable aluminum, copper and/or zinc could have been responsible for the toxicity.

4.4.1.3 Fish toxicology

Concerns over the presence of the two copper mines stimulated research into the potential toxicological effects of copper and zinc on Babine Lake sockeye. Davis and Shand (1978) found no acute toxicity at copper concentrations within the range of those found in ambient Babine Lake waters. Their study found that the 96 hr LC50 values obtained for sockeye salmon fry, fingerlings and smolts exposed to dissolved copper in lake water ranged between 210 -240 µg/L. It was concluded that the present low levels of copper in the lake (4 - 44 µg/L), coupled with the considerable complexing capacity of the water pose no acute threat to Babine sockeye. Osmoregulatory capability in Babine sockeye smolts was also tested. These studies suggested that the threshold total copper concentration which might disrupt osmoregulatory capability in Babine stocks was in the range of 109-154 µg/L copper.

4.4.2 Productivity of Skeena watershed sockeye nursery lakes, 1994

Monthly limnological surveys were carried out by DFO at four locations down the length of Babine Lake May-October 1994 as part of a survey of selected Skeena sockeye nursery lakes (see section 1.3.5.2). Preliminary water quality data from this project are found in Table 4.3. Babine was the most productive of the five lakes studied, with a daily photosynthetic rate far exceeding the others. A direct comparison of primary productivity, as photosynthetic rate, with previous measurements (Stockner and Shortreed 1976) is not possible because of differing methodologies. However, preliminary data indicate that primary productivity has increased slightly since 1973 (K. Shortreed personal communication). Possible explanations for an increase in productivity are the increase in logging in the watershed and the increased sockeye density due to the enhancement facilities.

Table 4.3 Babine Lake water quality and productivity May-October 1994 (mean epilimnetic concentrations)

Date	Temp °C	pH	Secchi depth m	Euphotic zone depth m	TDS mg/L	Total alkalinity mg CaCO3/L	Total P ug P/L	Nitrate ug N/L	Total Chlorophyll ug/L	Photosyn-thetic rate mg C/m2/d
15-May-94	4.9	7.58	5.8	7.5	59	36.54	6.0	74.2	0.85	65.4
18-Jun-94	11.2	7.65	4.2	6.5	59	36.70	6.5	40.0	1.91	117.3
16-Jul-94	15.0	7.47	5.1	7.8	61	35.04	5.7	30.3	2.16	179.3
20-Aug-94	18.0	7.50	5.8	7.0	59	37.27	4.0	15.4	1.80	153.8
10-Sep-94	14.7	7.19	6.1	6.8	63	37.60	5.0	28.3	1.75	155.4
4-Oct-94	11.1	7.18	6.0	7.2	66	37.72	5.0	31.4	2.29	164.3

4.5 LIQUID WASTE DISCHARGES

4.5.1 Granisle Mine PE-1608

4.5.1.1 Background

Granisle Mine is located on McDonald, Sterrett and Snowshoe Islands in Babine Lake about 5 km north-east of the Village of Granisle (Figure 4.3). Construction of the mine and a 4,500 tonne per day mill started in 1965 followed by production start-up in 1966. The discovery of additional reserves allowed expansion of the pit and increased mill throughput at a rate of 12,000 tonnes per day in 1973. In 1979 Noranda acquired and operated the Granisle Mine until June 1982 when poor economics forced closure.

The Granisle Mine open pit, located on McDonald Island, measures 1020 meters east-west by 780 meters north-south and is approximately 225 meters in depth from the highest crest to the pit floor. Tailings Ponds No. 1 and No. 2 were constructed partially in the lake channel between McDonald and Sterrett Islands. The No. 1 Tailings Pond, located south-west of the open pit, was used until 1972. The No. 2 Tailings Pond, located south of the pit, was operational from 1972 until operations concluded in 1982. The construction of a third tailings pond was started with mine rock being deposited along the east side and south shore of Sterrett Island. This extra storage capacity was not required and subsequent development limited. Three low grade stockpiles are located west, north-west and east of the pit and two small rock dumps are located to the north and north-east of the pit (Noranda 1993).

4.5.1.2 Permitted discharge

According the permit the authorized rate of effluent discharge is an annual average of 4,100 m^3/day and a maximum of 5,500 m^3/day. Effluent is discharged to the land and is virtually left untreated except for sanitary waste.

The characteristics are described as typical mine pit drainage, sanitary waste treated by septic tank and disposal field, runoff and tailings pond seepage. There are no permitted discharge parameters.

4.5.1.3 Receiving environment monitoring

There are seven sites specified in the permit for quarterly sampling of TSS, pH, SO_4, Cu(d), Fe(d) and Zn(d). Of the seven sites 4 are effluent and 3 are receiving environment as follows:

STNA - Babine Lake Control Station
STNC - Babine Lake immediately offshore from Tailings Dam No. 2
STND - Babine Lake immediately offshore adjacent to the settling pond
STNE - Settling Pond supernatant
STNF - Pit Water
STNG - Tailings Pond No. 2 Supernatant
STNH - Run-off from Crushing Plant area.

STNC and STND require one composite to be prepared from samples to be taken at three locations at three different depths.

Key water quality parameters, 1980 to 1993 for three receiving environment sites are found in Table 4.4. There is no indication in this dataset that dissolved copper concentrations have been affected in the vicinity of Granisle Mine. Because only dissolved copper data was collected, these data cannot be compared to the historic total copper concentrations referred to in section 4.4.1. It is interesting to note that at STNC, immediately offshore from Tailings Dam No. 2, sulphate concentrations appear elevated relative to the control STNA, but dissolved copper concentrations are not.

Table 4.4 Summary of Babine Lake water quality Granisle Mine PE-1608, 1980-1993

Location	Parameter	Mean	Max	Min	S.D.	N
STNA	pH	7.38	7.9	6.7	0.27	47
	Cu(d) mg/L	0.007	0.03	0.001	0.01	52
	SO4 mg/L	10.4	67	1	12.3	52
STNC	pH	7.41	8.3	6.9	0.28	46
	Cu(d) mg/L	0.005	0.04	<0.001	0.01	51
	SO4 mg/L	18.04	111	1	25.2	50
STND	pH	7.42	8.1	6.9	0.27	46
	Cu(d) mg/L	0.005	0.03	<0.001	0.004	51
	SO4 mg/L	11.1	97	1	15.4	50

The most recently available data, collected in 1993 from the mine runoff and pit water as well as the receiving environment stations in Babine Lake, are found in Table 4.5. Very high dissolved copper, zinc and sulphate concentrations are found in the open pit waters, and elevated concentrations are found in tailings pond supernatant and runoff from the plant area.

Table 4.5 Effluent and Babine Lake water quality Granisle Mine PE-1608, 1993

LOCATION	DATE	pH	TSS	Cu(d)	Zn (d)	Fe(d)	SO4
STNA	01/26/93	7.6	3	0.027	0.009	<0.030	4.9
	06/16/93	7.7	1	<0.001	<0.005	<0.030	5.9
	08/02/93	7.5		0.004	<0.005	<0.030	6.2
	10/12/93	8.1	<1	0.006	<0.005	<0.030	8.1
STNC	01/26/93	7.6	1	0.007	0.007	<0.030	6.6
	06/16/93	7.7	2	0.006	<0.005	<0.030	7.4
	08/02/93	7.3		0.009	<0.005	<0.030	6
	10/12/93	6.3	<1	0.008	<0.005	<0.030	5.5
STND	01/26/93	7.5	<1	0.003	0.006	<0.030	5.6
	06/16/93	7.7	<1	0.006	<0.005	<0.030	8.7
	08/02/93	6.7		0.005	<0.005	<0.030	6.7
	10/12/93	7.9	1	0.008	<0.005	<0.030	5.4
STNE	01/26/93			0.043	0.006	<0.030	
	01/27/93	7.3	<5	0.043	<0.005	<0.030	21
	03/23/93	7.1	<5	0.029	<0.005	<0.030	22
	04/20/93	7.3	<5	<0.005	<0.005	<0.030	<5.0
	06/26/93	7.8	<5	0.061	0.008	<0.030	41
	07/19/93	8.3	<5	0.057	0.009	<0.030	59
	08/27/93	7.8	<5	0.021	<0.005	<0.030	56
	10/03/93	6.8	<5	0.041	0.005	<0.030	101
STNF	01/26/93			0.245	0.191	<0.030	
	01/27/93	7.8	<5	0.281	0.215	<0.030	2097
	03/23/93	7.2	<5	0.338	0.059	<0.030	482
	04/20/93	7	<5	0.041	0.006	<0.030	108
	06/26/93	8.1	<5	0.225	0.195	0.04	2095
	07/19/93	8.1	<5	0.234	0.163	<0.030	2088
	08/27/93	7.3	<5	0.256	0.203	<0.030	2248
	10/03/93	6.8	<5	0.239	0.227	<0.030	2286
STNG	01/26/93			0.003	0.005	<0.030	
	01/27/93	7.9	22	0.009	<0.005	<0.030	1481
	03/23/93	7	6	<0.005	<0.005	<0.030	54
	04/20/93	7.2	10	<0.005	0.006	<0.030	671
	06/26/93	9.8	<5	0.02	0.006	<0.030	1022
	07/19/93	9.1	<5	0.009	<0.005	<0.030	998
	08/27/93	7.7	21	0.018	<0.005	<0.030	1063
	10/12/93	7.1	11	0.006	0.007	<0.030	1044
STNH	03/23/93	6.7	6	0.009	0.03	<0.030	198
	04/20/93	7.7	8	0.086	0.08	<0.030	965
	06/26/93	8	7	0.066	0.1	<0.030	1188
	07/19/93	8.1	<5	0.065	0.089	<0.030	1697
	08/27/93	7.7	18	0.029	0.1	<0.030	1160
	10/03/93	7.7	10	0.06	0.045	<0.030	1127

4.5.1.4 Granisle Mine Closure Plan

As partial fulfillment of reclamation permit M-6, an evaluation of ARD potential at Granisle Mine has been prepared (SRK 1994). The tailings impoundments were formed by constructing five embankments of mine rock on and between the two islands. Additional mine rock, that was not used in the construction of the embankments, was deposited in rock piles located to the north and north-east of the pit. Mine rock was also used as grading fill at the mill site and as road construction material. Low grade ore was stockpiled to the north west and to the east of the pit. In the later years of operation, the mine rock was also used to construct the initial access for a proposed tailings pond expansion.

The results of the field and laboratory testing combined with mathematical simulations, indicate that there is a potential for acid generation, and associated copper loadings, from all the mine rock piles on the Granisle minesite. The distribution and configuration of the geochemical units within the dam structures determine the drainage water quality, to some extent mitigating localized ARD production. ARD and dissolved copper loading from the site is further mitigated by the release of alkalinity from the stored tailings. As a consequence, acidity is neutralized, and a high proportion of the copper leached from the mine rock is precipitated on site within the rock piles and embankments as a secondary mineral phase.

The largest contributors of copper leaching from the site in the next 100 years are predicted to be Dams 3 and 5, on the west side of the tailings impoundment. The main causes of higher copper loadings appear to be relatively thin layers of reactive material in the causeway and the safety berm, an area which experiences only a limited release of alkalinity from the tailings.

The predictions indicate that the peak ARD loading from the minesite into the lake has already occurred. The predicted copper loading either enters Babine Lake directly, passes beneath the embankments into the lake, or flows overland to the shoreline. The estimated copper loading to Babine Lake peaked in the range of 6,000 to 11,000 kg/year in the late 1970's, then has declined to the range of 3,000 to 6,000 kg/year at present. The copper loading from the minesite is predicted to decline to a level below 2,000 kg/year by about the year 2200 and continue to diminish with time.

Further calculations indicate that the pit will take about 130 years to fill. The pit lake is predicted to remain near neutral in pH for a relatively long period before a decrease in the pH of the pit water would be observed. When the pit has filled, the copper concentration in the discharge from the pit is predicted to be about 10 mg/L.

There have been no NWMDRC comments from this report or the closure plan to date and review is ongoing. See section 4.6 for review and discussion.

4.5.2 Noranda Minerals Inc. Bell Mine PE-1505

4.5.2.1 Background

The Bell Mine is an open pit copper mine located on Newman Peninsula, Babine Lake (Figure 4.3). Operations began in 1970 with overburden and ore cover (cap rock) pre-stripping and the construction of the plant, roads and dams. Milling started in 1972, processing an average of

9,100 tonnes per day. Production was gradually increased to 15,500 tonnes per day by 1981 but, due to deteriorating market conditions, operation ceased by October of 1982. Limited pre-stripping took place between 1983 and 1985 and the mine reopened in 1985 at a milling rate of 15,500 tonnes per day. The Bell Mine operations were concluded in March 1992 when available ore was exhausted.

The pit was developed on slightly sloping ground near the center of Newman Peninsula with the plant located south west of the pit on the flattest ground in the area. Rock dumps were located to the north, east and south of the pit. The tailings impoundment was constructed to the south of the pit around an elongated depression that formerly contained Workburn Lake. Originally six saddle dams were constructed between rock ridges to enclose and deepen this area. In 1981, work began east of the tailings pond to construct two additional dams. These dams enclosed an area between the original dam and a rock ridge that would form the East Tailings Expansion area (Noranda 1993).

4.5.2.2 Permitted discharge

The water management system at Bell Mine utilized the Tailing Storage Facility for water storage and treatment. All flows which contained elevated metals were collected and directed to the tailing facility. As of 1993 all discharges are being directed to the open pit for long term storage except CP 3 which goes to the tailings pond. Treatment for discharge from the tailings pond is through natural attenuation. CP 8 discharges overland directly to lake. Bell mine has submitted a permit amendment application which proposes that all flows which meet permit requirements be diverted for direct discharge to the lake in order to conserve long term storage space.

EPP Permit PE-1505, amended March 8 1992, allows a maximum of 69,300 m^3/day of effluent to be discharged to the tailings impoundment. The characteristics of the effluent are described as combined treated sewage effluent and typical copper ore concentrator tailings, recycled tailings pond seepage, acid mine drainage, mine sump water and truck wash effluent associated with a bulk explosive storage compound. The treatment facilities include an extended aeration package sewage treatment plant and lime addition facilities throughout the mill process.

The maximum authorized discharge of tailings impoundment supernatant to Rum Bay in Hagan Arm of Babine Lake is 9,000 m^3/day with an annual maximum volume of 1,000,000 m^3. The permit stipulates the characteristics of the effluent shall be equivalent to or better than:

TSS	25 mg/L	Zn(d)	0.20 mg/L
pH	6.5-8.5	LC50	100%
Cu(t)	0.60 mg/L	BOD5	20 mg/L
Cu(d)	0.05 mg/L	Nitrite/Nitrate	10 mg/L as N
Fe(d)	0.30 mg/L	Total Hydrocarbons	5.00 mg/L.

During 1993, 928,246 m^3 of tailings pond supernatant was discharged to Rum Bay (Noranda 1993). Effluent quality of discharges which took place during the periods of April 26 - May 10 and June 10 - September 18, 1993 (Table 4.6) remained within the permit requirements.

Table 4.6 Effluent quality Bell Mine tailings pond decant discharge to Rum Bay PE-1505, 1993

	pH	TSS mg/L	Cu(d) mg/L	Cu(t) mg/L	Fe(d) mg/L	Zn(d) mg/L	BOD5 mg/L	NO2 mg/L	NO3 mg/L	LC50 %
Permit Max	6.5-8.5	25	0.05	0.6	0.3	0.2	20	10	10	100
Date										
3/15/93	8.5	3	0.008	0.008	0.03	<0.005	<5	0.012	0.476	100
4/29/93	8	<1	0.034	0.042	<0.03	0.043		0.012	0.123	
6/5/93	8.1	<1	0.025	0.054	<0.03	0.029		<0.001	0.054	
6/16/93	8.4	1	0.022	0.022	<0.03	0.018	<5	<0.001	0.005	
6/27/93	8.4	4	0.01	0.023	<0.03	0.013		<0.001	0.005	
7/10/93	8.3	<1	0.004	0.006	<0.03	0.008	<5	0.001	0.011	
7/18/93	8.3	<1	0.007	0.007	<0.03	0.005		<0.001	0.005	
7/23/93	8.3	<1	0.005	0.007	<0.03	0.006		<0.001	0.005	
8/3/93	7.7	4	0.037	0.065	<0.03	0.005		<0.001	0.005	
8/9/93	7.9	<1	0.039	0.039	<0.03	0.013		<0.001	0.005	
8/19/93	7.9	3	0.017	0.028	<0.03	0.017		<0.001	0.005	
8/24/93	8.1	<1	0.019	0.031	<0.03	0.014		<0.001	0.005	
9/3/93	7.8	1	0.005	0.005	<0.03	<0.005		<0.001	0.005	
9/12/93	8.1	9	0.007	0.016	<0.03	<0.005		<0.001	0.005	
11/6/93	7.9	12	0.007	0.009	<0.03	<0.005	<5	<0.001	0.005	

4.5.2.3 Receiving environment monitoring

Water quality.— A brief summary of limnological data gathered over the last two decades in Babine Lake is found in section 4.4.1. Further monitoring was conducted in 1991-1992 for closure planning (Rescan 1992*b*). Total copper concentrations averaged 4 µg/L at the Main Arm station, and 5 µg/L in Morrison Arm (chosen as a second control site). These data agree well with historical data for this area of Babine Lake. 1991-1992 copper concentrations nearshore to the western side of Newman peninsula in the vicinity of Bell Mine averaged less than 4 µg/L. The near-shore stations in 1991-1992 showed a lower copper concentration compared to those observed in 1984 (14 µg/L to 47.5 µg/L) which may be attributable to seepage control measures initiated by the Bell Mine in the mid-1980's.

Average copper levels were slightly higher in Hagan Arm (5.8 µg/L) than in the main body of Babine Lake but remained largely unchanged relative to conditions reported in 1974 and 1984. The authors state that it is conceivable that copper may have been historically elevated in Hagan Arm waters due to the high level of mineralization in the area and the poor water exchange of Hagan Arm waters with the main lake. All other metals were present at levels similar to those found in the main lake. A comparison of water quality in Hagan Arm to Morrison Arm reveals that total copper concentrations are similar, while sulphate and dissolved copper concentrations are slightly higher in Hagan Arm.

The copper complexing capacity of Babine Lake was estimated to be 60 µg/L in 1992. This is similar to the complexing capacity estimated previously at 100 µg/L. The complexing capacity is largely attributed to the presence of dissolved organic constituents in the lake, which significantly ameliorate the toxicity of metals in solution.

Sediment quality.— Elevated copper and iron concentrations in lake sediment samples have been documented in Woolverton Bay, Black Spruce Swamp Bay and adjacent to the outfall in Rum

Bay, all in Hagan Arm. The bottom sediments in Rum Bay, in the vicinity of tailing water discharge, exhibited copper concentrations of approximately 740 µg/g relative to background concentrations up to 120 µg/g.

High copper concentrations (2,670 µg/L) observed at localized areas in Woolverton Bay are believe to be the result of seepage from the A-Frame waste rock dump prior to collection. Aluminum and iron are also elevated at this nearshore site. Dissolved copper concentrations in the near-surface pore waters from cores collected in Woolverton Bay were at least two-fold higher than levels measured in the core-top (supernatant water), indicating copper is being released to pore solution near the sediment-water interface. Diffusive flux estimates presented in the Closure Plan suggest, given a residence time of water in Woolverton Bay of approximately 30 days, that a steady-state benthic efflux of copper from the sediments could add about 3 µg/L of dissolved copper to the Woolverton Bay waters.

In the main arm of Babine Lake elevated copper concentrations in lake bottom sediments have been observed in localized areas near the freshwater intake west of the plant site and Ferry Bay south of the Bell Mine east dock. The enrichment areas identified appear to be the result of the mine drainage except for some sediments located at the base of steep shoreline cliffs believed to be caused by natural erosion.

Lake biology.— Mean chlorophyll *a* measurements, which represent an estimate of phytoplankton biomass, at four sites in the Main Arm and three sites in Hagan Arm were essentially identical. (Section 4.4.2 discusses recent DFO sampling which indicates that Babine Lake primary productivity may have increased slightly since 1973).

Densities and species composition of zooplankton in Hagan Arm were similar to those in the main arm of Babine Lake, with the exception that the cladoceran *Daphnia rosea* appeared in far greater numbers in the vicinity of the discharge outfall in Rum Bay than at any of the other sites sampled.

Since zooplankton are consumed by predators, they play an important role in the cycling of metals through higher trophic levels, for example fish. Zooplankton tissue analyses for metals indicated that generally the lowest tissue metal levels were observed in the Main Arm, intermediate levels were found at the entrance and center of Hagan Arm, while the highest levels were observed in the vicinity of the outfall in Rum Bay. For example, zooplankton tissue mean concentrations of copper were 33.5, 59.5 and 105.0 mg/kg from Main Arm, Hagan Arm, and Rum Bay, respectively. Zooplankton tissue concentrations of arsenic, cadmium, copper, iron, lead, manganese, mercury and zinc were all higher in the vicinity of the outfall to Rum Bay. The recent metal data suggested a reduction in tissue metals had taken place since sampling by Godin and others (1985).

The benthic invertebrate data which has been collected from Babine Lake in the vicinity of Bell and Granisle Mines by both Hatfield (1989) and Rescan (1992*b*) indicates relatively low benthic numbers and diversity reflecting both the oligotrophic nature of the lake and effects of elevated metal concentrations. Benthic communities were predominantly comprised of facultative fauna, those benthic organisms that may persist in relatively poor as well as good water quality conditions. The balance of the benthic invertebrate community composition was largely tolerant taxa which are known to dominate communities affected by habitat degradation.

Fish.— Kokanee (the non-anadromous form of sockeye), rainbow trout, lake trout, lake whitefish and burbot were captured and analyzed for muscle and liver metals levels. Rescan states that tissue metal levels in the musculature of fish sampled from Babine Lake were within the range reported for fish in unpolluted waters in British Columbia and Canada. Fish livers were analyzed for metal concentrations and metallothionein. Metal concentrations of cadmium, copper and zinc in fish liver tissues from both the Main Arm and Hagan Arm were higher relative to data reported for all fish, except burbot, in unpolluted waters. Liver tissue levels of copper at all locations were up to 12 times greater (range 144 - 336 mg/kg-wet wt.) than the levels reported for livers of fish from unpolluted waters (1.5 - 18.0 mg/kg-wet wt.).

Metallothionein analyses was conducted on liver tissues from four lake trout and three burbot (these being the longest living of the species captured). Mean metallothionein concentration in lake trout was 5320.29 μg/g, and mean concentration for burbot was 2456.7 μg/g. All fish sampled for metallothionein analyses appeared healthy upon capture.

4.5.2.4 Bell Mine Closure Plan

In 1992 Noranda submitted a Closure Plan for the Bell Mine (illustrated in Figure 4.4) to the Northwest Mine Development Review Committee (NWMDRC). Geochemical analysis of mine rock from the site demonstrated that portions of the mine rock which were used in dam construction and were placed in rock dumps on the site are potentially capable of generating net acidity. Some samples were shown to be already generating net acidity. Although portions of the rocks were found to be capable of neutralizing a significant amount of acidity, there is insufficient excess neutralization potential to offset the cumulative acid potential in the rock.

Portions of the older and fresh tailings were shown potentially capable of net acid generation as well. However, no acidic water has ever been reported within the impoundment indicating that neutralization potential remains available within the tailings area.

Further kinetic testwork was used to produce a prediction of water chemistry at the site in the future. All of the mine rock dumps, as well as some of the tailings dams and plant site, are predicted to produce net acidity in drainage waters within the next 5 to 35 years. The predicted time from the start of net acid generation to complete depletion of the sulphide content of the rock is from 20 to 80 years. The areas, representative collection ponds, predicted year of acid generation and sulphide depletion and predicted water chemistry during sulphide oxidation with acid neutralization (pH = 7.0) and at full neutralization potential depletion are summarized in Table 4.7. Following full sulphide depletion, extremely high dissolved copper, zinc and iron concentrations in very acidic drainage waters are predicted. Modeling indicates that acidic water is not expected to seep from the tailings mass.

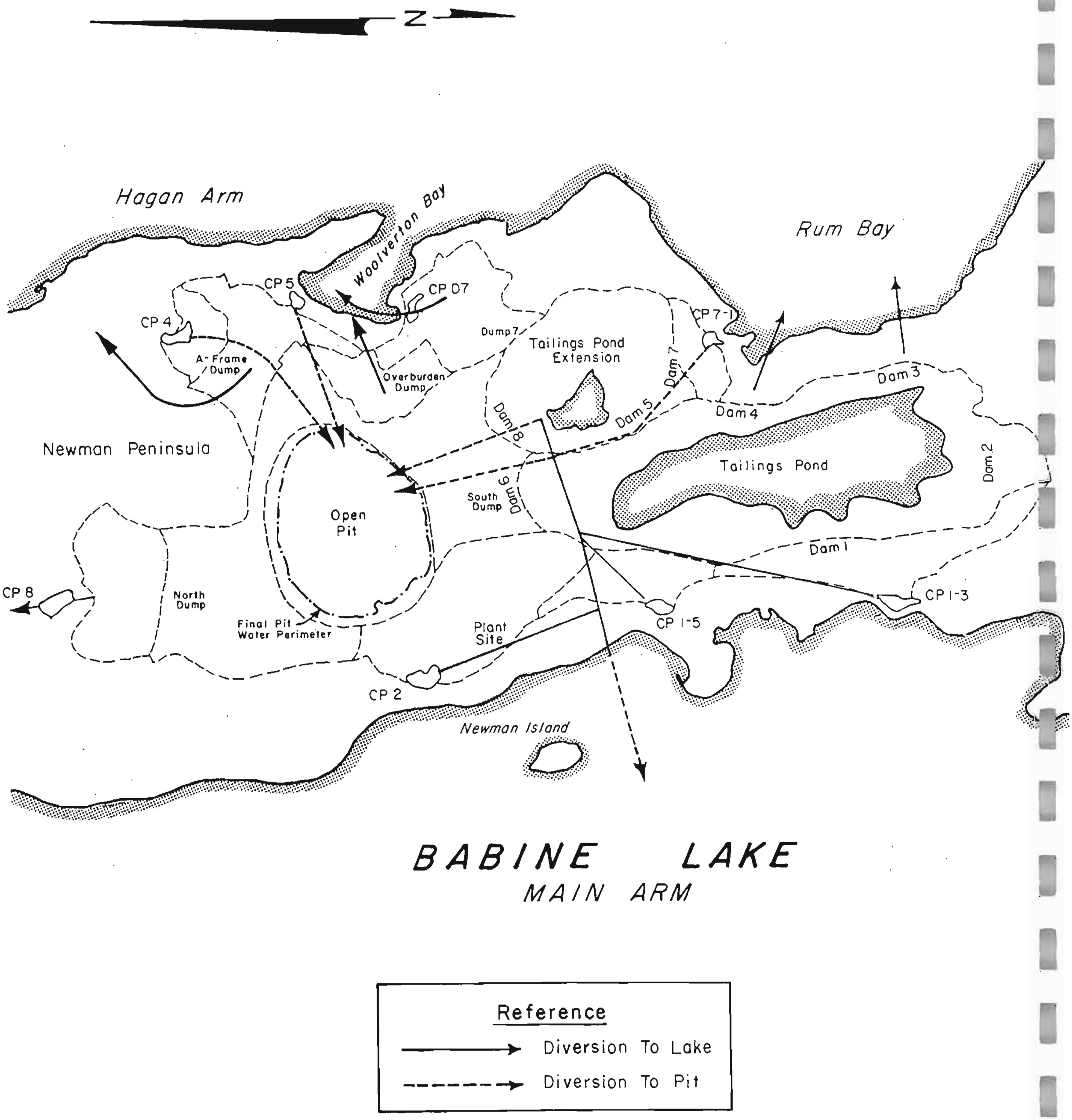


Figure 4.4 Schematic of proposed Bell Mine water collection areas and discharges (adapted from Noranda Minerals Inc. Bell 92 Closure Plan)

Table 4.7 Predicted acid generation and water chemistry at Bell Mine PE-1505

Rock Dump or Dam (Collection Pond)	Volume of Material m3 (millions)	Predictions for Acid Generation (year)	Predictions for Sulphide Depletion (year)	*	pH	Cu(d) mg/L	Fe(d) mg/L	Zn(d) mg/L
North Dump (CP 8)	6	2020	2100	a	7.0	<0.01	<0.03	<0.01
				b	7.0	0.2	0.08	0.06
				c	2.5	800	500	5.0
Dump 7 (CP D7)	6	2020	2040	a	7.0	<.0.5	<0.03	<0.01
				b	7.0	0.2	0.8	0.06
				c	2.5	800	500	5
A-Frame (CP 4, CP 5)	4.5	2000	2070	b	6.3	8	<0.03	0.07
				c	2.5	800	500	5
Dam 1 & 2 (CP1-3, CP1-5)	16.8	2010	2060	a	7.6	0.2	<0.03	5
				b	7.0	0.2	0.08	0.4
				c	2.5	800	500	0.06
South Dump Plant Site (CP 2)	8.5	2010	2060	a	7.0	4.0	<0.03	0.4
				b	7.0	0.2	0.08	0.06
				c	2.5	800	500	5
Dam 3 & 4	1.4	2030	2060	a	7.8	<0.02	<0.03	<0.01
				b	7.0	0.2	0.08	0.06
Tailings	49	2000		a	7.0	<0.01	<0.03	<0.01

Source: Noranda 1992

* a = Measured in 1992
b = Predicted at pH = 7.0
c = At full Neutralization Potential Depletion

The closure plan proposes to divert as much drainage water as possible into Babine Lake as long as the water meets discharge quality criteria. If and when the discharge exceeds the criteria for discharge, they will be diverted to the open pit. The closure plan proposes that collection ponds CP 2, CP 1-3 and CP 1-5 will be combined into a single outfall and discharged at depth in Babine Lake. Conversely, due to existing good water quality, collection ponds CP 8, CP D7, CP 4-1 and CP 3-1 will be discharged at surface into Hagan Arm. Runoff with unacceptable water quality will be directed to the open pit.

The water quality criteria proposed in the Closure Plan for discharge to Hagan Arm and the Main Arm of Babine Lake, at surface and at depth, are shown in Table 4.8. These proposed criteria for discharge are 2 to 20 times higher than the currently permitted discharge limits for dissolved copper of 0.05 mg/L.

Compilation of the flows and loadings indicates the pit will fill to maximum design capacity by about year 2050. The pit water is predicted to reach steady values of pH 2.7 and 2.200 mg $CaCO_3$/L by the year 2060. Water treatment of pit effluent will be required prior to discharge via a submerged outfall into Babine Lake.

Table 4.8 Proposed dissolved copper criteria for discharge to Hagan Arm and Main Arm Babine Lake PE-1505

Discharge	Discharge Criteria Concentration (mg/L)
SURFACE DISCHARGE TO HAGAN ARM	
CP 3-1	0.3
CP 4-1	0.3
CP D7	0.1
CP 8	0.1
SUBMERGED DISCHARGE INTO HAGAN ARM AND MAIN ARM	
Tailings Pond Water	1.0
CP 2, CP 1-3, CP 1-5	1.0
CP D7	1.0

A complex model of the proposed discharges in terms of contaminant dispersion and receiving water flushing was carried out for the Main Arm deep water discharge. Modeling of the proposed shoreline discharges to the surface waters of Hagan Arm predicted that the mixing areas for Woolverton Bay and the head of Hagan Arm were less than 8,000 m^2 per site. Modeling indicated that the dissolved copper concentration of these discharges should not exceed those values listed in Table 4.8 in order that the dilution zone concentrations do not exceed the upper limit of observed background concentrations (9.0 µg/L). Similarly, worst-case dissolved aluminum in the seepage pond discharges should not exceed those values in order that the dilution zone concentrations remain within the 30-day average MOELP aquatic life guideline of 50.0 µg/L. The projected worst-case dissolved zinc concentrations were calculated to remain below the 30.0 µg Zn/L (tentative) MOELP criteria for the protection of aquatic life.

4.5.2.5 NW Mine Development Review Committee comments

EPP - Engineering Section:

In general EPP - Engineering found that the plan demonstrates a low potential for contamination from tailings, dams and waste dumps via groundwater to Babine Lake and that, for the most part, the water management plan addresses the capture of surface mine waters and provides contingencies for handling water which does not meet discharge criteria.

Issues which need further attention include:

- further review of estimates regarding the time to net acid generation and time to sulphide depletion;
- development of groundwater monitoring programs; and
- clarification of discharge criteria and contingencies for collection ponds, diversion structures and the pit.

EPP - Environmental Impact Section:

The Environmental Impact Section raised numerous technical concerns related to the assessment of impacts of mine discharges to the aquatic environment of Babine Lake;

however, they note that all of these concerns appear technically resolvable. Due to the significance of the fisheries resources of the lake, EPP recommends a conservative approach to the review of the Closure Plan.

Key concerns to be addressed regarding impacts to Babine Lake include:
- projection of future changes through the use of benthic invertebrate diversity index interpretations combined with sediment chemistry;
- the need for additional toxicity studies on the lake;
- the need for an independent assessment of the mathematical dilution and dispersion models used for determining proposed maximum metals discharge concentrations;
- the need for further assessment of uncertainties in the review of metals accumulation in lake sediments;
- the need for comparison of metal loadings for the periods of mine operation versus mine closure, in order to accurately assess impact predictions and acceptable discharge criteria;
- the need for further consideration of proposed deep water discharge, based on productivity of shallow versus deep waters;
- development of post closure environmental effects monitoring programs, to include biotic health as well as water quality;
- the need to address uncertainties, in spite of the EPP-Engineering review, regarding potential for groundwater contamination of the lake; and
- further review of the assessment of water quality trends in Babine Lake, which is considered flawed.

Department of Fisheries and Oceans:

Although the impacts of mining on Babine Lake fisheries are uncertain, DFO has found biological indicators which suggest that fishery resources in the lake are experiencing some stress. In general, therefore, DFO agree with MOELP that a conservative approach should be taken in determining acceptable levels of discharge to the lake.

The following issues need to be resolved with respect to the Closure Plan:
- the need for a series of toxicity tests to determine maximum acceptable concentrations of metals in mine discharges;
- further investigation of the most suitable discharge location and depth;
- development of specific monitoring objectives and sampling programs; and
- further discussion of long-term water management and treatment options.

Environment Canada - Conservation and Protection:

Environment Canada has generally endorsed proposed plans to discharge contaminated flows to the pit, divert other flows to Babine Lake, reclaim the surface of the land, and to treat pit waters in the future for discharge.

Based on data presented, as well as an independent analysis of humidity cell results, the Environment Canada reviewer found evidence to suggest that, with the possible exception of the A-Frame waste dump, Bell waste rock has a high degree of chemical "inertia", or a resistance to ARD production.

These comments were followed up with a discussion of percolation theory, which again suggests that Bell waste rock will not cause accelerating ARD if the dumps are treated through normal reclamation practices of re-contouring, till covers and revegetation.

With respect to tailings ARD potential, Environment Canada agrees with the Closure Plan position that the acid front should become immobile in the tailings mass within a few decades.

At the end of 1995 the Bell Mine Closure Plan was still under review. See section 4.6 for review and monitoring recommendations.

4.5.3 Village of Granisle - PE-1507

4.5.3.1 Background

Prior to 1970, Granisle Copper Ltd. operated a 2 cell lagoon system for the townsite of Granisle. In 1970, with plans of a new mine north of Granisle, the Village was prompted to submit a permit application to the Pollution Control Branch. A permit was issued on February 28, 1972 and subsequently amended on February 3, 1989. The population increased from 350 to 1700 during the period from 1971 to 1979. The Village of Granisle population peaked at around 2000 during operation of the mine and then decreased to about 600 when Bell mine closed in 1992.

4.5.3.2 Permitted discharge

The permit is for the discharge of treated domestic sewage to Babine Lake. The works authorized are an activated sludge treatment plant, chlorination facilities, polishing lagoon, sludge lagoon and outfall. The outfall length and depth are 150 m and 2.8 m respectively.

Permit PE-1507 authorizes a maximum discharge rate of 546 m^3/day with characteristics equivalent to or better than 25 mg/L BOD and 25 mg/L TSS. The monitoring required includes a monthly effluent grab sample analyzed for BOD, TSS and fecal coliforms as well as a daily record of effluent flow rates.

Summary data for 1972 to 1994 are shown in Table 4.9. Since 1984, on average, effluent quality has remained within permit limits, with occasional exceedances. The operation of the chlorination facilities showed great improvement in the 1992-1994 period.

Data available for 1994 shows that BOD was exceeded once (38 mg/L) and TSS was exceeded once (26 mg/L). Fecal coliforms were generally <10 MPN/100 mL and flows remained well below the permit limit of 546 m^3/day.

An application to amend the permit filed by the Village of Granisle on March 21, 1994 requests an increase in permit limits from 25/25 to 45/60 mg/L BOD/TSS. This request is a result of occasional non-compliance with the current permit. The higher permit limits are in line with the Pollution Control Objectives.

Table 4.9 Effluent quality summary Village of Granisle sewage treatment plant PE-1507, 1972-1994

Year	BOD mg/L			TSS mg/L			Fecal Coliform MPN		
	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.
1972 - 77	34.0	<10	74	40	9	16			
1978	41.0	26	60	35	12	82			
1979	36.0	17	63	33	19	62			
1984	12.6	10	32	7	1	20	10.0	10	10
1985	12.6	10	20	13	2	64	12.9	10	45
1986	11.7	10	17	13	2	48	13.6	10	30
1987	17.6	5	55	12	1	32	81.8	10	800
1988	7.6	5	11	8	1	38	12.7	10	40
1989	13.7	5	24	10	5	16	12.1	7	26
1990	15.5	<5	39	15.6	7	26	30.3	<2	180
1991	13.3	<5	33	5.3	<1	13	8.6	<2	10
1992	8.1	<5	14	7.3	2	26	10.0	<10	<10
1993	13.1	<5	33	8.1	1	29	10.0	<10	<10
1994	17.6	<10	38	11.1	4	26	10.0	<10	<10

4.5.3.3 Receiving environment monitoring

There has been no receiving environment monitoring to date in the vicinity of the sewage treatment plant.

4.5.3.4 Granisle community water system

As a result of potential waterborne illness within the Village of Granisle during the month of March 1991, an investigation was conducted of the village water system by Ministry of Health (G. Anderson, Northern Interior Health Unit, letter on file EP-1507). A malfunction of the chlorination system was found to be the problem, which was subsequently rectified. Inspection of the system revealed that the sewage outfall discharges into the lake a few hundred meters from the water intake, which is located in shallow water. Typical fecal coliform counts per 100 mL of discharge effluent are 10, however elevated fecal coliform counts have been documented. A dye test of the sewage outfall indicated that the lake current flows in the direction from the outfall (west) toward the community water intake (east).

Recommendations included: location of the water intake into deeper water further from the sewage outfall; improvements to the chlorination and distribution system; and increased monitoring frequency of fecal coliform organisms at the sewage systems outfall.

4.5.3.5 Discussion

In general biological treatment appears to be good at the Granisle STP and discharge rate is fairly low with the present reduced population base. However this is a direct discharge to valuable nearshore fish habitat and no assessment of potential toxicity to fish has been carried out. Ammonia and nitrite are parameters of concern because of toxicity to fish and other aquatic organisms. Dechlorination has not been required under PE-1507, although chlorine is known to be highly toxic to fish. It is suggested that residual chlorine (monthly) and rainbow trout LC50 toxicity (quarterly) be added to the monitoring requirements for this plant.

4.5.4 Fort Babine Enterprise Society PE-8046

4.5.4.1 Background

Fort Babine Enterprises Society was formed in 1986 to represent the economic development interests of the Village of Fort Babine, whose residents are part of the Babine Lake Band. One of the Society's proposed projects was the development of a fishing/camping resort on government leased land across Babine Lake from the Village of Fort Babine. After exploring several treatment options, it was decided that treated sewage would be discharged to the lake on a continuous basis. Permit PE-8046 was issued on October 24, 1990 to authorize this discharge.

The resort is located on the north arm of Babine Lake, approximately 1.5 km south of where the lake flows into the Babine River. The short section of river between Babine and Nilkitkwa lakes is known as "Rainbow Alley" because of its excellent rainbow trout sport fishing. The resort is operational from May 1 to October 31 every year with not more than one or two people living on site during the winter months. During peak operating periods it is estimated that a maximum of 34 m^3/d of treated effluent will be discharged to the lake.

4.5.4.2 Permitted discharge

Permit PE-8046 authorizes a maximum discharge rate of 34 m^3/day with effluent characteristics equivalent to or better than 45 mg/L BOD, 60 mg/L TSS and 400 CFU/100 mL fecal coliforms. The works authorized are two facultative lagoons, a chlorination/dechlorination lagoon, chlorination works, an outfall pipe and related appurtenances. Sampling is to be carried out quarterly for BOD and TSS, and monthly for fecal coliforms. A record of daily average and maximum number of persons staying at the resort over each month of operation must be maintained.

The EPP technical report for permit PE-8046 states that due to the extreme toxicity of chlorine to fish, the applicant has requested that a disinfection requirement initially be waived as long as fecal coliform levels are below 400 CFU/100 mL. This request is reflected in the current permit. Also stated in the technical report is the following:

> The size of the discharge is relatively small, and after a minimum 240 days retention in the facultative lagoons it is expected that the BOD and suspended solids in the discharge will be much lower than the 45 mg/L and 60 mg/L, respectively, required by the Municipal Objectives for discharges to fresh water. Even if chemical disinfection is required at some point in the future, as long as the sewage is thoroughly dechlorinated prior to lake disposal, this discharge is expected to have no direct impact on the fisheries resource in the vicinity.

4.5.4.3 Receiving environment monitoring

To date there has been no monitoring data submitted by the permittee and no receiving environment data is on file.

4.5.5 Campbell's Babine Lodge PE-7180

4.5.5.1 Background

At the time of permit application in 1984 the resort, then known as Kidner Lodge, had already been operating for at least 18 years. The resort consists of a lodge, 2 trailers, 6 cabins and 20 recreational vehicle campsites located at Topley Landing. The original sewage treatment system consisted of a septic tank and a tile field. The tile field had been failing for many years and the surfacing effluent had been running into Babine Lake. With an expansion of the facilities, the sewage treatment works were upgraded in 1984 with the installation of a rotating biodisc system, chlorination facilities and an outfall.

According to the EPP technical report for permit PE-7180, dated May 16 1984, this is a relatively small discharge to Babine Lake, and it is not expected to have an environmental impact. The only concern in this case is that the discharge may pose a potential health threat, and for this reason it is recommended that the applicant be required to chlorinate during the high tourist season, from June 1 to September 15. During the balance of the year the resort is normally occupied by 2 or 3 people. Due to the sensitivity of the ecosystem supported by Babine Lake, DFO has requested that any chlorination of sewage be followed by dechlorination prior to discharge to the lake.

4.5.5.2 Permitted discharge

Sewage is treated in a package treatment plant, followed by chlorination and dechlorination and discharged via outfall to Babine Lake. The permit states the outfall length to be 122 m. The maximum authorized rate of discharge is 25 m^3/day with characteristics equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The permit requires grab sampling twice per year for TSS, BOD, chlorine residual and fecal coliforms. A record of the daily average and maximum number of persons staying at the resort over each month of operation must also be maintained. To date no monitoring data has been submitted.

Two grab samples of the effluent have been taken by EPP, one in 1986 and one in 1987. The data are shown in Table 4.10.

Table 4.10 Effluent discharge to Babine Lake Campbell's Babine Lodge PE-7180, 1986 - 1987

Date	pH	TSS mg/L	Spec. Cond. uS/cm	BOD mg/L	Fecal Coliforms MPN/100 mL
86/06/03	6.8	9	248	<10	
87/02/16	6.8	15	580	<10	<20000

4.5.5.3 Receiving environment monitoring

An investigation of sewage discharges to Babine Lake at Topley Landing was carried out by EPP July 16-18, 1990.

The investigators report that the lake bottom is quite shallow at this site out to a ledge well offshore, beyond which it drops off into deep water. Using the depth sounder, the approximate end of the sewage discharge pipe appeared to be in 5-6 metres of water. According to Mr.

Kidner, the discharge is 15 metres offshore, which would put it in 2 metres of water. Sample sites were the sewage discharge, tap water from the lodge and four sites along the shoreline (Tables 4.11 and 4.12).

Table 4.11 Fecal coliform concentrations in discharge, tap water, and Babine Lake Campbell's Babine Lodge PE-7180, July 16-18, 1990

Fecal coliforms MPN/100mL						
Date	Discharge	Site 1	Site 2	Site 3	Site 4	Tap Water
90/07/16	29700	<2	<2	3	<2	<2
90/07/17	21000	11	2	2	7	2
90/07/18	87000	8	8	<2	5	<2

Table 4.12 BOD and nutrient concentrations in discharge and Babine Lake Campbell's Babine Lodge PE-7180, July 16-18, 1990

	Discharge			Site 1		Site 2		Site 3	Site 4
mg/L unless stated	7/16/90	7/17/90	7/18/90	7/16/90	7/18/90	7/16/90	7/18/90	7/16/90	7/16/90
Spec. Cond. uS/cm	400	320	330	72	75	78	71	78	77
BOD	16	12	11						
T.Org. Nitrogen	3.74	2.4	2.48	0.35	0.22	0.26	0.24	0.28	0.3
T. Kjel. Nitrogen	8.64	4.38	4.68	0.35	0.24	0.27	0.25	0.29	0.31
T. Nitrogen	19.4	18.4	17.5	0.4	0.29	0.32	0.29	0.34	0.36
Ammonia (N)	4.9	1.98	2.2	0.005	0.015	0.01	0.012	0.008	0.01
NO3+NO2 (N)	10.8	14	12.8	0.05	0.05	0.05	0.04	0.05	0.05
Ort. Dis-Phosphorus	4.4	6.2	3.4	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
T. Diss. Phosphorus	4.4			0.004		0.004		0.007	0.003

This limited dataset indicates that chlorination/dechlorination was not being carried out during the sampling period, as fecal coliform concentrations were very high in the discharge. The samplers state that the flow through this system is minimal, however, and there is no detectable impact on the lakeshore or tap water quality. The permit requirements for BOD and TSS were not exceeded. The other parameters are well within the criteria for the protection of aquatic life.

4.5.6 Coyote Lodge and Marina PE-446

4.5.6.1 Background

Permit PE-446 was first issued on November 26, 1971 and amended on April 1, 1981 and August 4, 1987. The most recent amendment on April 28, 1992 reflects the change in ownership and name from Totem Lodge and Marina to Coyote Lodge and Marina. Coyote Lodge and Marina consists of a mobile home park and resort located at Topley Landing. Although the chlorination/dechlorination system has been installed since 1987, there have been numerous incidents where dechlorination chemicals have run out.

Permit PE-446 authorizes a maximum discharge rate of 45 m^3/day with characteristics equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The works authorized are an extended aeration type secondary treatment plant, chlorination/dechlorination systems and an outfall which terminates at least 150 meters into Babine Lake. Grab sampling is required twice per year for TSS, BOD and fecal coliforms. A record of the daily average and maximum number of persons staying at the resort over each month of operation must also be maintained.

Effluent quality, 1992-1994, is within permit limits and fecal coliform concentrations are low (Table 4.13). The average number of people staying at the lodge during July, August and September 1993 are as follows: July - 29 people/day, August - 24 people/day and September - 7 people per/day. Peak months are July, August and September with 5-6 people staying at the resort for the remainder of the year.

Table 4.13 Effluent discharge to Babine Lake Coyote Lodge & Marina PE-446, 1992-1994

Date	TSS mg/L	BOD mg/L	Fecal Coliforms MPN/100 mL
92/07/06	7	37	<1
92/08/31	8	11	<1
93/07/26	3	4	8
93/09/28	18	16	<1
94/07/27	26	6	<1
94/09/02	19	6	4

4.5.6.2 Receiving environment monitoring

There is no receiving environment monitoring required by the permit. However, monitoring data collected by EPP on July 16-18, 1990 (at the same time as Campbell's Lodge) are found in Tables 4.14 and 4.15. The investigators noted the following:

> Coyote Lodge, PE-446, has an activated sludge sewage treatment plant. The outfall is approximately 155 m off shore, and was estimated using a depth sounder to be about 2 metres deep. It was observed on July 16, 17 and 18 that there were chlorination chemicals deployed in the sewage treatment facility, but that there were no dechlorination chemicals. Using a Hach chlorine kit, total and free chlorine were measured in the dechlorination chamber prior to the release of the effluent to the lake. On July 16, total chlorine was measured at 0.13 mg/L, free chlorine was measured at 0.05 mg/L. On July 18, total chlorine was 0.2 mg/L and free chlorine was 0.14 mg/L. This indicates the dechlorination chamber was not working at all. At the time of the investigation the flow in the activated sludge facility was small. There is no flow meter or sampling point downstream from the treatment facility.

The discharge was shown to be within permit limits for TSS and BOD, and fecal coliform concentrations were low in the discharge and lakeshore samples taken in July 1990. However, the permit specifies dechlorination, which was not being implemented at the time of the investigation. There are no data on resulting chlorine concentrations in lakeshore water. The maximum criterion for protection of aquatic life is 0.1 mg/L total residual chlorine because of chlorine's toxicity to fish.

Table 4.14 Fecal coliform concentrations in discharge and Babine Lake Coyote Lodge & Marina PE-446, July 16-18, 1990

	Fecal coliforms MPN/100 mL			
Date	Discharge	Site 1	Site 2	Site 3
90/07/16		3	9	4
90/07/17	4			
90/07/18	122	5	2	

Table 4.15 Babine Lake water quality in vicinity of Coyote Lodge & Marina discharge PE-446, July 16-18, 1990

	Site 1		Site 2		Site 3
mg/L except conductance	16-Jul-90	18-Jul-90	16-Jul-90	18-Jul-90	16-Jul-90
Spec. Cond. uS/cm	73	68	70	69	72
T.Org. Nitrogen	0.31	0.24	0.3	0.26	0.29
T. Kjel. Nitrogen	0.32	0.25	0.31	0.27	0.3
T. Nitrogen	0.36	0.28	0.35	0.3	0.34
Ammonia (N)	0.01	0.008	0.012	0.013	0.011
NO3+NO2 (N)	0.04	0.03	0.04	0.03	0.04
Ort. Dis-Phosphorus	<0.003	<0.003	<0.003	<0.003	<0.003
T. Diss. Phosphorus	0.004		0.005		0.005

4.5.7 Tukii Lodge PE-8841

4.5.7.1 Background

Tukii Lodge, which consists of a restaurant, manager dwelling, cabins and campsites, is located at Smithers Landing. A permit was issued on June 28, 1993 for the discharge of effluent from Tukii Lodge to Babine Lake.

4.5.7.2 Permitted discharge

The maximum rate of discharge authorized is 18 m^3/day with an average of 8 m^3/day. Discharge may occur at intervals of not less than 4 days and at an average of once in every 10 days. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The works authorized are a facultative lagoon system, chlorination system, dechlorination pond and an outfall which terminates at least 230 feet into Babine lake.

There has been no sampling carried out to date due to the fact that there has been no positive discharge from the lagoon. Once discharge commences the monitoring requirements are as follows:

Immediately upstream of the dechlorination pond - chlorine residual mg/L

Immediately downstream of the dechlorination pond - chlorine residual mg/L

BOD mg/L

TSS mg/L

Fecal Coliform MPN/100 mL.

Tap Water Supply - Fecal Coliform MPN/100 mL

Grab samples must be collected twice per year during peak season. A record of the daily average and maximum number of persons staying a the resort over each month of operation must be maintained as well.

4.5.7.3 Receiving environment monitoring

There are no receiving environment monitoring data on file.

4.5.8 Minor discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PR-1715	Regional District of Bulkley Nechako	Smithers Landing	Municipal refuse to ground. Frequently noncompliant with permit. Scheduled for closure.	66 tonnes/yr. Cover once/month.
PR-2617	Regional District of Bulkley Nechako	Granisle	Municipal refuse to ground Frequently noncompliant with permit	840 tonnes/yr. Cover once/week. Open burning of non-putrescible wastes.
PR-2591	Regional District of Bulkley Nechako	Topley Landing	Septic sludge disposal to ground - municipal landfill now closed	50 m^3/yr.
PR-7158	Department of Fisheries and Oceans	Pinkut Creek	Municipal and industrial refuse to the ground - potential leachate contamination of Pinkut Creek.	0.2 m^3/day.

4.6 SUMMARY AND REVIEW OF MONITORING NEEDS

Babine Lake, 150 km long, is the largest natural lake in British Columbia. The Babine River is recognized as a world class wilderness river for steelhead sport fishing and is one of only six Class I angling streams in the province. Babine Lake is an important sockeye salmon nursery lake. DFO artificial spawning channels on the Fulton River and Pinkut Creek produce about a third of adult sockeye stocks in the Skeena watershed.

Because of the valuable commercial and sport fisheries and the presence of two open pit copper mines on the lake, many water quality and limnological studies have been conducted over the years. In general, Babine Lake is an oligotrophic lake, with waters stained by organic matter entering from swamps and bogs in the surrounding drainage basin. Nutrient levels are low as is primary productivity, although there is some evidence that productivity may be increasing.

4.6.1 Interaction of forestry and water quality

4.6.1.1 Log transportation and storage on Babine Lake

The past forestry practice of log handling, transportation and storage in the lake was shown to degrade water quality at log handling sites. Log storage and handling in the shallow, poorly mixed waters of Morrison Arm, in particular, resulted in high BOD, low oxygen levels, and a build-up of organic leachates. This practice was discontinued in the late 1980's, and it is assumed that affected sites are recovering.

4.6.1.2 Stream protection practices

Several major forestry companies operate in the Babine watershed, with timber transported to mills located in the Hazeltons, Smithers, Houston and Burns Lake. An assessment of stream protection practices in the mid-1980's indicated that accelerated harvest of blowdown and beetle infested timber had occurred in some areas, particularly the Fulton River and Morrison Creek drainages. In general, reserves of up to 50 m had been left along significant salmon spawning tributaries, and were quite adequate in protecting aquatic resources. However, the lack of site specific inventory in some areas had resulted in inconsistent treatment of smaller fish streams. For example, some streams were being both logged across and, in some instances, skidded down to landings, resulting in a loss of fish production capabilities due to stream blockage and diversion, bank damage and channel instability. The prevalence of windthrow of trees left along streams has resulted in the widespread use of machine reserves rather than conventional buffer strips for many lower order streams.

Roads were identified as the main sources of sediment to streams. Road related erosion appeared to be most prevalent in the Morrison Creek drainage which has soils which are poorly-drained and difficult to work. DFO indicated that high water temperature following logging was a concern in tributaries which are swamp and lake-headed, such as Morrison Creek. The rate of cut in the Fulton drainage had been examined because of DFO concerns over possible water quality effects on the spawning channels (possibly due to increased sediments and nutrients).

4.6.1.3 Babine River Corridor LRUP and other planning processes

While logging has taken place for many years in the drainages immediately surrounding Babine Lake, in the early 1990's roads and forestry activities were advancing into the previously wilderness Babine River portion of the watershed. The Babine Corridor LRUP, completed in 1994, recommended a 14,000 hectare corridor of land along the Babine River as a candidate wilderness area under PAS. A special forestry management zone borders the corridor, and managed forest development is allowed elsewhere. Active road development and logging is now occurring in the Nilkitkwa, Nichyeskwa and eastern portions of the Babine River drainage.

LRMP planning processes are near completion (Kispiox and Bulkley TSAs) or are ongoing (Morice and Lakes TSAs) which may recommend special management practices for other sensitive areas. An area which is under study for wilderness area designation under PAS is the Sutherland River valley, which drains into the southern end of Babine Lake.

4.6.1.4 Monitoring needs

An assessment of stream protection practices in the mid-1980's indicated that accelerated harvesting in the Babine watershed had led to some damage to streams resulting in a loss of potential fisheries production. The Forest Practices Code, in combination with LRMP monitoring, is expected to improve compliance with stream protection guidelines. In addition, rehabilitation of streams which had been damaged by past forestry practices has been undertaken through the Watershed Restoration Program.

One of the recommendations of the Babine Corridor LRUP was the implementation of multi-year monitoring of forestry impacts on suspended sediment loadings in the upper Babine watershed. Subsequently, automated samplers have been installed at three locations. In addition, for the past two years an independent monitor has collected information on compliance of forestry activities with the LRUP management prescriptions, and has collected sediment samples during ongoing road-building and logging activities. The monitor has identified a number of cases of noncompliance with LRUP prescriptions and also identified two road locations which were contributing sediment to streams during rainfall events. As a result, corrective action was taken immediately and site specific recommendations concerning road construction, maintenance and deactivation were prepared.

Little or no implementation or stream protection monitoring is taking place in other portions of the watershed. There is a need for both short- and long-term water quality and watershed processes monitoring to assess the effectiveness of new management prescriptions and to assess long-term change. Strategies for short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.

4.6.2 Interaction of mining and water quality

4.6.2.1 Granisle Mine

During the life of the Granisle Mine (1965-1982), McDonald and Sterrett Islands were joined together by five embankment dams, and two tailings impoundments now fill what was the channel between islands. Mine rock was used in the construction of the embankment dams, for grading fill at the mill site and for road construction. A recent evaluation of ARD potential from Granisle

Mine indicates that acid generation is expected from all of the rock dumps and dams at the minesite. Peak ARD loading from the mine, estimated to have been 5,000 to 11,000 kg/year total copper (the main contaminant), occurred in the mid 1970's, and will diminish gradually over the next many centuries. Presently about half the ARD loading drains or has been diverted to the open pit, which is predicted to fill in about 130 years. The remainder flows overland to the shoreline or passes through or beneath the embankment dams directly into the lake. Extremely high conductivity at 29 m depth just east of the Granisle Mine was interpreted by Godin (EPS 1985) as seepage through the tailings dam. Although a final closure plan has not been completed, these findings indicate that: 1) substantial copper loading has already entered the lake; 2) it will be impossible to collect or treat a portion of the ARD from this site because it enters below the surface of the lake; and 3) when the open pit reaches capacity, in about 130 years, ARD treatment will be needed prior to discharge of overflow to the lake.

4.6.2.2 Bell Mine

The Bell Mine, which operated 1970-1992, is located on a peninsula separating Hagan Arm from the Main Arm of Babine Lake about 8 km north of the Granisle Mine. An open pit was developed near the center of the peninsula, with rock dumps located to the north, east and south of the pit. A tailings impoundment was constructed to the south of the pit around a former lake. Six saddle dams were constructed between rock ridges to enclose and deepen this area. Later, two additional dams were constructed between the original dam and a rock ridge to form a tailings expansion area. The Bell Mine Closure Plan predicts that all of the mine rock dumps, as well as some of the tailings dams and plant site, will produce net acidity in drainage waters within the next 5 to 35 years. Some drainages are already acidic and being diverted to the open pit. Noranda predicts the time from the start of net acid generation to complete depletion of the sulphide content of the rock is from 20 to 80 years; however, the ability to predict this time-frame accurately has been questioned. The closure plan proposes a fairly complex system to divert as much drainage water as possible into Babine Lake as long as the water meets proposed new discharge quality criteria. When any drainage exceeds these criteria for discharge, it would be diverted to the open pit for storage until the pit fills, in about 50 years. Water treatment would presumably be necessary prior to discharge of pit water to the lake. The Bell Mine closure plan proposes new discharge criteria, which greatly exceed the present allowable dissolved copper discharge under the mine's waste permit, as well as MOELP water quality criteria.

4.6.2.3 Background water quality and biotic conditions

Historic copper levels.— In 1974 Stockner and Shortreed (1976) found that concentrations of trace metals in Babine Lake were generally low. Metals levels were not significantly different in the vicinity of Bell and Granisle mines except for copper levels, which averaged 4.2 µg/L, compared to a mean of 2.3 µg/L in the main body of the lake. Subsequent studies in 1975-1976 indicated that mean copper concentrations averaged across all Main Lake stations were slightly higher (5 µg/L) than in 1974. Corresponding values for copper in the water near the Bell and Granisle minesites in 1975-1976 were 5.7 µg/L and 4.3 µg/L respectively. These values are about the same as those observed in 1974 and were similar to those in the main lake. Water quality monitoring in Hagan Arm in 1974 found that concentrations of copper (14 µg/L), iron and zinc were significantly higher than at sites near Granisle mine and Main Lake stations.

In 1983-1984, EPS conducted a study on the water quality of Babine Lake, both mid-lake and in close proximity to the Bell and Granisle mines, and in Hagan Arm. The study concluded that alkalinity, conductivity, copper and zinc values in Rum Bay and Hagan Arm were higher than in the Main Arm. Slight but noticeable changes were evident in the water quality in the vicinity of the two mines, where conductivity, total residue, calcium and copper concentration were higher in 1984 (41 µg/L near Bell and 7 µg/L near Granisle). Mean copper concentrations in Rum Bay and Hagan Arm were 13 µg/L. EPS conducted monitoring again in 1990, which found similar copper values to those found in 1984. Copper concentrations at the Main Arm station averaged 5 µg/L, Hagan Arm 12.3 µg/L, Rum Bay 11 µg/L, and a station east of Granisle Mine averaged 8.2 µg/L.

Water quality surveys in 1991-1992 found mean total copper concentrations at the Main Arm station and in Morrison Arm were similar to historical data and to copper concentrations nearshore to the western side of Newman peninsula in the vicinity of Bell Mine. The near-shore stations in 1991-1992 showed a lower copper concentration compared to those observed in 1984, which was attributed to seepage control measures initiated in the mid-1980's. Mean copper levels were slightly higher in Hagan Arm than in the main body of Babine Lake but remained largely unchanged relative to conditions reported in 1974 and 1984. It is conceivable that copper may have been historically elevated in Hagan Arm waters due to the high level of mineralization in the area and the poor water exchange of Hagan Arm waters with the main lake.

Bottom sediments and benthic invertebrates.— Sediments with elevated copper concentrations have been found the vicinity of the two mines and in Hagan Arm since 1972. Rescan (1992*b*) reports high copper concentrations (2,670 µg/L), as well as aluminum and iron, at localized areas in Woolverton Bay, in Hagan Arm. This is believed to be the result of seepage from a waste rock dump prior to collection. Dissolved copper concentrations in the near-surface pore waters from cores collected in Woolverton Bay were at least two-fold higher than levels measured in the core-top (supernatant water), indicating copper is being released to pore solution near the sediment-water interface.

The benthic invertebrate data which has been collected from Babine Lake in the vicinity of Bell and Granisle Mines by both Hatfield (1989) and Rescan (1992*b*) indicates relatively low benthic numbers and diversity. Benthic communities were predominantly comprised of facultative fauna, those benthic organisms that may persist in relatively poor as well as good water quality conditions.

Godin (1992) investigated the bioavailability of metals from some contaminated sediments collected near the mines in 1990. Bioavailability was demonstrated in toxic and chronic effects to aquatic insects using the *Chironomus tentans* emergence test, a bioassay technique using midge larvae. High levels of exchangeable copper, aluminum and/or zinc could have been responsible for the toxicity.

Zooplankton.— Since zooplankton are consumed by predators, they play an important role in the cycling of metals through higher trophic levels, for example fish. Zooplankton tissue analyses for metals indicated that generally the lowest tissue metal levels were observed in the Main Arm, intermediate levels were found at the entrance and center of Hagan Arm, while the highest levels were observed in the vicinity of the outfall in Rum Bay.

Fish.— Davis and Shand (1978) found that the 96 hr LC50 values obtained for sockeye salmon fry, fingerlings and smolts exposed to dissolved reagent-grade copper added to lake water ranged between 210 -240 µg/L. It was concluded that the present levels of copper in the lake (4 - 44 µg/L), coupled with the considerable complexing capacity of the water posed no acute threat to Babine sockeye. Osmoregulatory capability studies of sockeye smolts suggested that the threshold total copper concentration which might disrupt osmoregulatory capability in Babine stocks was in the range of 109-154 µg/L copper.

Kokanee (the non-anadromous form of sockeye), rainbow trout, lake trout, lake whitefish and burbot were captured and analyzed for muscle and liver metals levels in 1991-1992. Metal levels in the musculature of fish sampled from Babine Lake were within the range reported for fish in unpolluted waters. However, musculature has been proven not to be the most suitable body part for determining the extent of heavy metal accumulation of the entire organism (Forstner and Wittmann 1981) because the absolute increase of heavy metals in muscle tissue of contaminated fish is often much lower than in other organs. It appears that the musculature only becomes enriched by metals when the contamination is extremely high. Organs with the greatest affinity to heavy metals would appear to be more suited for evaluation, particularly liver, gill and kidney. A review of biological monitoring for heavy metals in aquatic environments prepared for the BC Acid Mine Drainage Task Force (EVS 1990) recommends using bone metal levels for fish to indicate chronic exposure levels and gill, liver or kidney levels to illustrate recent metabolic activity.

Fish livers, collected in 1991-1992 were also analyzed for metal concentrations and metallothionein. Metal concentrations of cadmium, copper and zinc in fish liver tissues from both the Main Arm and Hagan Arm were higher relative to data reported for all fish, except burbot, in unpolluted waters in British Columbia and Canada. Liver tissue levels of copper at all locations were up to 12 times greater (range 144 - 336 mg/kg-wet wt.) than the levels reported for livers of fish from unpolluted waters (1.5 - 18.0 mg/kg-wet wt.).

Metallothionein analyses was conducted on liver tissues from four lake trout and three burbot (these being the longest living of the fish species captured). All fish sampled for metallothionein analyses appeared healthy upon capture. Mean metallothionein concentration in lake trout was 818.51 nmole/g, and mean concentration for burbot was 378.00 nmole/g. Metallothionein normally occurs in tissues in only trace amounts; however exposure to sublethal doses of certain metals such as cadmium, copper, mercury and zinc induces thionein synthesis and the binding of the apoprotein to the metal, thus forming metallothionein. Metallothionein and other hepatic proteins are believed to provide a protective role against toxic effects by sequestering and reducing the amount of free metal in tissues, thereby reducing potential toxicity.

Metallothionein has been identified in fish contaminated with metals in numerous field studies review by Hamilton and Mehrle (1986). Roch and others (1982) used metallothionein as an indicator of metal stress in rainbow trout in an extensive study of lakes along the Campbell River, Vancouver Island, which were contaminated with metals due to ARD. This study demonstrated a downward trend from the most-contaminated to the least-contaminated lake in the concentration of hepatic metallothionein in the fish. Criterion for metallothionein concentrations have not been suggested because there appears to be a great deal of variability between metals mixtures, fish species and ages, and unknown environmental variables. It is interesting to note that concentrations in Babine Lake trout were about three times higher than hepatic concentrations in rainbow trout from the most contaminated lake in the Campbell River study (mean=269 nmole/g). The further application of MIMS analysis (analysis of the distribution of metals between different hepatic protein pools) as an indicator of metal stress in salmonids is a new, and as yet unsubstantiated, technique.

McCarter and Roch (1983) demonstrated that coho salmon continuously exposed to sublethal levels of dissolved copper developed hepatic metallothionein concentrations in proportion to the logarithm of the concentration of copper to which the fish were exposed. Singleton (1987) has suggested that site specific criteria for metals mixtures could be developed using experimentally derived chronic toxicity data and confidence limits derived from the metallothionein/metals regression. This technique relates a metal level directly to a measurable biochemical response in fish. Furthermore, assumptions concerning the additive, synergistic, or antagonistic effects of the several metals found in ARD are not necessary because the metallothionein technique measures these combined effects directly.

Resident fish such as rainbow trout, lake trout and kokanee have been on a decline in Babine Lake for some time for unknown reasons. In addition, very high parasite infestation of juvenile sockeye is a strong stress factor in Babine Lake rendering them more susceptible to other environmental stresses (P. Lemieux, DFO, personal communication).

Organic complexing capacity.— Chau and Wong (1975) showed that Babine Lake waters have a high copper complexing capacity. They found that the copper in water samples taken from the vicinity of the two mines was tightly bound to organic complexing molecules. They estimated that the copper complexing capacity of Babine Lake waters was about 100 µg/L. The copper complexing capacity of Babine Lake was estimated to be 60 µg/L in 1992 (Rescan 1992*b*).

Discussion.— The Bell and Granisle mines are owned by the same company and it is obvious that the two closure plans must be developed simultaneously, based on combined discharges and accounting for the uncontrollable nature of discharges from submerged tailings dams at Granisle Mine. The long-term nature of ARD generation (centuries) make the closure planning for these mines particularly difficult, as does the fact that they are located in an extremely sensitive and valuable fish habitat. Noranda is presently requesting an increase in permitted discharge concentrations for dissolved copper at Bell Mine which are 2 to 6 times greater (for surface discharges) and 20 times greater (for deep water discharges) than presently permitted.

A review of historical data suggests that, overall, there have not been negative fisheries effects from the mining activities. There are, however, some indicators of bioaccumulation and stress due to ambient copper concentrations, despite the documented high organic copper complexing capacity of Babine Lake waters:

- Bottom sediments from areas near the mines and in Hagan Arm have elevated concentrations of copper, aluminum, iron and zinc, with some evidence of acute and chronic toxicity to sediment dwelling insects. There are signs that copper is diffusing into the overlying water column from near surface sediments in an area of localized contamination in Woolverton Bay.

- The benthic invertebrate community of Babine Lake is predominated by facultative and tolerant species. The benthic invertebrate diversity index for some sites in Hagan Arm has declined.
- Zooplankton tissue analyses for metals indicates an increase in concentration with proximity to mining activities. Zooplankton are an important food source for many species of fish.
- Metal concentrations of cadmium, copper and zinc in fish liver tissues from both the Main Arm and Hagan Arm were higher relative to data reported for all fish, except burbot, in unpolluted waters. Liver tissue levels of copper at all locations were up to 12 times greater than the levels reported for livers of fish from unpolluted waters.
- Hepatic metallothionein concentrations in lake trout and burbot were elevated compared to unpolluted lakes. Metallothionein is recognized as an indicator of metals stress in salmonids.

4.6.2.4 Mass balance for copper and other metals

The cycling of trace metals in freshwater lakes is a complex and poorly understood subject. Given the fisheries and recreational values at stake in Babine Lake, discharge limits must be set cautiously. The Bell Mine closure plan presents a complex effluent dilution and dispersion model for predicting copper, zinc, aluminum and silver concentrations in receiving waters and sediments resulting from surface and subaqueous discharges to Hagan and Main Arms of Babine Lake. The accuracy of these predictions must be reviewed by someone with expertise in this type of modeling, and when additional aquatic toxicity and sediment geochemical and toxicity data is available. Modeling must include present known discharges from both mines, discharges proposed from both mines in the short-term, and a strategy for dealing with future discharges when both open pits fill (in about 50 to 150 years).

Babine Lake presents a somewhat unusual situation compared to literature studies on the cycling of metals in soft-water lakes. It is dystrophic, highly coloured by the presence of complex organic substances, and it is oligotrophic, with low phytoplanktonic productivity. It appears that not all of the ionic copper entering Babine Lake is immediately complexed by organic ligands and rendered biologically unavailable, since elevated copper concentrations are found in the top centimeter of Rum Bay and Hagan Arm sediments, in zooplankton, and in fish. However, the presumption is that an adequate supply of complex organics exist and will continue to exist in Babine Lake waters to complex, and thus render non-toxic, a large amount of ionic copper. The result of formation of copper complexes with soluble organic substances is an increase in solubility, rather than sedimentation (Wangersky 1986).

In a study of copper and zinc budgets in a soft-water lake with high complexing capacity, Reynolds and Hamilton-Taylor (1992) found virtually no sedimentation of copper. Rather, the entire calculated annual copper input was found to leave via the outlet (largely in solution, some as algae, whereas more than half the dissolved input of iron lead and zinc was retained in the lake via sedimentation. It would be very helpful to have modeling as to the eventual fate of these soluble copper-organic compounds.

To date there has been little or no water quality sampling of Babine River. However, it seems logical that sampling at the lake outlet, particularly during periods of spring and fall overturn, might prove to be a cost effective, long-term method of monitoring for water quality change in the lake, at least as far as copper is concerned. If it is determined that any increase in copper or other metals loading to Babine River is to be expected due to ARD discharges, the development of specific water quality and sediment objectives for the river is suggested.

4.6.3 Datasets critical to the development of water and sediment quality objectives for the Babine watershed

The development of water and sediment quality objectives for the Babine watershed has been recommended by MOELP in order to set discharge criteria and to focus monitoring during the prolonged period of ARD generation and management from the two mines. The MOELP water quality criteria for the protection of aquatic life (30-day average copper ≤2 µg/L and maximum copper ≤5.5 µg/L) are thought to be more stringent than necessary for Babine Lake for the following reasons: Babine Lake has historically had ambient copper concentration which exceed the criteria; toxicity is believed to be reduced by the copper complexing capacity of natural dissolved organic ligands in lake water; copper concentrations causing and chronic copper toxicity in young Babine Lake sockeye using lake water as diluent (with addition of reagent grade copper) were higher than values obtained in bioassays using diluent water with low complexing capacity.

4.6.3.1 Acute and chronic toxicity of ARD to Babine Lake biota

Both acute and chronic toxicity data will be required for objectives setting, utilizing a battery of biological assessment tests. Factors such as the multiple metals found in ARD from both mines and the organic complexing capacity of Babine Lake waters (which varies seasonally) need to be addressed. Therefore, *in-situ* studies (preferably) or laboratory bioassays using Babine Lake water as diluent are suggested. The toxicant should be treated and untreated mine drainage waters of varying dilutions to represent the range of metal concentrations in proposed discharges and to establish dose/response relationships.

Water quality objectives have recently been developed for the ARD-impacted Tsolum River watershed on Vancouver Island (Deniseger and Pommen 1995). This study recommend monitoring for "free" copper, which is an estimate of the amount of dissolved copper which is not organically bound, and proposes an analytical method. In addition to detailed analysis of total and dissolved metals concentrations, analysis should include humic acid, dissolved organic carbon and "free" copper to further develop the relationship between these parameters.

The most promising and proven biological monitoring techniques (EVS 1990) are benthic community responses and growth and reproductive parameter of fish populations. The benthic invertebrate community may be particularly useful in the Babine Lake situation, since benthic response may relate both to changes in water and sediment quality. The use of mesocosm studies, in this case using constructed or artificial ponds, is suggested as the most direct means of measuring benthic community responses to a gradient of ARD additions. A mesocosm technique has proven useful for stream environments receiving ARD additions from other minesites in British Columbia (Limnotek 1992).

Young sockeye (fry, fingerlings and smolts) are the species of greatest interest; however, kokanee, lake trout, rainbow trout, burbot, lake whitefish and peamouth chub are also expected to be impacted by mine discharges. The fish species used would preferably be a Babine Lake stock, or acclimated to ambient lake water prior to testing. Both 96 hr LC50 to assess acute toxicity, and 21 day LC50 (including measurement of growth rate) to assess chronic toxicity, are suggested. The following studies are suggested for additional assessment of chronic toxicity: histological examination of gills, growth and saltwater survival in smolts exposed to sublethal ARD concentrations; and hepatic biochemical response (metallothionein concentration and distribution).

4.6.3.2 Sediment quality objectives

The minimum toxicological dataset requirements for derivation of freshwater sediment quality guidelines for the protection of aquatic life (CCME 1995) are shown below:

- At least four studies are required on two or more sediment-resident invertebrate species that occur in North American waters. These must include at one benthic crustacean species and one benthic arthropod species other than a crustacean.
- At least two of these studies must be partial or full life-cycle test that consider ecologically relevant end points (e.g., growth, reproduction, developmental effects).

The Sediment Quality Triad approach (Chapman and others 1987) consists of three components: sediment chemistry which measures contamination; sediment bioassays which measure toxicity; and biological community structure (*in situ* or field parameters) which measure alteration. Sediment toxicity bioassays ideally would include a range of test including acute lethal, acute sublethal and chronic tests. Tests and test organisms recommended for ARD (EVS 1990) are:

- *Daphnia magna*: both acute (48 hr) and chronic (7 day);
- *Hyallela azteca*: sublethal acute (10 day) lethality; and
- *Chironomus tentans*: chronic (10 day) partial life-cycle.

Spiked-sediment toxicity tests may be necessary to further refine dose/response relationships. Consideration should be given to conducting all bioassays over a longer timeperiod than 10 days. In an assessment of hardness and humic concentration effect on the bioaccumulation and toxicity of copper, Winner (1985) noted that, in bioassays using *Daphnia* spp., a 21 day exposure period was not long enough for determining an ecologically relevant no effect concentration. Previous studies have shown that copper concentrations which cause mortality beyond a 21-day exposure also cause a reduction in filtration rate, growth and negative phototactic behavior.

5. SKEENA RIVER TO BULKLEY RIVER CONFLUENCE

Below the confluence of the Babine River, the Skeena flows southward approximately 55 km to join the Bulkley River at Hazelton (Figure 5.1). The major tributary to this reach is the Kispiox River, which joins the Skeena about 12 km upstream of Hazelton. The Kispiox drains an area of the Nass Basin, an area of low relief. The basin is dotted by hundreds of small lakes, which together with the drainage pattern display the underlying orientation of the folded bedrock. The Nass Basin is climatologically unique. Moist, mild Pacific air gains access to the area by way of the Nass River valley, greatly reducing the rainshadow effect at this location east of the Coast Mountains. As a consequence, this area is humid and moist. Winter temperatures are moderated by the Pacific air yet summer temperatures are considerably warmer than coastal areas.

Fisheries resources are high in the Kispiox and Skeena Rivers, with record sized steelhead in the Kispiox. The Skeena and the Kispiox (including tributaries) and are Class II angling streams. (See section 2.2.4 for explanation of classified waters.)

5.1 HYDROLOGY

The drainage area of the Kispiox River is 1879 km^2 (at hydrometric gauge Station 08EB004). Monthly mean, maximum and minimum discharge for Station 08EB004, Kispiox River near Hazelton, are shown in Table 5.1 and Figure 5.2. On average the Kispiox River contributes about 9% of the flows of the larger Skeena River at their confluence.

The drainage area of the Skeena at Glen Vowell is about 25,900 km^2. Hydrometric Station 08EB003 is located on the Skeena at Glen Vowell (IR) a few km upstream of the confluence of the Skeena and Bulkley Rivers. Monthly mean, maximum and minimum discharges for the Skeena at Glen Vowell, are shown in Table 5.2 and Figure 5.3.

Notice that different discharge scales are used in Figures 5.2 and 5.3. In addition to much higher discharges overall, the Skeena has a higher discharge peak during freshet, reflecting the melting of the snowpack in its mountainous headwaters. The flow regime in the Kispiox is much less variable than that of the Skeena, a reflection of the evenly moist climate, the presence of many lakes and wetlands in the headwaters, and the relatively low elevation of the headwaters.

5.2 LAND USE HISTORY

5.2.1 Settlements

Two principal Gitksan winter villages were located in this reach at the time of first record: Gitanmaax at the confluence of the Skeena and Bulkley Rivers, and Kispiox at the confluence of the Kispiox and Skeena Rivers (Sturtevant 1990). In 1879 and 1880, missions were established in Gitanmaax and Kispiox respectively. Glen Vowell, located on the east shore of the Skeena just north of Gitanmaax, was established before 1900 as a Salvation Army village by people from Kispiox, Kisgegas and Kuldo (abandoned villages on the upper Skeena).

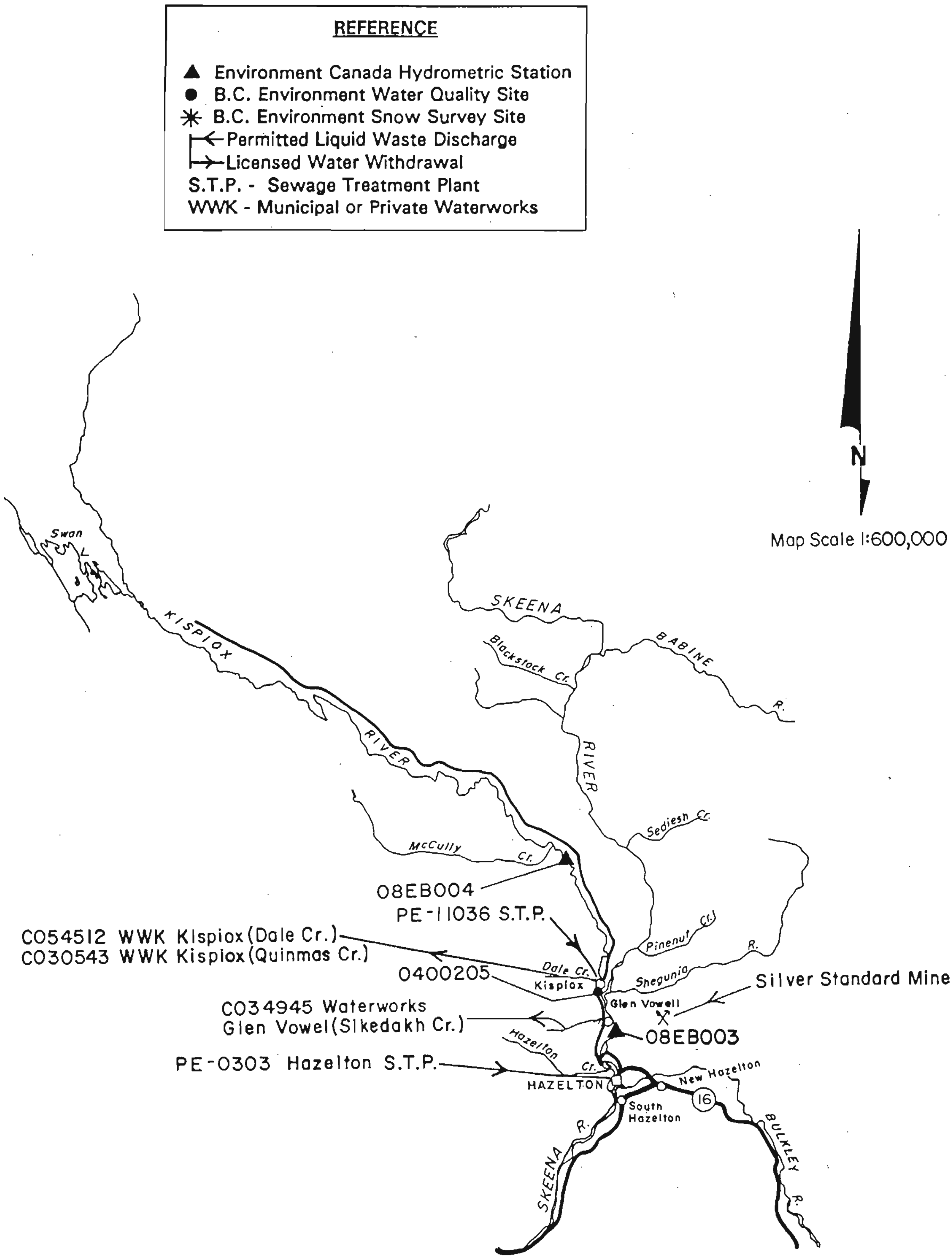


Figure 5.1 Skeena River to Bulkley River confluence

Table 5.1 Monthly discharge summary Kispiox River near Hazelton, Station 08EB004

Latitude: 55 26 01 N
Longitude: 127 42 51 W
Drainage Area Gross: 1870 km2
Period of Record 1963-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	21.6	19.8	46.4	80.0	159	212	165	76.7	81.6	139	79.7	47.2
Monthly Min.	4.17	3.36	2.84	12.2	56.9	82.1	30.5	11.7	14.2	21.7	8.06	5.02
Monthly Mean	8.17	7.84	9.66	36.3	104	128	75.3	37.6	38.6	79.3	31.0	13.2

Average 7-day, 10-year low flow is 2.79 m3/s with 95% confidence limits of 2.37 and 3.38.

Figure 5.2 Discharge envelope Kispiox River near Hazelton

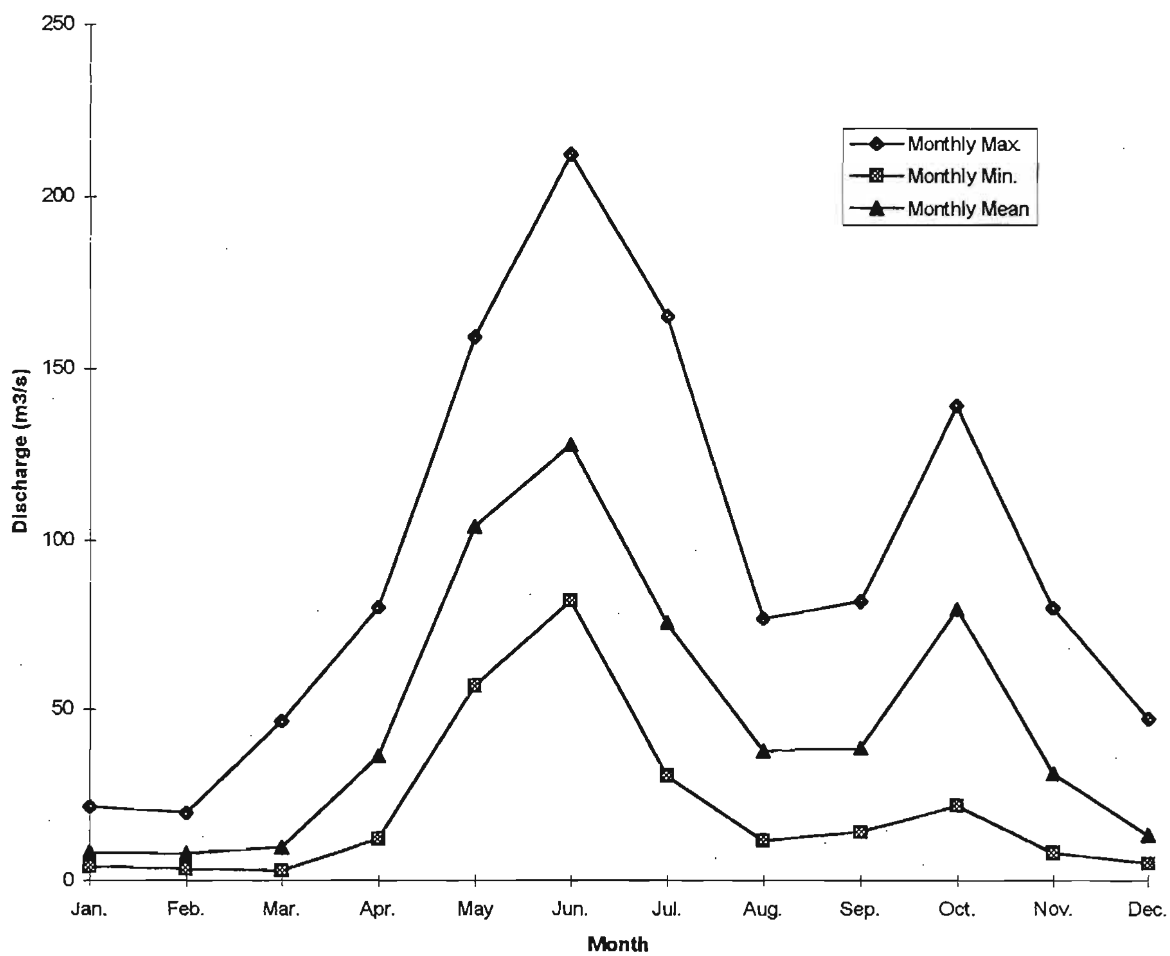


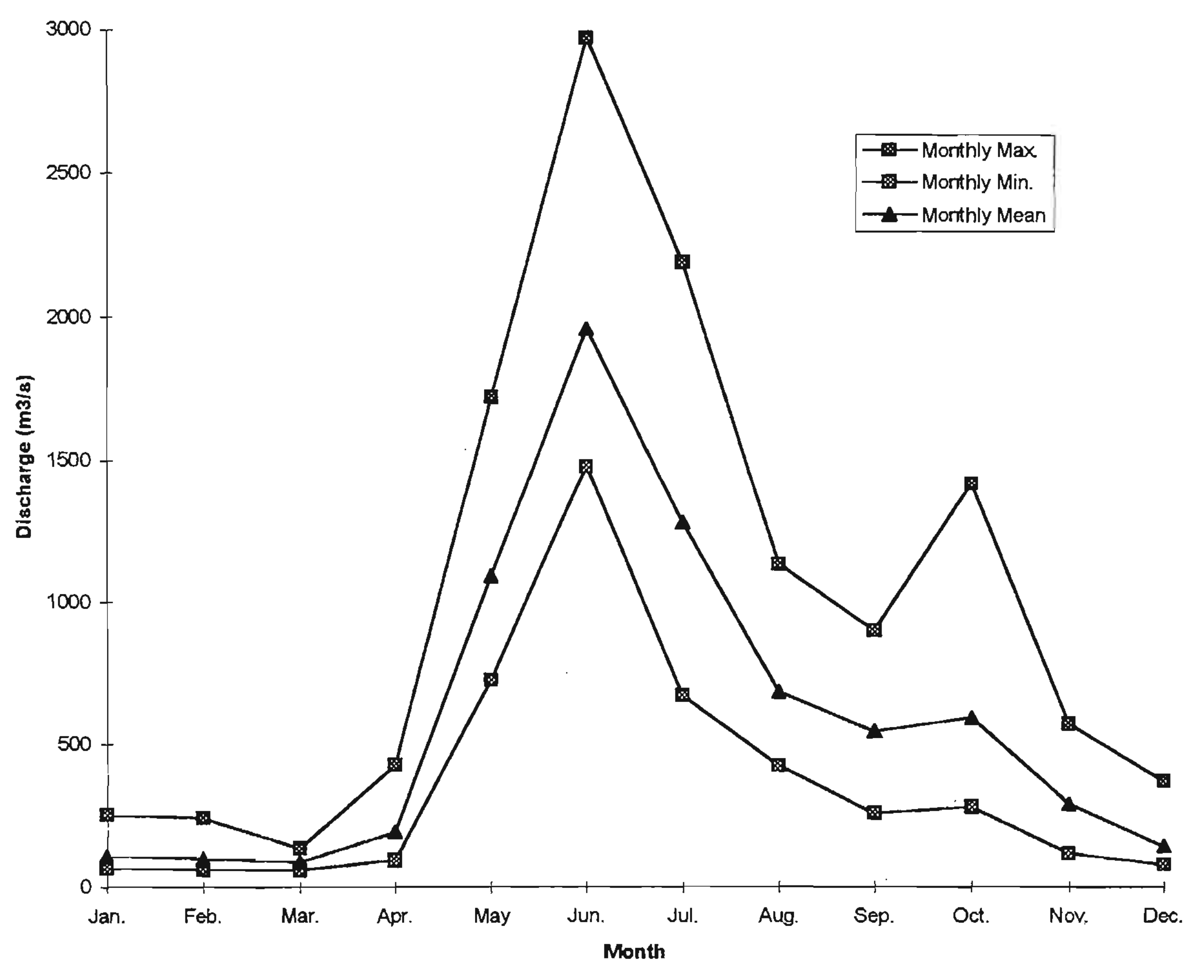
Table 5.2 Monthly discharge summary Skeena River at Glen Vowell, Station 08EB003

Latitude: 55 18 09 N
Longitude: 127 40 11 W
Drainage Area Gross: 25 900 km2
Period of Record 1960-1985

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	251	242	135	425	1720	2970	2190	1130	897	1420	568	369
Monthly Min.	66.2	61.1	58.7	92.5	724	1480	670	422	256	277	116	77.4
Monthly Mean	108	97.3	86.9	191	1090	1960	1280	682	542	591	288	142

Average 7-day, 10-year low flow is 53.4 m3/s with 95% confidence limits of 46.8 and 60.5.

Figure 5.3 Discharge envelope Skeena River at Glen Vowell



The Skeena River was navigable by canoe as far inland as the junction of the Skeena and Bulkley Rivers, where passage is blocked by a narrow precipitous canyon on the Bulkley River. Thus Gitanmaax had been an annual gathering place for trade between the Tsimshian, Gitksan and interior tribes.

In 1866, the Collins Overland Telegraph line was constructed through the Bulkley valley to Skeena Forks (as the junction of the two rivers was known), then north along the Skeena and Kispiox rivers. The telegraph line was abandoned the same year. Skeena Forks, later named Hazelton, grew quickly to become the main site of Skeena River trading. The Gitksan had a trail running from Gitanmaax over the Babine mountains to Babine Lake, and this was the route used by the miners in the 1870's to reach claims in the Omineca gold fields to the east. In 1880 the Hudson's Bay Company established a store at Hazelton and began supplying their forts in the interior from Port Simpson at the mouth of the Skeena, by river to Hazelton, and then by pack train to the interior.

In the early 1900's the provincial government established the Dominion Telegraph line to Dawson City in the Yukon using much of the old Collins Telegraph route through the Bulkley, Skeena and Kispiox valleys. By this time interest in trade, agriculture and mineral exploration was bringing permanent settlers into the area.

The 1914 completion of the Grand Trunk Pacific Railway (now the CNR) along the south side of the Bulkley River, across the river from Hazelton, was a hard blow to the community. The promoters of the two new townsites of South Hazelton and New Hazelton, located on the rail line, expected the town to amalgamate with them. But "Old" Hazelton continued to be the distributing center for the area and today all three townsites survive.

Today the village of Kispiox has a population of 1038, Glen Vowell a population of 292, and Gitanmaax a population of 1337 (Ministry of Aboriginal Affairs 1992). The Village of Hazelton, which is located adjacent to Gitanmaax and shares many services, has an estimated 1994 population of 355 (BC Statistics). New Hazelton and South Hazelton are discussed further in sections 8.2 and 9.2 respectively.

5.2.2 *Agriculture*

The broad, rolling Kispiox River valley has a long history of agricultural settlement, although most early settlers were involved in hewn-tie production for the railway, mineral prospecting or other jobs in conjunction with land clearing for agriculture.

Today there are an estimated 20-30 ranches in the Kispiox, with approximately 500 breeding cows. Agricultural grazing on Crown land is administered by MOF through range units. In 1992, the Prince Rupert Forest Region range database showed 10 range tenures in the Kispiox Forest District and 1060 authorized Animal Unit Months (AUMs) of grazing. Grazing permits were issued for 227 cattle, 9 horses and 400 sheep in 1992. The use of sheep in the Kispiox District has risen dramatically in the last few years for deciduous vegetation control on harvested cutblocks. The sheep are generally trucked into the district for the grazing season by contractors and wintered elsewhere.

5.2.3 Forestry

Early settlers in the Kispiox valley were employed in tie-making for the railway, in conjunction with land clearing for agriculture. Portable sawmills were later used throughout the area. These small scale selective and strip logging operations persisted until the 1960's. Logging and milling operations have expanded rapidly since the mid-1960's. While earlier operations concentrated on high-value timber in easily accessible sites, more recent operations have expanded roads and logging activities into much of the forest land base throughout the Kispiox and lower Skeena watersheds. Major forestry operators in the Kispiox TSA are Skeena Cellulose Carnaby, with a large mill south of Hazelton, and Isolite Stege Forest Products of South Hazelton.

5.2.3.1 Stream protection practices

Stream protection practices in the interior of the Prince Rupert Forest Region (Bustard and Wilford 1986) is reviewed in section 1.3.4. Bustard (1986*b*) conducted an assessment of stream protection practices in the Kispiox and other TSAs using a combination of interviews and field inspections. He notes the Kispiox TSA had been in the center of interaction between forest operations and public concern for the preservation of the upper areas in the Kispiox River valley for more than a decade. Despite the fact that the Kispiox River itself is renowned for its run of summer steelhead trout, and that salmon occur throughout the many small tributaries, there had never been a detailed evaluation of logging-fisheries interactions in the watershed.

Bustard found that streamside treatment in the Kispiox TSA varied widely and ranged from intact reserves to logging to the edge of streams. During the mid-1980's there was a shift away from intact strips of timber along fish creeks to the use of directional falling and 20-30 m wide machine reserves when feasible. In some situations a minimum diameter is specified for trees that are to be left in the reserve, allowing for the removal of the larger high value timber while still ensuring that some trees remain. DFO staff indicated that they were satisfied with machine reserves, and in many situations preferred them to the alternative of leave strips that may be subject to windthrow.

Keeping logging debris out of small creeks, particularly in winter logged areas, was reported to be a major difficulty. Small tributaries and side channels of larger fish creeks are numerous in the Kispiox. Inventory was poor of these small drainages that are often important fish producers especially for coho salmon and steelhead trout.

Field inspections of streamside areas in the Kispiox indicated that in areas where intact reserves had been left, such as along the outlet stream of Fish Lake, the streams were well protected and there was very little evidence of blowdown. A number of machine reserves were examined and their effectiveness varied depending upon site characteristics. In the first example, a machine reserve on Beaverlodge Creek provided adequate protection, largely due to an abundance of deciduous cover present on this system.

In the second example, a machine reserve on an alluvial flats at Steep Canyon Creek was not as effective at maintaining the stability of the channel and ensuring a continued recruitment of large woody debris. Bank erosion may have been accelerated at the site that was examined. However, the alternative of leaving a reserve strip of trees, including large spruce, may have been subject to windthrow in this situation.

In the third example, both Ironside Creek and its tributary were logged across and major clean-up of debris in the stream was ordered. It is probable that the tributary to Ironside Creek was quite badly damaged by the logging operations. However, the subsequent clean-up that was carried out appeared excessive and may have destabilized the creek even more.

Forest service staff suggested that there may be net benefits to the streams in the district from higher water temperatures and the shift of streamside vegetation to more deciduous cover following logging. In contrast, DFO staff indicated that higher temperatures would not be desirable in the many lake-headed streams in the Kispiox. They also had concern for proposals to remove the deciduous vegetation that was left in machine reserves with herbicide applications.

Roads were identified as the prime cause of stream siltation in the Kispiox. Fisheries agencies indicated that they felt road construction was good except for isolated incidents, although they suggested that sometimes there was not enough consideration given to examining alternative, less sensitive routes for road locations. Road construction in the vicinity of Footsore Lake in the upper Kispiox during November 1984 was identified as the worst example of road construction. Streams in this area were thought to be particularly sensitive since they are lake-headed and not capable of transporting high sediment loads. Field examination of the site indicated that sedimentation was continuing at this site, particularly during wet periods, and despite grass-seeding of the area.

The effects of logging on increased peak flows in the Kispiox River was reported to be a persistent issue raised by the public. An analysis by Wilford (1985) indicated that the watershed is too much of a mosaic of timber ages and types to result in a sufficiently large proportion of the watershed being logged at one time to alter the run-off regime. However, some concern for earlier seasonal runoff due to altered snowmelt patterns on small extensively logged streams was expressed by fisheries personnel.

5.2.3.2 Kispiox LRMP

Because of public concern for the preservation of the upper areas in the Kispiox valley, a planning process for the Kispiox began in 1989. The Kispiox process occurred prior to, and concurrent with, the development of legislation and policy regarding regional land use planning. A Consensus Management Direction was completed in 1994, recommending a change in timber harvesting methods to include smaller clearcuts, emphasizing selection systems and dispersing harvests through the supply area (see further discussion in section 3.2.3.1). Protection of water quality and enhancement of tourism and recreation were emphasized in the plan. A Wilderness Area at Swan Lake, in the headwaters of the Kispiox River, was recommended to PAS.

In the Kispiox LRMP, water quality in designated Community Watersheds will be monitored before and after harvest. The objective is to maintain hydrological stability through the development and implementation of standards and procedures. Site specific watershed management plans will be developed for designated Community Watersheds under the Forest Practices Code.

Monitoring.— A monitoring committee will be established consisting of five people from the general public and one representative from each of agencies. The committee will evaluate field results through GIS analysis and maps provided by the resource agencies and licensees and will participate in field trips. A strategy for monitoring the consensus statements will be drawn up and be included in an annual report.

5.3 WATER WITHDRAWALS

A summary of licensed water withdrawals from the Skeena and Kispiox Rivers in this reach is found in Table 5.3. The domestic and irrigation licenses are concentrated in the agricultural region in lower and middle Kispiox valley. Community waterworks are located on Sikedakh Creek (Glen Vowell), Dale Creek and Quinmas Creek (Kispiox). These watersheds are recognized as Community Watersheds by MOELP Water Management.

Licensed water withdrawals for the Kispiox drainage, including irrigation, total 0.13 m^3/s. The 7 day average 10 year low flow for the Kispiox River (1963-1993) is 2.79 m^3/s with 95% confidence limits of 2.37 and 3.38 (Table 5.1). Licensed water withdrawals equal about 5% of the 7 day average low flows, which would present a minor impact on water quality and/or in-stream flows for fisheries. In addition, the annual low flows in the Kispiox occur during the winter when irrigation will not be in effect. There may, however, be licensed and unlicensed water withdrawals from small tributaries of the Kispiox which are ungauged. Licensed water withdrawals from the Skeena River total less than 0.1 m^3/s, which is negligible compared to 7 day average low flow of 53.4 m^3/s (Table 5.2).

Table 5.3 Licensed water withdrawals Skeena River to Bulkley River confluence

Input streams - Skeena R

Domestic

GD	m3/d	m3/s
(1 license)		
1000	4.5	5.26E-05

Irrigation*

AF	m3/d	m3/s
(1 license)		
400	8223.2	9.52E-02

Waterworks

License	Licensee		GD	m3/d	m3/s
	GlenVowell Indian Band				
C034945	(Sikedakh Cr)		15000		
C049457	(Sikedakh Cr)		15000		
		total	30000	136.4	1.58E-03

Input streams - Kispiox R

Domestic

GD	m3/d	m3/s
(15 licenses)		
10500	47.7	5.52E-04

Irrigation*

AF	m3/d	m3/s
(7 licenses)		
529	10875.2	1.26E-01

Waterworks

License	Licensee		GD	m3/d	m3/s
	Kispiox Indian Band				
C054512	(Dale Cr.)		40000		
C030543	(Quinmas Cr.)		35000		
		total	75000	341.0	3.95E-03

* Irrigation licences have been converted from acre-feet to m3/s by assuming 2 months of operation, 12 hours/day in the summer.

5.4 WATER QUALITY AND AQUATIC RESEARCH

5.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly 1983 - 1987 from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). The summary water quality data for the Kispiox River station 0400205 (Figure 5.1) are found in Table 5.4. This station was generally sampled once per month for five years.

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

The Kispiox is a soft water river, with neutral to slightly alkaline pH, which has clear, slightly tea coloured waters for most of the year. The colouration is due to natural organic substances, such as humic acids, contributed by swamps and wetlands in the drainage, and is not harmful to human health. Alkalinity and calcium concentrations are in a range which would provide moderate buffering from acidic inputs. TSS loadings are much higher during freshet than the remainder of the year. Nutrient concentrations are low. The range of total metals levels often exceed the MOELP criteria for the protection of aquatic life at the hardness levels present. Mean total metals levels are generally very close to the criteria. However, dissolved metals levels are often less than or equal to the detection limit.

Table 5.4 Water quality summary Kispiox River, Site 0400205, 1983-1987

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	19	14	5	30	11.1	7.4	5
pH	55	55	7.1	7.9	7.46	0.18	7.4
Conductance (umhos/cm)	56	56	56	157	86.6	19.3	85
Total Residue (mg/L)	56	56	50	187	73.3	26.4	66
Filterable Residue (mg/L)	14	14	34	76	56.0	12.6	56
Non-filterable Residue (mg/L)	51	48	1	94	13.2	19.6	5
Turbidity (NTU)	53	53	0.5	64.0	6.50	10.00	3.0
Alkalinity (mg/L)	55	55	24.2	51.7	36.85	7.31	37.5
Hardness Total (mg/L)	12	12	30.1	52.7	39.32	7.70	36.9
Hardness Dissolved (mg/L)	7	7	28.9	49.2	39.55	9.53	41.9
Total N (mg/L)	22	22	0.05	0.49	0.180	0.097	0.16
T.K.N. (mg/L)	55	55	0.03	0.29	0.120	0.056	0.11
Ammonia (mg N/L)	55	18	0.005	0.049	0.0126	0.0123	<0.005
NO2 + NO3 (mg N/L)	55	45	0.02	0.22	0.074	0.039	0.06
Total Carbon (mg/L)	33	33	6	15	11.2	2.5	12
Organic Carbon (mg/L)	22	19	1	6	2.6	1.6	2
Inorganic Carbon (mg/L)	55	55	3	14	9.2	2.4	9
Chloride (mg/L)	15	9	0.5	1.6	0.67	0.36	0.5
Ortho P (mg/L)	50	8	0.003	0.008	0.0045	0.0018	<0.003
Silica (mg/L)	14	14	3.1	4.9	4.15	0.53	4.2
Sulfate (mg/L)	19	19	3.4	7.7	5.33	1.40	5.2

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	54	49	0.03	4.02	0.489	0.813	
As	79	8	0.001	0.008	0.0021	0.0024	<0.001
Ca	56	56	8.25	17.70	12.660	2.500	12.30
Cd	79	0					<0.0005
Co	56	5	0.10	0.24	0.146	0.054	<0.1
Cr	56	2	0.01	0.03	0.020		<0.01
Cu	56	39	0.001	0.060	0.0050	0.0102	0.002
Fe	56	56	0.05	6.71	0.720	1.180	0.30
Mg	56	56	1.41	2.65	1.930	0.310	1.93
Mn	56	29	0.01	0.18	0.044	0.042	0.01
Mo	57	10	0.0005	0.020	0.0111	0.0056	<0.01
Ni	56	0					<0.05
P	56	56	0.004	0.134	0.0190	0.0230	0.012
Pb	56	33	0.001	0.006	0.0023	0.0014	0.001
V	56	2	0.01	0.04	0.025		<0.01
Zn	56	15	0.005	0.060	0.0154	0.0169	<0.005

Source:Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 5.4 (continued) Water quality summary Kispiox River, Site 0400205, 1983-1987

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	48	34	0.02	0.16	0.055	0.031	0.04
As	63	3	0.001	0.001	0.0010		<0.001
B	48	0					<0.01
Ba	48	33	0.01	0.02	0.013	0.005	0.01
Ca	48	48	8.25	16.80	12.360	2.480	12.50
Cd	63	0					<0.0005
Co	48	1	0.11	0.11	0.110		<0.1
Cr	48	0					<0.01
Cu	63	15	0.001	0.002	0.0011	0.0003	<0.001
Fe	51	51	0.02	0.36	0.075	0.057	0.06
K	14	14	0.10	0.30	0.170	0.072	0.20
Mg	48	48	1.09	2.41	1.770	0.330	1.75
Mn	48	5	0.01	0.02	0.012	0.005	<0.01
Mo	48	0					<0.01
Na	15	15	1.00	3.30	2.090	0.690	2.00
Ni	48	0					<0.05
P	56	52	0.003	0.017	0.0057	0.0024	0.005
Pb	63	4	0.001	0.001	0.0010		<0.001
V	48	0					<0.01
Zn	61	1	0.005	0.005	0.0050		<0.005

Source:Wilkes and Lloyd 1990

[a] Minimum detectable concentration

5.5 LIQUID WASTE DISCHARGES

5.5.1 Kispiox Band Council PE-11036

5.5.1.1 Background

Kispiox Village is located on Indian Reserve #1 on the Skeena River approximately 11.5 km upstream of Hazelton. As a result of population growth and unsuitable septic systems due to poor percolation, the Kispiox band submitted a waste permit application for an aerated lagoon system discharging to the Skeena River in September 1991.

According to the technical report for permit PE-11036 dated December 21, 1992, DFO expressed their opposition to the installation of a sewage outfall in the Skeena River based on their Environmental Assessment Review Program screening results. They expressed serious concerns about the potentially adverse impacts of the outfall construction and maintenance, and of the sewage plume on fish and fish habitat. They recommended that ground disposal be considered in order to minimize the impacts on fisheries in the Skeena and Kispiox Rivers. Ground disposal alternatives were studied and determined to be too costly. As a result the Band Council decided to continue with the aerated lagoon system plans.

The two aerated lagoons, which are in series, were designed to handle an estimated population size of 1550, which has been projected for the year 2001. Currently the population of Kispiox Village is 650.

Apparently the installation of the outfall pipe in the Skeena River went poorly, as the diffuser broke after the first installation and had to be replaced, requiring much instream work. In addition, there have been leaks in the lining of the aerated lagoons, and for this reason there have not yet been any discharges to the river (P. Lemieux, DFO, personal communication).

5.5.1.2 Permitted discharge

Permit PE-11036 was issued on November 8, 1993 and authorizes the Kispiox Band Council to discharge effluent from a municipal sewage treatment facility to the Skeena River. The maximum authorized rate of discharge is 890 m^3/day. The average authorized rate of discharge is 360 m^3/day. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD, 60 mg/L TSS and 100% survival 96-hour LC50.

The monitoring program required under permit is presented in Table 5.5. The most recent permit inspection, which was conducted on July 26, 1994, indicated that there was no positive discharge and had been none to date. Samples taken by EPP staff on November 23, 1993 from lagoon #2 show TSS of 22 mg/L and BOD of <10 mg/L, which is well below the permit limits.

5.5.1.3 Receiving environment monitoring

The Skeena River and Kispiox River support very important aboriginal and sport fisheries. Adult summer-run steelhead concentrate near the confluence of Shegunia Creek and the Skeena River between August and the following May, as well as upstream of the confluence of the Skeena and Kispiox Rivers. These fish are in a holding pattern through the winter months when river temperature and flow are at annual minimum values. There are several aboriginal gill net fishing sites on the left bank and downstream of the Skeena, intercepting migrating adult salmon in the fall. A flourishing sport fisheries exists, including considerable guide activity, developed around accumulations of adult steelhead in the area. Up to 700 anglers/day use this portion of the Skeena, a Class II river, from early July to freeze up,

In the river section near Kispiox, spawning habitat is absent, but good rearing areas for young coho salmon and trout are present year round in the vicinity of Shegunia Creek and Kispiox River. Young chinook salmon likely are not abundant due to lack of preferred habitat elements in the river channel. Young pink, chum, and sockeye salmon would be abundant in spring (May) as smolting occurs and large numbers engage in downstream migration (Technical Report PE-11036 1992).

A study carried out by fisheries biologist consultants Smith and Associates concluded that due to significant dilution and the absence of industrial or large commercial facilities as well as the absence of chlorine, the potential impacts on resident and migratory fish would be minimal (Smith 1991).

Table 5.5 Kispiox Band Council PE-11036 Monitoring Program

Parameter	Sample Type	Sampling Frequency	Reporting Frequency
Effluent Flow Rate, m3/day	Field Measurement	Continuously	Monthly
Temperature, Degrees C	Field Measurement	Monthly (M)	M
Dissolved O2, mg/L	Field Measurement	M	M
pH	Field Measurement	M	M
BOD5, mg/L	Grab	M	M
TSS, mg/L	Grab	M	M
Ortho-Phosphorus, mg/L	Grab	M	M
Organic N, mg/L	Grab	M	M
NH3 - N, mg/L	Grab	M	M
NO2 - N, mg/L	Grab	M	M
NO3 - N, mg/L	Grab	M	M
96-hour LC50	Grab	Semi-annually	S/A

5.5.1.4 Discussion

The dilution ratio was calculated for this discharge using the 7 day average 10 year low flow of the Skeena at Glen Vowell minus that of the Kispiox River (Tables 5.1 and 5.2). The dilution ration of the permitted average discharge rate is >3500:1 and dilution ratio for the maximum permitted discharge rate is >8500:1.

Data on discharge quality are not available. The monitoring program required for this permit is quite thorough, and does include toxicity testing. Toxicity within the mixing zone of this effluent is of concern to DFO because of the location of the outfall in an area heavily utilized by over-wintering adult summer-run steelhead.

5.5.2 Silver Standard Mine

5.5.2.1 Background

Silver Standard Resources Inc. contracted Bruce Geotechnical Consultants Inc. (BGC) to develop an action plan to assess the present state of tailings at the Silver Standard Mine and to determine if any reclamation is required. A report entitled Action Plan for Preliminary Investigation of Tailings at Silver Standard Mine, Hazelton, B.C., dated December 30, 1994 was submitted to the NWMDRC on February 1, 1995 for comments.

The Silver Standard Mine is located 8 km northeast of Hazelton, B.C. The mine is at 1300 feet on the northwest slope of Glen Mountain, and is accessed via the Silver Standard Road. Mineral occurrences on Glen Mountain were discovered during the active period of prospecting which resulted from the building of the Grand Trunk Pacific Railway in 1909 to 1913. High grade lead and zinc ores were shipped from the mine in 1910. In 1917 a 50 ton gravity mill was built and operated until 1920 when poor mill recovery and lower metal prices caused the mine to cease operations.

Several unsuccessful attempts were made to reopen the mine prior to 1947 when Silver Standard Resources acquired the property and built a 50 ton/day flotation mill near the 1300 level portal. Production commenced in October of 1948. By the end of production in March 1958, nearly 177,700 tons of ore had been milled, producing 37,792 wet tons of concentrate. Approximately 140,000 to 150,000 tons of tailings were produced. Assuming a settled density of 1.3 to 1.4 tonnes per cubic meter, a total tailings volume of 100,000 to 115,000 m^3 was discharged from the mill.

Tailings were discharged from a short wooden stave pipeline onto the open hillside adjacent to the mill site. The tailings formed a path 15 to 20 meters as they flowed approximately 50 m downhill to a small creek. The tailings filled the shallow narrow creek valley to a width of approximately 20 to 30 m wide as they moved downstream. The creek has subsequently cut partially through these previously deposited tailings. Tailings continued to flow downstream to partially fill a swamp. As estimated from air photos, this swamp is approximately 300 m long and 100 m wide. Given that approximately 100,000 to 115,000 m^3 of tailings are estimated to have been discharged and that they cover an area of approximately 30,000 m^2, the tailings are expected to be no more than 3 to 4 m thick through this area. Minor quantities of tailings appear to have continued downstream to a second swamp. This lower swamp is approximately 530 m long and 150 m wide, and has been flooded by beaver dams. The extent of tailings deposition under the water cover is unknown.

The flow from these swamps eventually makes its way to the Skeena River, apparently via a small creek which runs through a farmer's field prior to discharge to the river.

5.5.2.2 Receiving environment monitoring

Observations made by Silver Standard Resources in the fall of 1994 showed that tailings had oxidized to depths ranging from 5 to 20 cm throughout the tailings deposition area. This would suggest approximately 90% of the tailings remain unoxidized.

A series of water quality samples were collected on October 9, 1994. Sample sites included the 1300 level Adit, LLW1 in the creek upstream of the tailings, LLW2 in the creek below where the tailings have entered the creek, LLW3 in the creek at the outlet of the small swamp containing the tails, LLW4 in the creek downstream side to the west of a road, and LLW5 at the edge of the beaver ponds in the lower flooded swamp (BCG 1994). Data are presented in Table 5.6.

5.5.2.3 Discussion

The minimum detectable concentrations for arsenic, cadmium, copper and lead shown in Table 5.6 are too high to assess potential aquatic life impacts from these discharges. It is apparent however, that there is ARD generation from both adit drainage and the unconfined tailings. Zinc exceeds water quality criteria for aquatic life at the 1300 Adit, LLW2 in the creek below the tailings, and LLW3 in the creek at the outlet of the small swamp containing the tails. The cadmium criterion is exceeded at LLW2.

Table 5.6 Water quality summary in the vicinity of Silver Standard Resources, October 9, 1994

Parameter	1300 Adit	LLW1	LLW2	LLW3	LLW4	LLW5
pH	7.17	6.97	7.21	7.18	7.15	6.7
Conductivity (uS/cm)	660	663	665	608	602	260
Hardness (mg/L as CaCO3)	307	295	306	275	272	110
TDS mg/L	528	531	532	487	482	208
TSS mg/L	<1	18	7	<1	<1	10
Total Alkalinity (as CaCO3)	272	225	222	222	200	115
Total Acidity mg/L	10.6	29.7	19.2	12.5	7.7	10.6
Sulphate mg/L	129	146	168	166	147	23
Total As mg/L	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Diss. As mg/L	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Cd mg/L	<0.025	<0.025	0.03	<0.025	<0.025	<0.025
Diss. Cd mg/L	<0.025	<0.025	0.03	<0.025	<0.025	<0.025
Total Cu mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Diss. Cu mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Total Fe mg/L	<0.03	0.06	<0.03	0.04	0.05	0.73
Diss. Fe mg/L	<0.03	0.06	<0.03	0.03	0.05	0.6
Total Pb mg/L	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Diss Pb mg/L	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Total Zn mg/L	1.35	0.17	3.57	1.16	0.87	0.04
Diss. Zn mg/L	1.18	0.16	3.12	1.04	0.79	0.03

The fact that pH is not depressed and alkalinity values remain high indicates the presence of considerable amounts of neutralizing minerals in contact with both drainage waters and tailings. The characteristic of relatively high zinc concentrations in neutral drainage waters has been observed before in western Canadian ores (SRK 1989). When acid drainages encounter mineralization with high neutralization potential, most metals, such as copper, precipitate out to low levels as the ARD is neutralized. However zinc tends to remain in solution at relatively high concentrations until the pH is raised to values above 9.5. It is suggested that 90% of tailings remain unoxidized, indicating the potential for long-term ARD generation from this site.

The preliminary investigation for this site is continuing.

5.5.3 Village of Hazelton PE-303

5.5.3.1 Background

The Village of Hazelton and the Gitanmaax Indian Reserve No. 1 are located at the confluence of the Skeena and Bulkley Rivers approximately 100 km northeast of Terrace. The two communities are served by a common wastewater treatment plant located in Hazelton at the end of Government St. adjacent to the Hazelton/Gitanmaax boundary.

The existing plant was constructed in 1972 and consists of a package activated sludge treatment plant housed inside a metal building. Treated wastewater from the plant is discharged to the Skeena River (KWLG&S 1993).

The Village has not been able to comply with the permit flow requirement of 455 m^3/day due to excessive groundwater infiltration (up to 50% of the flow) and due to an increased number of houses connected on the Reserve. Due to two bypasses in December 1992, the Village was required to install an overflow alarm in the lift station.

In order to address these deficiencies and allow for continued growth of the Hazelton/Gitanmaax communities, the Village of Hazelton has been pursuing alternative treatment options as well as funding sources. Population being served by the treatment plant as of 1992 was 1,190. This number is expected to increase to 2,170 by the year 2012.

5.5.3.2 Permitted discharge

Permit PE-0303 was originally issued on September 19, 1969 and most recently amended on July 21, 1983. The permit allows for a maximum discharge rate of 455 m^3/day with effluent characteristics equivalent to or better than 100 mg/L BOD and 100 mg/L TSS. (The BOD and TSS requirements under this permit have been set in compliance with Pollution Control Objectives for discharges with high dilution ratios such as this one.)

A discharge flow rate measurement and effluent monitoring for BOD, TSS and fecal coliforms is to be completed and reported quarterly. Table 5.7 summarizes effluent quality from January 1992 to December 1994. The permitted discharge flow rate was exceeded occasionally up until November 1993 and since then has been exceeded consistently. BOD and TSS have remained in compliance for most of the period shown.

Table 5.7 Effluent quality Hazelton Sewage Treatment Plant PE-303, 1992-1993

Date	TSS mg/L	BOD mg/L	FECAL COL MPN/100 ml	Flow Avg m3/day	Date	TSS mg/L	BOD mg/L	FECAL COL MPN/100 ml	Flow Avg m3/day
01/24/92	45	55	5000	486	01/01/94				546
02/01/92				530	02/01/94				574
03/01/92				513	03/01/94				648
04/13/92	20	80	900000	437	04/05/94	35	23	170000	604
05/30/92				498	05/01/94				556
06/30/92				518	06/12/94	26	22	23	580
07/13/92	33	66	900000	461	07/01/94				569
08/31/92				440	08/01/94				606
09/30/92	103	88	60000	423	09/01/94				590
10/31/92				451	10/18/94	13	5	170000	548
11/30/92				404	11/01/94				548
01/04/93	44	44	700000	440	12/13/94	49	29	1700000	570
01/31/93				526					
02/28/93				448.5					
03/31/93	22	10	700000	634					
04/30/93				498					
05/31/93				498					
06/30/93		31	2400	544					
07/31/93				521					
08/31/93				538					
09/30/93				514					
10/31/93				441					
11/03/93				542					
12/01/93	10	52	240000	606					

EPP assessed toxicity of the Hazelton/Gitanmaax effluent sampled May 20, 1993 using three different bioassay methods: rainbow trout (RBT) 96-h LC50, Daphnia 48-h LC50, and 5 and 15 minute Microtox EC50. The effluent was non-toxic to Daphnia and in the Microtox assay. Results were inconclusive for rainbow trout because of insufficient sample size (reported LC50 <30%).

5.5.3.3 Receiving environment monitoring

There is no receiving environment monitoring required for this permit.

5.5.3.4 Discussion

The average daily discharge reported by the Hazelton STP for 1994 is 588.5 m^3/day, or 0.007 m^3/s. The estimated 7 day average 10 year low flow in the Skeena at Glen Vowell of 53.4 m^3/s (Table 5.2). The dilution ratio calculated for this discharge is >7600:1. The Skeena River is joined by the Bulkley River immediately downstream of this discharge, providing additional dilution. Therefore it appears that sufficient dilution is available at this site to mitigate impacts from a properly treated sewage discharge.

The limited data available suggests that effluent quality, although within permit limits, could be improved at this plant. The occasional bypass of the treatment plant altogether is obviously not desirable, and Hazelton should be encouraged to find alternative treatment options.

Toxicity within the mixing zone of this effluent to over-wintering adult steelhead and resident trout is a concern at this site as well. It is suggested that, at minimum, the monitoring program for this discharge should be modeled after that of the Kispiox STP, with monthly sampling for BOD, TSS and nutrients, and semi-annual or quarterly sampling for toxicity with RBT 96 hour LC50. Toxicity sampling should occur during summer and winter low flow periods.

5.6 SUMMARY AND REVIEW OF MONITORING NEEDS

The Kispiox valley was one of the earliest areas of settlement, and agriculture and forestry are still the prominent land-use activities in the watershed. The Kispiox and Skeena River are Class II angling streams, the Kispiox being renowned for its record sized summer-run steelhead.

5.6.1 Water quality assessment

The Kispiox is a soft water river, with neutral to slightly alkaline pH, which has clear, slightly coloured waters for most of the year. Alkalinity is in a range which would provide moderate buffering from acidic inputs. TSS loadings are much higher during freshet than during the remainder of the year. Nutrient concentrations are low. Mean total metals levels are generally very close to the MOELP criteria for the protection of aquatic life at the hardness levels present. Dissolved metals levels are often less than or equal to detection limits.

5.6.2 Interaction of agriculture and water quality

The Kispiox is a rather unique valley, in which sport fishermen, who have traveled from around the world, climb farmer's fences and cross cultivated fields to reach their destination stream. It is surprising, then, that there has been no evaluation of interactions of agriculture and water quality in the Kispiox, despite the presence of an estimated 20-30 ranches with approximately 500 breeding cows. Most of this activity is focused along the mainstem Kispiox River. There are about 10 range tenures, located mainly on tributary streams. Grazing permits are issued for over 200 cattle, 400 sheep and a few horses.

Monitoring needs.— Unless careful stream protection practices are followed, runoff from winter feedlots and areas of heavy cattle use can affect water quality by direct toxic effects, by the addition of nutrients and bacteria, and by creating oxygen demand. Improper livestock grazing can also result in a decline in streambank vegetation and stability. One monitoring need for this reach of the watershed is an assessment of the interaction of agriculture and water quality. See section 12 for further discussion.

5.6.3 Interaction of forestry and water quality

5.6.3.1 Stream protection practices

An assessment of stream protection practices by the forest industry in the Kispiox was conducted in the mid-1980's. It was noted that, despite the fact that the Kispiox River itself was famous for its run of summer steelhead trout, there had never been a detailed evaluation of logging-fisheries interactions in the watershed. Field inspections of streamside areas in the Kispiox indicated that, in areas where intact riparian reserves had been left, the streams were well protected and there was very little evidence of blowdown.

A number of machine reserves were examined and their effectiveness varied depending upon site characteristics. Some reserves provided adequate protection and others were not as effective at maintaining the channel stability and ensuring continued recruitment of large woody debris. In the worst example, a fish-bearing creek and its tributary were logged across and major clean-up of debris in the stream was ordered.

Roads were identified as the prime cause of stream siltation in the Kispiox. DFO staff indicated a concern that higher water temperatures due to streamside logging would not be desirable in the many lake-headed streams in the Kispiox.

An MOF forest hydrology analysis indicated that the Kispiox watershed was too much of a mosaic of timber ages and types to result in a sufficiently large proportion of the watershed being logged at one time to alter the run-off regime. However, some concern for earlier seasonal run-off due to altered snowmelt patterns on small extensively logged streams was expressed by fisheries personnel.

5.6.3.2 Kispiox LRMP

Because of public concern for the preservation of the upper areas in the Kispiox valley, a planning process for the Kispiox began in 1989. A Consensus Management Direction was completed in 1994, recommending a change in timber harvesting methods to include smaller clearcuts, emphasizing selection systems and dispersing harvests through the supply area. Protection of water quality and enhancement of tourism and recreation were emphasized in the plan. A Wilderness Area at Swan Lake, in the headwaters of the Kispiox River, was recommended to PAS.

5.6.3.3 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is a major land-use activity in this reach. The only review of stream protection practices in the mid 1980's identified instances of stream degradation in the Kispiox watershed and identified road building and lack of road maintenance as the main source of sediment to streams. The FPC is expected to improve compliance with stream protection guidelines. Rehabilitation of streams which were damaged by past practices is the mandate of the Watershed Restoration Program.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring, under the guidance of the Kispiox LRMP monitoring committee, is also necessary to ensure that management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.

5.6.4 Interaction of mining and water quality

An action plan has been formulated to address the ongoing ARD generated by old tailings at the abandoned Silver Standard Mine northeast of Hazelton. This lead-zinc mine operated in the early 1900's, and again through the 1950's. Tailings were discharged from the mill onto an open hillside, flowed downhill to fill a narrow creek valley, then flowed down to partially fill a swamp system which drains to the Skeena River.

There is insufficient monitoring data at this time to assess this discharge and a preliminary investigation is ongoing. The limited monitoring data available show elevated zinc concentrations in drainage waters and indicate the potential for long-term ARD generation from unoxidized tailings on site.

5.6.5 Interaction of urban developments and water quality

5.6.5.1 Kispiox sewage treatment plant

Sufficient data are not yet available for this plant to assess the discharge relative to permit requirements. Concern has been raised by DFO, however, concerning the location of this discharge in an area of the Skeena River which is known to be heavily utilized by over-wintering steelhead trout. While the dilution ratio is substantial, there is concern that over-wintering resident trout and steelhead may be attracted into the effluent mixing zone by warmer water temperatures, and thus be exposed to undiluted effluent.

It is important that every effort be made to achieve non-toxic effluents when discharging into important steelhead trout over-wintering habitat such this. It should be noted that both summer-run steelhead and their over-wintering habitat are rare, making this a special situation. See section 12 for further discussion of monitoring needs for municipal sewage treatment plant discharges.

5.6.5.2 Hazelton/Gitanmaax sewage treatment plant

The Village of Hazelton/Gitanmaax sewage treatment plant, which also discharges to the Skeena River, has been operating poorly for several years, due to increased population and excessive groundwater infiltration. The occasional bypassing of the treatment plant altogether is obviously not desirable, and Hazelton should be encouraged to find alternative treatment options.

The dilution ratio at this site is approximately 7600:1 and is even greater a short distance downstream at the confluence with the Bulkley River. It appears that the dilution available in the Skeena River at Hazelton would be sufficient to mitigate impacts from a properly treated sewage effluent. The limited data available suggests that effluent quality, although within permit limits, could be improved at this plant.

Toxicity within the mixing zone of this effluent to over-wintering adult steelhead and resident trout is a concern. The question of over-wintering resident trout and steelhead in the mixing zone of this effluent should be specifically addressed in the planning for degree of treatment and outfall configuration for any new facility.

It is suggested that, at minimum, the monitoring program for this discharge should be modeled after that of the Kispiox STP, with monthly sampling for BOD, TSS and nutrients, and semi-annual or quarterly sampling for toxicity with RBT 96 hour LC50. Toxicity sampling should occur during summer and winter low flow periods.

6. MORICE RIVER AND LAKE

The Morice River heads in the Tahtsa Ranges and flows north easterly across portions of the Nechako Plateau to join the Bulkley River near Houston (Figure 6.1). The Morice River watershed contains numerous large lakes, including Morice, Nanika and Kidprice. Major tributaries to the Morice are the Nanika River, Gosnell Creek and Owen Creek, which drains Owen Lake.

The Morice River has very high fisheries values and supports steelhead trout, chinook and pink salmon and serves as a migration pathway for sockeye and coho salmon. Heavily used spawning areas are found throughout the river. The Morice, including tributaries, is a Class II angling stream which is heavily used by local and visiting anglers, hunters, boaters and campers. (See section 2.2.4 for explanation of classified waters.) In 1985 the Morice was listed as a candidate in the Provincial Recreation Corridors Program.

6.1 HYDROLOGY

Hydrometric stations are located on the Nanika River at the outlet of Kidprice Lake (Station 08ED001), on the Morice River at the outlet of Morice Lake (08ED002), and just upstream of the confluence of the Bulkley River near Houston (08ED003 - discontinued) (Figure 6.1). Environment Canada is undertaking a review of the hydrometric network. Both remaining stations on the Morice may be subject to discontinuation unless funding support from other agencies is found.

Monthly mean, maximum and minimum discharge for Station 08ED002, Morice River near Houston (located near the outlet of Morice Lake) are shown in Table 6.1 and Figure 6.2. The drainage area of the Morice at the mouth is 4,279 km^2, compared to 1,740 km^2 for the upper Bulkley River. The Morice contributes more than 90% of the flows to the Bulkley River at their confluence near Houston and up to 99% of flows at certain times (Nijman 1986).

6.2 LAND USE HISTORY

The Morice watershed is within the land claim area of the Wet'suwet'en. There are no modern settlements within the Morice watershed and only a few grazing tenures. Forestry and mining exploration are the main human activities.

6.2.1 Forestry

Logging in the Morice watershed expanded from small scale selective and strip logging operations with portable mills in the late 1960's to primarily clearcut logging used today. When constructed in 1970, the Northwood Pulp and Timber mill located near the Morice River, was the largest sawmill in British Columbia.

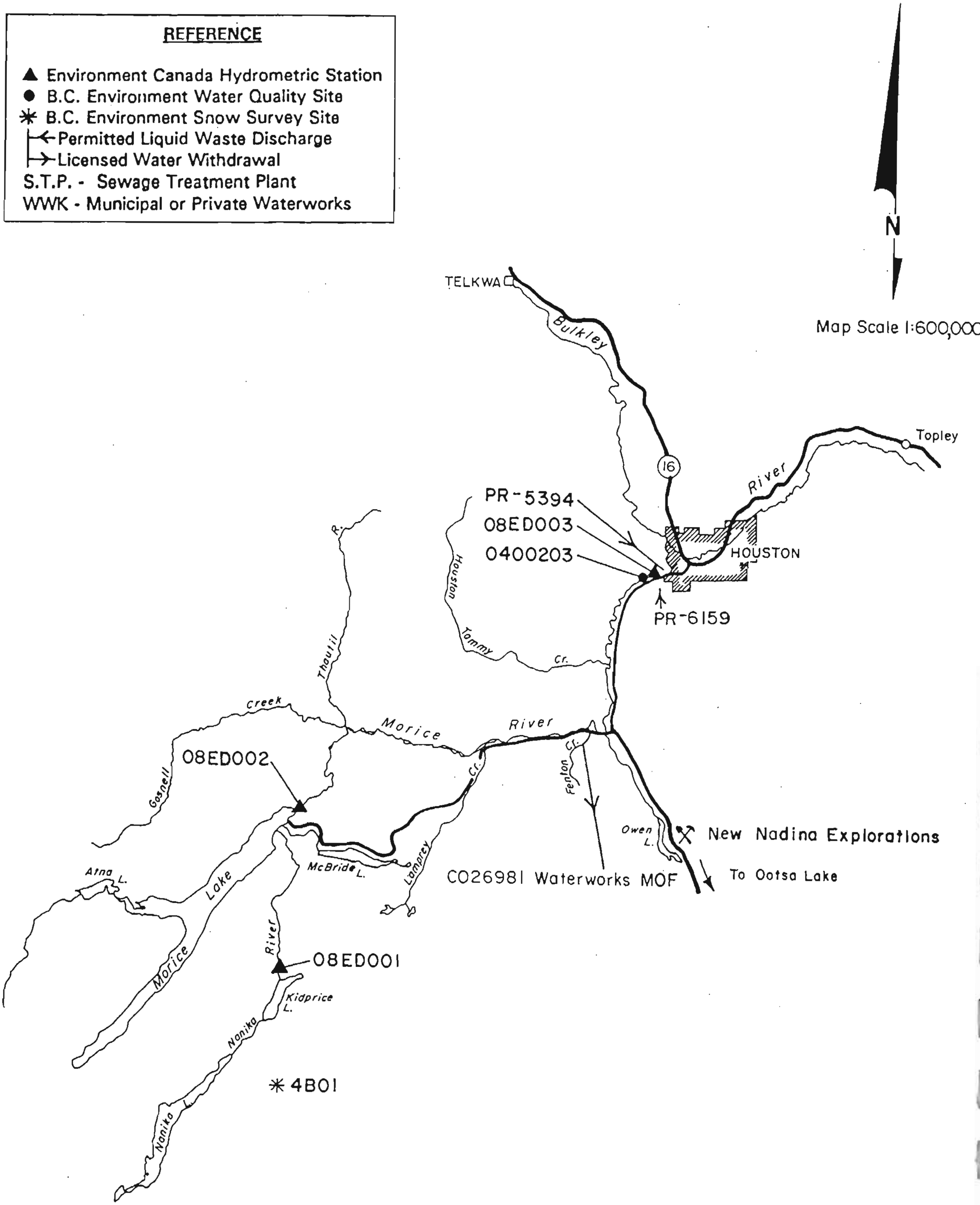


Figure 6.1 Morice River and Lake

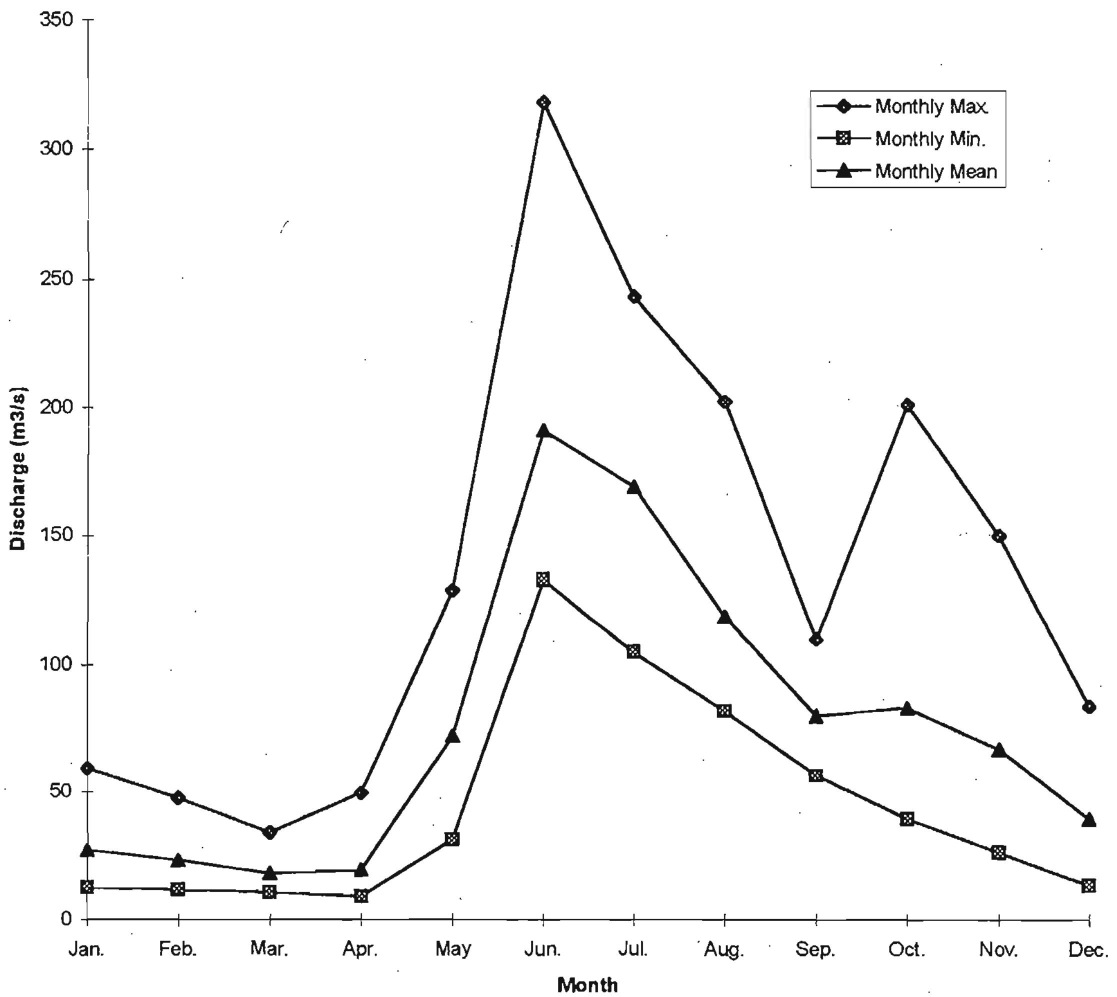
Table 6.1 Monthly discharge summary Morice River [at outlet of Morice Lake], Station 08ED002

Latitude: 54 07 05 N
Longitude: 127 25 26 W
Drainage Area Gross: 1910 km2
Period of Record 1961-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	59.2	47.3	33.7	49.3	129	318	243	202	110	201	150	83.6
Monthly Min.	12.2	11.3	10.3	8.7	30.9	133	105	81.7	56.1	39.3	25.7	13.2
Monthly Mean	26.8	22.8	17.7	18.9	71.9	191	169	119	79.8	82.8	66.6	39.2

Average 7-day, 10-year low flow is 9.46 m3/s with 95% confidence limits of 8.40 and 10.7.

Figure 6.2 Discharge envelope Morice River [at outlet of Morice Lake], Station 08ED002



Houston Forest Products and Northwood Pulp and Timber, both with milling facilities in the District of Houston, are the main operators in the Morice watershed. The Morice River Forest Service Road parallels the Morice River south of Houston for its entire length and the watershed has been subjected to active road development and logging for many years. The valley is well-accessed and contains a large proportion of highly productive, valley-bottom stands. In 1983 a forest fire burned a large tract of forest on both sides of the river. The fire, along with severe wind damage (1984) and insect pest outbreaks led to a dramatic increase in salvage logging.

6.2.1.1 Stream protection practices

Stream protection practices in the interior of the Prince Rupert Forest Region (Bustard and Wilford 1986) are reviewed in section 1.3.4. Bustard (1986*b*) conducted an assessment of stream protection practices in the Morice TSA, and others, using a combination of interviews and field inspections. There are more sensitive fisheries sites in active logging areas in the Morice TSA than in other interior districts in the region. Logging operations around tributaries of the Bulkley and Morice rivers encompass high value salmon and steelhead streams. Joint inventories supported by Northwood and MOELP had been undertaken in the Gosnell Creek drainage to aid in forest development planning.

Bustard found extensive logging in the vicinity of streams in the Morice TSA, and many examples of different streamside treatments. There had been a shift away from total riparian reserves along streams in recent years due to windthrow problems in the reserves that had been left (with forest companies going back into the reserve strips to remove the blowdown in subsequent years). As in other districts in the interior, there had been a shift towards the use of machine reserves at accessible sites on fish creeks. Most forestry and fisheries personnel interviewed indicated that they were satisfied that machine reserves provided adequate streamside protection.

Field observations of streamside reserves indicated mixed results. A reserve left below the topographic break on Lamprey Creek was very effective in maintaining the immediate streamside area and in ensuring the continued recruitment of large stable debris into the stream. However, there was some evidence of windthrow and subsequent beetle attack.

Sediment from roads, due to both construction and inadequate maintenance, was cited as the main impact from logging activities on streams in the Morice. As well, blockage of fish movements due to poor culvert installation and maintenance was cited as a problem. These concerns were quite widespread due to the distribution of steelhead trout and coho salmon through many of the smaller tributaries in the district. A number of special procedures such as settling ponds in ditches at bridge approaches had been used at various locations in the Morice TSA. However, erosion control measures such as grass-seeding and cross-drains on roads (installed after the operations are complete) were seldom used at any sites in the district.

Field inspection in the Morice revealed considerable inconsistency in that careful measures to prevent erosion and streambank damage that were carried out at the streamside (measures that were usually quite effective in achieving objectives) were often offset by a lack of erosion control measures on roads, skid trails or fire guards. There was a general lack of water bars on roads where operations had finished - particularly on winter roads and steeper skid trails. For example, the benefits of directionally felling away from a small creek tributary to Nado Creek were offset by a skidder crossing at the lower end of the creek that diverted the creek down the road (eroding the road) into a second channel 500 m downstream.

The author noted a growing awareness of the importance of some wetlands for coho rearing and of the need to maintain adequate access into these areas for juvenile fish movements. In the past, some of this habitat, for example along the Morice River road, has been drained to enable easier road maintenance.

Concerns were raised over the rate-of-cut in the Cedric Creek watershed, a small steelhead tributary of the Morice River. Logging was curtailed due to what was considered an excessive amount of logging already present.

6.2.1.2 Watershed assessment of Cedric, Lamprey, Fenton and Owen Creeks

A survey of logging related impacts on four tributaries of the Morice River was conducted by Saimoto (1994) under the newly established Watershed Restoration Program. These four tributaries of the Morice were chosen for initial assessment due to the presence of past and present logging activities, plus the availability of historic data from the late 1970's and early 1980's. The author states that, in general, because of the gentle rolling nature of the terrain, erosion problems were relatively minor. However about half of the sites examined had been impacted by roads or cutblocks in some manner.

Due to the timing of the study (autumn), many of the small class 1 headwater streams were dry. However, this is where most of the problems related to logging were found. Small creek beds tended to be located adjacent to or in cutblocks, with little or no riparian vegetation remaining around the creek bed. Large woody debris was sometimes high, and erosion from banks of the creek was often evident. Re-examination of many sites during higher runoff periods (in the spring) was recommended, as well as interim recommendations for restoration of impacted sites.

Cedric Creek.— Cedric Creek was dry at the time of the survey. However, previous researchers (Morris and Eccles 1975, cited in Saimoto 1994) had reported Cedric Creek as being a relatively large creek at this site and productive for rainbow trout. The total lack of riparian vegetation along Cedric Creek for about 60 m immediately downstream of the crossing of a main logging road was thought to increase water temperature and likely contribute to decreased water flow during the dry season. Replanting of riparian vegetation along this section of the stream was recommended.

Lamprey Creek.— Lamprey Creek and its tributaries offer some excellent habitat for steelhead and other salmonids, although Bustard (1993, cited in Saimoto 1994) reports a decrease in juvenile steelhead numbers from the early 1980's to present. Only minor problems related to past logging practices were found in the Lamprey system. Most of the problems were related to roads and road construction rather than to cutblocks. Logging roads and their construction have increased the amount of debris in the creek, and have led to an increase in siltation, particularly during higher runoff periods. Recommendations at various sites included grass seeding and replanting of riparian vegetation. It was also suggested that when roads are deactivated by culvert or bridge removal, the man-made structure should be completely removed from the streambed, and exposed soil reseeded. In some instances culverts had been left lying in or near the stream following deactivation.

Fenton Creek.— A culvert in Fenton Creek at the Morice River Road presented a barrier to fish passage to the upstream sections of creek, at least in some flows. In addition, a sharp turn in the Morice River Road at this location was contributing to siltation of Fenton Creek (by direct drainage from the sloping road surface). Mowing of riparian vegetation in order to increase visibility at the turn also leads to further destabilization of the bank. It was suggested that the Morice River Road crossing at Fenton Creek should be assessed by a hydrologist and engineer for recommendations as to the alteration of the creek crossing to reduce siltation, erosion and to allow for growth of riparian vegetation on the downstream side of the creek. In addition, the alternative crossing should provide passage for fish at all water levels. Culvert installation was recommended for at least two old road crossings and bridge repair was recommended for a new road crossing in the headwaters of Fenton Creek.

Owen Creek.— Owen Creek has been identified as an important tributary to the Morice for the production of steelhead and coho. Since the replacement of the culverts with a bridge at the Morice River Road crossing, accessibility of the upper reaches of Owen Creek has been ensured. Most of the problems identified in this system appeared to be related to siltation from logging roads. Recommendations included settling ponds in the roadside ditches, and stabilization of streambanks with rip-rap and grass seeding. The practice of logging and slashburning to the streambank of the smaller tributaries of Owen Creek was noted. In this area, logging close to the edge or into gullies had resulted in windthrow which increased the debris in the creek. It was suggested that cutblocks remain at least 3 m away from the edge of gullies rather than logging up to the topographical break.

6.2.1.3 Morice River Corridor LRUP

In 1985 the Morice River was proposed as a candidate in the Provincial Recreation Corridors Program. A corridor planning process was started and in 1988 an options report, concentrating on recreation and landscape values, was reviewed by the planning committee. After reviewing the Options Report the planning committee decided that more information was needed and that the plan should address a wider range of resource issues. The committee also reached a consensus that the Morice River should not be recommended for registration as a Recreation Corridor as greater local control and management flexibility could be achieved without this status.

The Morice River LRUP was completed in 1992. The LRUP establishes a narrow zone, varying between 0.3 and 1.5 km, encompassing the river floodplain and immediate upland, which is to be managed for maintenance of fish, wildlife and recreation values. Timber production is not a management objective, and the area is removed from the working forest land base. No pesticides or fertilizers will be applied. Where possible no roads or landings will be built, and access trails will be deactivated after use. The remainder of the planning area is divided into various less restrictive management zones.

A process to develop an LRMP for the entire Morice TSA is underway. The LRMP will be a higher level planning process which will incorporate the Morice corridor LRUP.

Monitoring.— MOF maintains the primary responsibility for monitoring the effectiveness and compliance of the guidelines established by the LRUP. The Morice LRUP committee will reconvene approximately 12 months after approval of the guidelines to conduct a technical review.

6.2.2 Mining

In addition to numerous mineral exploration sites, the Silver Queen Mine (located on the east side of Owen Lake) operated briefly in the 1970's (see section 6.5.1).

6.2.3 Kemano Completion Project

The original Alcan Aluminum Co. Ltd. Kemano Completion Project of the mid-1980's proposed, in part, damming the Nanika River at the outlet of Kidprice Lake and diverting about 62% of the mean annual flow via tunnel to the Nechako Reservoir and the Alcan turbines at Kemano. The Nanika-Kidprice portion of the project was later dropped as the result of a 1987 agreement between the Federal and Provincial governments and the company. Following the 1987 agreement, the company proceeded only with the portion of the project affecting flows in the Nechako River, in the Fraser River drainage. In 1994 the British Columbia government announced that the entire Kemano Completion Project had been canceled.

6.3 WATER WITHDRAWALS

Licensed water withdrawals from Morice River and Lake are summarized in Table 6.2. Water use is low in this reach, totaling 128 m^3/d. The 7 day average 10 year low flow of the Morice River is 9.46 m^3/s with 95% confidence limits of 8.40 and 10.7 (Table 6.1). The licensed water withdrawals within this reach total 0.001 m^3/s, and are many orders of magnitude less than available water supply.

Table 6.2 Licensed water withdrawals Morice River and Lake

Input streams							
Domestic/stock watering			Work camp				
GD	m3/d	m3/s	License	Licensee	GD	m3/d	m3/s
(9 licenses)			C026981	Ministry of Forests	7000	31.8	3.68E-04
21200	96.4	1.12E-03		(Fenton Creek)			

6.4 WATER QUALITY AND AQUATIC RESEARCH

Water Quality Objectives for the Morice and Bulkley Rivers are discussed in Section 7.4.2 (upper Bulkley River).

6.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly 1983 - 1987 from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Summary water quality data for the Morice River station 0400203 (Figure 6.1) are found in Table 6.3. This site was generally sampled once per month for five years from 1983-1987.

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

Morice River water is soft, with a mean hardness of 32 mg/L $CaCO_3$, with pH near neutral. Mean alkalinity (23.4 mg $CaCO_3$/L), a measure of pH buffering capacity, is low. An alkalinity of less than 20 mg $CaCO_3$/L indicates a waterbody would be sensitive to acidic inputs. Morice River water is typically very clear, although TSS readings can be high during freshet. Conductance and dissolved solids are very low. The Morice has the least coloured waters of the seven Skeena watershed sites monitored. Low colouration and low organic carbon (mean=5.6 mg/L) suggest that there is little organic input from swamps and bogs in the drainage. Nutrient levels are extremely low, in many cases less than the detection limits. The range of total metals levels often exceed the criteria levels for protection of aquatic life at the hardness levels measured and mean total metals are often near the criteria levels. However, dissolved metals levels are generally less than the detection limits.

Table 6.3 Water quality summary Morice River at Houston, Site 0400203

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	20	9	5	30	12.2	9.1	5
pH	55	55	6.7	7.7	7.27	0.20	7.3
Conductance (umhos/cm)	56	56	43	127	52.6	12.1	50
Total Residue (mg/L)	56	56	28	193	53.8	37.3	40
Filterable Residue (mg/L)	17	17	25	55	37.4	9.3	34
Non-filterable Residue (mg/L)	49	43	1	149	16.6	32.2	3
Turbidity (NTU)	53	53	0.5	44.0	5.06	8.62	1.6
Alkalinity (mg/L)	55	55	18.6	57.5	23.40	5.76	21.7
Hardness Total (mg/L)	7	7	18.9	98.1	32.01	29.23	21.1
Hardness Dissolved (mg/L)	11	11	17.9	24.9	21.72	2.42	22.2
Total N (mg/L)	21	21	0.02	0.27	0.120	0.070	0.10
T.K.N. (mg/L)	55	54	0.02	0.03	0.095	0.063	0.07
Ammonia (mg N/L)	55	17	0.005	0.024	0.0082	0.0047	<0.005
NO2 + NO3 (mg N/L)	55	44	0.02	0.11	0.038	0.018	0.03
Total Carbon (mg/L)	34	34	4	15	7.4	3.0	6
Organic Carbon (mg/L)	22	17	1	8	2.2	2.0	1
Inorganic Carbon (mg/L)	55	55	4	15	5.6	1.7	5
Chloride (mg/L)	18	3	0.5	0.5	0.50		<0.5
Ortho P (mg/L)	50	0					<0.003
Silica (mg/L)	14	14	3.1	6.0	4.10	0.87	3.9
Sulfate (mg/L)	14	14	2.2	3.7	2.81	0.36	2.9
Fluoride (mg/L)	3	1	0.17	0.17	0.17		<0.1

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	51	47	0.02	3.06	0.390	0.594	0.10
As	78	5	0.001	0.003	0.0016	0.0009	<0.001
Ca	56	56	6.33	18.90	7.876	1.799	7.41
Cd	78	2	0.0005	0.0021	0.00130		<0.0005
Co	56	2	0.11	0.14	0.125		<0.1
Cr	56	2	0.01	0.01	0.01		<0.01
Cu	56	41	0.001	0.007	0.0022	0.0014	0.001
Fe	56	56	0.02	3.53	0.425	0.644	0.17
Mg	56	56	0.54	19.60	1.320		0.87
Mn	56	25	0.01	0.15	0.040	0.038	<0.01
Mo	56	1	0.02	0.02	0.02		<0.01
Ni	56	0					<0.05
P	56	54	0.003	0.142	0.0174	0.0256	0.008
Pb	56	30	0.001	0.007	0.0023	0.0013	0.001
V	56	1	0.01	0.01	0.010		<0.01
Zn	56	19	0.005	0.050	0.0147	0.0145	<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 6.3 (continued) Water quality summary Morice River at Houston, Site 0400203

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	56	32	0.01	0.17	0.053	0.035	0.20
As	78	0					<0.001
B	56	0					<0.01
Ba	56	51	0.01	0.03	0.013	0.005	0.01
Ca	56	56	5.59	17.60	7.542	1.690	7.18
Cd	77	0					<0.0005
Co	56	0					<0.1
Cr	56	0					<0.01
Cu	78	11	0.001	0.003	0.0014	0.0007	<0.001
Fe	60	58	0.01	0.16	0.051	0.040	0.03
K	14	14	0.20	0.40	0.290	0.061	0.30
Mg	56	56	0.54	3.04	0.860	0.380	0.78
Mn	56	0					<0.01
Mo	56	0					<0.01
Na	14	14	0.80	2.00	1.210	0.340	1.10
Ni	56	0					<0.05
P	55	37	0.003	0.012	0.0052	0.0023	0.004
Pb	78	6	0.001	0.007	0.0023	0.0023	<0.001
V	56	0					<0.01
Zn	77	3	0.005	0.010	0.0070	0.0026	<0.005

Source: Wilkes and Lloyd 1990
[a] Minimum detectable concentration

6.5 LIQUID WASTE DISCHARGES

6.5.1 New Nadina Explorations Ltd. (Formerly Silver Queen Mine)

6.5.1.1 Background

Silver Queen Mine, now owned by New Nadina Explorations Ltd., is located immediately east of Owen Lake about 49 km southwest of Houston. The Silver Queen property has been the site of prospecting activity since mineralization was first discovered in Wrinch Creek Canyon in 1912. Several groups carried out extensive exploration programs, as well as drifting, raising and trenching. In 1972, a mining operation to support a 500 tonne per day mill was completed. However, due to management problems, the operation ceased production in 1973.

Historically this site has been documented to show elevated levels of zinc (in the order of 50 mg/L and higher) with neutral pH in the discharges during freshet. These high levels remain for approximately one week and then gradually return to more typical levels of 1-2 mg/L. As a result of a pollution abatement order issued to the company in the spring of 1990, a number of treatment options were studied and eventually diversion of the drainage to a wetland area was found to be the most practical option.

The Silver Queen Mine is drained by Wrinch Creek and by Cole Creek. Both creeks drain into the east side of Owen Lake. Water from the two existing mine adits drain into the tailings pond and thence to the wetland. Seepage from the waste rock piles on the west side of the property flows through another smaller wetland area before entering a culvert draining to Owen Lake.

6.5.1.2 Receiving environment monitoring

Owen Lake has high fisheries capability and contains populations of Dolly Varden char, rainbow trout, mountain whitefish, burbot and several species of coarse fishes. There is good public access to Owen Lake and it is a popular recreational fishery. Owen Lake drains to the north via Owen Creek for 12 km to its confluence with the Morice River.

A review of 1990-1994 monitoring data (Table 6.4) indicated that the concentrations of zinc in the adit drainage after wetland treatment (Site #4) were several orders of magnitude reduced from the adit discharge levels. Total zinc concentrations from the adit 1990-1994 averaged 13.2 mg/L, with maximum concentrations during freshet (maximum 40.1 mg/L April 6, 1994). This zinc is largely dissolved (average 11.4 mg/L). The adit drainage is slightly alkaline (average pH 8.2, maximum 9.0) Copper concentration is 0.225 mg/L average and 1.18 mg/L maximum. Iron concentration is 2.43 mg/L average and 7.16 mg/L maximum. After diversion through a tailings pond and a wetland, total zinc concentrations at Site #4 drainage into Owen Lake average 0.056 mg/L.

In 1993 high levels of zinc and copper were discovered at another culvert (Site #5). It was determined that the seepage from the waste rock piles on the west side of the property were contributing to this contaminated runoff and that the smaller wetland area through which it was draining was not sufficient for treatment. At the Site #5 drainage into the lake, zinc averages 8.1 mg/L, again mostly in the dissolved form. Dissolved copper concentrations at Site #5 were also elevated, 0.018 mg/L average and 0.274 mg/L maximum.

A memo to file dated December 30, 1994 stated that the contaminated runoff discovered in 1994 had been diverted to the lower end of the tailings area for treatment in the main wetlands area.

Although there has been some monitoring of the discharges from the property, there has been no receiving environment monitoring in affected creeks or Owen Lake.

6.5.1.3 Discussion

High zinc concentrations in alkaline mine drainages has been observed before at mines in western Canada. When acid rock drainage encounters alkaline mineralization, such as limestone deposits, most of the metals in the ARD will precipitate out. The exception is zinc, which remains in solution until the pH is raised to values above 9.5.

The criterion for the protection of aquatic life for zinc is 0.03 mg/L (Appendix 1). The criterion for copper is dependent on hardness, but assuming hardness <50 mg $CaCO_3$/L (Morice River hardness), the criterion would be $\leq$0.002 mg/L. The very high zinc and copper concentrations in drainage from the adit and waste rock dump are definitely within a range which could be expected to be toxic to aquatic life, if untreated. The 1994 data indicates the discharge from the wetland treatment (Site #4) was improved, but still exceeded criteria. It appears unlikely that diverting additional contaminated drainages from the waste rock dump to the wetland will improve this situation.

Table 6.4 Zinc concentration in adit discharge, tailings pond and runoff, Silver Queen Mine 1990-1994

Zn (Total) (mg/L)						Zn (Diss)(mg/L)				
Date	Site #1 Adit Discharge	Site #2 Inlet Tailings Pond	Site #3 Outlet Tailings Pond	Site #4 Road Culvert	Site #5 Upper Road Culvert	Site #1 Adit Discharge	Site #2 Inlet Tailings Pond	Site #3 Outlet Tailings Pond	Site #4 Road Culvert	Site #5 Upper Road Culvert
90/04/19	34.30		1.580			33.20		1.550		
92/05/12	10.60		0.335							
92/06/19	6.95	2.14	0.335	0.046		4.20	2.14	0.283	0.037	
92/07/09		0.54	0.081				0.37	0.079		
92/08/09		0.56	0.030	0.021			0.36	0.030	0.016	
92/10/23	2.88	1.02	0.500	0.093		2.61	1.08	0.496	0.091	
93/04/05	22.80	7.42	0.530	0.160		23.10	7.46	0.532	0.142	
93/05/23	6.52	1.95	1.590		6.500	6.52	1.95	1.590		5.680
93/06/06	5.06	2.72	0.604		4.290	4.98	2.70	0.458		4.280
93/06/20	4.38	0.91	0.353		6.400	4.24	0.42	0.252		6.350
93/07/05	3.62	1.77	0.193		7.100	3.61	1.45	0.083		6.920
93/07/09	4.41	1.97	0.194	0.019		4.26	1.67	0.076	0.019	
93/08/06	2.25	1.67	0.233		13.500	2.11	1.25	0.185		13.400
93/09/11	1.53	0.73	0.126		19.000	1.53	0.52	0.115		19.000
94/03/29	10.10	3.14	1.470		44.300	9.67	3.13	1.300		41.400
94/04/06	40.10	20.80	7.860		13.800	35.60	20.80	6.560		13.500
94/04/13	38.80	20.60	7.980		14.200	32.70	20.50	7.980		13.200
94/04/20	31.00	14.10	12.800		1.580	26.90	14.10	12.800		1.490
94/04/27	23.40	10.50	5.460		2.240	19.20	9.61	5.260		2.050
94/04/28	24.40	8.04	5.170	0.120	2.240	15.60	5.40	4.140	0.077	2.680
94/05/04	19.10	5.49	4.240	0.111	2.680					
94/05/11	17.30	4.36	2.170	0.068	2.610	16.00	4.28	2.170	0.068	2.610
94/05/18	15.40	4.02	1.560	0.067	2.620	13.60	3.67	1.430	0.037	2.540
94/05/25	12.50	2.27	0.622	0.055	2.060	11.60	2.00	0.536	0.046	2.020
94/06/01	11.60	2.65	0.698	0.051	2.700	10.70	2.34	0.640	0.046	2.650
94/06/15	9.86	1.39	0.481	0.045	3.540	9.16	1.13	0.457	0.041	3.540
94/06/29	8.39	1.90	0.334	0.036	5.000	8.08	1.69	0.314	0.036	4.990
94/07/13	7.51	1.24	0.244	0.030	5.180	4.32	0.87	0.223	0.027	5.180
94/07/27	6.79	1.51	0.364	0.028	6.940	5.53	0.86	0.323	0.026	6.940
94/08/10	5.65	0.83	0.487	0.021	7.140	4.53	0.49	0.444	0.021	7.100
94/08/24	5.03	0.91	0.390	0.014	7.710	1.46	0.24	0.239	0.014	7.370
94/09/27	4.80	0.35	0.303	0.018	11.000	4.12	0.12	0.242	0.018	7.110
Average	13.23	4.25	1.854	0.056	8.097	11.40	3.88	1.693	0.045	7.913

A long-term remediation plan for this property should be developed. Although discharges from the property have been monitored, there has been no receiving environment monitoring in the two affected creeks or Owen Lake to determine effects, if any, from the discharge. Given the metals levels which apparently have occurred in the two streams, aquatic life may have been impacted already. The second question which needs to be addressed is if, and how, these discharges may have affected Owen Lake. It is assumed that recovery of the lake will occur naturally when contaminated discharges are curtailed. However, the possibility and aquatic implications of contaminated lake bottom sediments, particularly in the vicinity of the mine discharges, also needs to be addressed.

6.5.2 Northwood Pulp & Timber Ltd. PR-5394

6.5.2.1 Background

Northwood Pulp & Timber Limited is a sawmill operation located in Houston B.C. The woodwaste refuse site, which had been in operation since about 1970, was closed in 1990. The site is located on the Morice River floodplain, consisting of a series of old oxbows and sand and gravel bars.

In 1985 it was discovered that streams of leachate were surfacing at the toe of the northwest corner of the dump. The leachate goes to the Morice River via an open ditch. At the time of this discovery, leachate and toxicity samples were taken by EPP staff. Results indicated that, although concentrations of resin acids were low, the test fish did show signs of stress. As a result of this discovery the permit was amended to include a leachate monitoring program.

A subsequent amendment to the permit in 1988 discusses the fact that leachate did not go directly to the Morice River but rather filtered through a sand/gravel bank prior to discharge to the river. As a result of the 1988 amendment the company was required to upgrade the existing natural earth berm to ensure at least 0.5 m height above high water mark. The berm was to act as a trickle filter for the leachate.

6.5.2.2 Permitted discharge

The permit does not specify flow or parameter limits for the leachate, however a monitoring program is specified.

6.5.2.3 Receiving environment monitoring

Monitoring is required to be undertaken once per year each spring at the first sign of leachate flow. Samples are to be taken from the drainage ditch along the western perimeter of the reclaimed woodwaste landfill at one location south of all leachate outflow points. The monitoring program consists of the following parameters:

- Flow, m^3/day;
- Colour (true);
- Total Residue, mg/L;
- LC50 Bioassay, 100%;
- Resin Acids, mg/L;
- Ammonia NH_3, mg/L;
- Phenols, mg/L;
- BOD5, mg/L;
- pH; and
- Specific Conductance.

Monitoring data from 1994 are shown in Table 6.5. The leachate was found to be non-toxic to rainbow trout with an LC50 of >100%. Total phenolics concentration (0.016 mg/L) was an order of magnitude greater than the water quality objective (for prevention of fish tainting) of 0.001 mg/L.

6.5.2.4 Discussion

Flow data would be necessary in order to assess the significance of this discharge. There is a good deal of dilution available in the Morice at this location. Site specific fisheries information immediately downstream of the discharge would also be very useful. If the discharge site is within an area heavily utilized by over-wintering steelhead trout, for instance, further receiving environment monitoring would be warranted.

Table 6.5 Woodwaste leachate prior to discharge to Morice River Northwood Pulp and Timber PR-5394, 27-Apr-94

pH	pH units	7.68
Conductivity	uS/cm	211
True Color	CU	90
TSS	mg/L	141
BOD5	mg/L	<10
Ammonia N	mg/L	0.06
Phenols	mg/L	0.016
Resin Acids	mg/L	<1
96 Hour LC50 Bioassay	%	>100

6.5.3 Minor discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PR-6159	Houston Forest Products	Houston	Woodwaste to the ground	120 m^3/day

6.6 SUMMARY AND REVIEW OF MONITORING NEEDS

6.6.1 Water quality assessment

According to available data, water quality in the Morice River is excellent. Morice River water is soft, with pH near neutral. An alkalinity of >20 mg Ca CO_3/L indicates the waterbody would not be sensitive to acidic inputs. Morice waters are typically very clear, although TSS levels are generally high during freshet. Conductance, dissolved solids and colouration are low. Nutrient levels are extremely low, in many cases less than detection limits. While total metals levels may often exceed the criteria levels for protection of aquatic life, dissolved metals levels are generally less than detection limits.

6.6.2 Hydrometric data needs

WSC is undertaking a review, with the goal of reducing the hydrometric network. All stations in the Morice watershed may be subject to discontinuation unless funding support from other agencies is found. The Morice River contributes approximately 90% of flows to the Bulkley River downstream of Houston. It has been suggested by several researchers (Coulson 1989, McBean and others 1992) that a potential effect of climate change (warming) may be reduced summer and early autumn flows in streams of the Interior Plateau hydrologic regions, such as portions of the Morice watershed. Long-term stream flow data are critical to the assessment of current and future water withdrawals and waste loadings in the Bulkley basin.

Station 08ED001, on the Nanika River, should no long be needed, since not only the Nanika-Kidprice diversion, but the entire Kemano Completion Project have been canceled. The hydrometric station at the outlet of Morice Lake (Station 08ED002) has been in operation for the longest timeperiod. The hydrometric station at the mouth of the Morice (discontinued Station 08ED003) may have some advantages over the upstream site. This station measures discharge from the entire watershed, and is more accessible.

6.6.3 Interaction of forestry and water quality

The Morice River Forest Service Road parallels the Morice south of Houston for its entire length and the watershed has been the site of active road development and logging for many years.

6.6.3.1 Stream protection practices

An assessment of stream protection practices in the Morice TSA, conducted in the mid-1980's, noted that there were more sensitive fisheries sites in active logging areas in the Morice TSA than in other interior districts in the region. Logging operations around tributaries of the Morice River encompass high value salmon and steelhead streams.

Extensive logging was taking place in the vicinity of streams, with many examples of different streamside treatments. There had been a shift away from total riparian reserves along streams in recent years due to windthrow problems. As in other districts in the interior, there had been a shift towards the use of machine reserves at accessible sites on fish creeks. Most forestry and fisheries personnel interviewed indicated that they were satisfied that machine reserves provided adequate streamside protection.

Field inspection in the Morice revealed considerable inconsistency in that careful measures to prevent erosion and streambank damage that were carried out at the streamside (measures that were usually quite effective in achieving objectives) were often offset by a lack of erosion control measures on roads, skid trails or fire guards. For example, the benefits of directionally felling away from a small creek tributary to Nado Creek were offset by a skidder crossing at the lower end of the creek that diverted the creek down the road (eroding the road) into a second channel 500 m downstream. A number of special procedures such as settling ponds in ditches at bridge approaches had been used at various locations in the Morice. However, there was a general lack of water bars on roads where operations had finished, particularly on winter roads and steeper skid trails.

A growing awareness was noted of the importance of some wetlands for coho rearing and of the need to maintain adequate access into these areas for juvenile fish movements. In the past, some of this habitat, for example along the Morice River road, has been drained to enable easier road maintenance.

Concerns were raised over the rate-of-cut in the Cedric Creek watershed, a small steelhead tributary of the Morice River. Logging was curtailed due to what was considered an excessive amount of logging already present.

6.6.3.2 Watershed assessment of Cedric, Lamprey, Fenton and Owen Creeks

A survey of logging related impacts on four tributaries of the Morice River was conducted in 1994 under the Watershed Restoration Program. It was found that, in general, because of the gentle rolling nature of the terrain, erosion problems were relatively minor. However about half of the sites examined had been impacted by roads or cutblocks in some manner. Most of the problems identified in the four drainages appeared to be related to siltation from logging roads. Small, class 1, streams tended to be located adjacent to or in cutblocks, with little or no riparian vegetation remaining around the creek bed. Large woody debris was sometimes high, and erosion from banks of the creek was often evident.

Cedric Creek was dry at the time of the survey. However, in 1975, researchers had reported Cedric Creek as being a relatively large creek at this site and productive for rainbow trout. There was no clear explanation for the change. The total lack of riparian vegetation along Cedric Creek for about 60 m immediately downstream of the crossing of a main logging road was thought to increase water temperature and likely contribute to decreased water flow during the dry season.

Lamprey Creek and its tributaries offer some excellent habitat for steelhead and other salmonids, although a decrease in juvenile steelhead numbers since the early 1980's had been reported. Only minor problems related to past logging practices were found in the Lamprey system.

A culvert in Fenton Creek at the Morice River Road presented a barrier to fish passage to the upstream sections of creek, at least in some flows. In addition, a sharp turn in the Morice River Road at this location was contributing to siltation of the creek. It was suggested that the Morice River Road crossing at Fenton Creek should be assessed as to the alteration of the creek crossing to reduce siltation and to allow for growth of riparian vegetation. In addition, the alternative crossing should provide passage for fish at all water levels.

Owen Creek is as an important tributary to the Morice for the production of steelhead and coho. Since the replacement of the culverts with a bridge at the Morice River Road crossing, accessibility of the upper reaches of Owen Creek had been ensured.

6.6.3.3 Morice River Corridor LRUP

The Morice River LRUP, completed in 1992, establishes a narrow zone, varying between 0.3 and 1.5 km, encompassing the river floodplain and immediate upland, which is to be managed for maintenance of fish, wildlife and recreation values. Timber production is not a management objective, and the area is removed from the working forest land base. The remainder of the planning area is divided into various less restrictive management zones. A process to develop an LRMP for the entire Morice TSA is underway.

6.6.3.4 Northwood woodwaste refuse site

The Northwood Pulp and Timber woodwaste refuse site, which had been in operation since about 1970, was closed in 1990. The site is located on the Morice River floodplain, consisting of a series of old oxbows and sand and gravel bars. In 1985 it was discovered that streams of leachate were surfacing at the toe of the northwest corner of the dump. Later the company was required to upgrade the existing natural earth berm to act as a trickle filter for the leachate.

Monitoring in 1994 found the leachate to be non-toxic to rainbow trout, however, total phenolics concentration was considerably greater than the water quality objective for prevention of fish tainting.

Flow data would be necessary in order to assess the significance of this discharge, given that there is a great deal of dilution available in the Morice at this location. Site specific fisheries information immediately downstream of the discharge would also be very useful. If the discharge site is within an area heavily utilized by over-wintering steelhead trout, for instance, further receiving environment monitoring would be warranted.

6.6.3.5 Monitoring needs

There have been few monitoring data collected to assess forestry interaction with water quality, although forestry is the major land-use activity in this reach. The entire watershed is well-roaded and logging is now moving into smaller, higher elevation tributaries.

One review of stream protection practices in the mid 1980's identified instances of stream degradation in the Morice and identified road building and lack of road maintenance as the main source of sediment to streams. A WRP survey of logging related impacts on four tributaries of the Morice River in 1994 found that about half of the sites examined had been impacted by roads or cutblocks in some manner. The FPC is expected to improve compliance with stream protection guidelines, and the Watershed Restoration Program is intended to address problems such as rehabilitation of streams, road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring, under the guidance of the Morice LRMP monitoring committee, is also necessary to ensure that management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.

6.6.4 Interaction of mining and water quality

6.6.4.1 Silver Queen Mine

The inactive Silver Queen Mine, located on the eastern shore of Owen Lake, has been historically documented to show elevated levels of zinc in the discharges during freshet. As a result of a pollution abatement order issued to the company in the spring of 1990, a number of treatment options were studied and eventually diversion of the drainage from the two mine adits to a wetland area was found to be the most practical option.

Zinc concentration in the adit drainage, 1990-1994, averaged 13.2 mg/L (maximum 40.1 mg/L). This zinc was largely dissolved and the drainage was slightly alkaline. Copper concentration averaged 0.225 mg/L (maximum 1.18 mg/L). Iron concentration averaged 2.43 mg/L (maximum 7.16 mg/L). These concentrations exceed the federal Metal Mining Liquid Effluent Regulations for mine discharges. After being diverted through a tailings pond and wetland, zinc levels were several orders of magnitude reduced to an average of 0.056 mg/L (maximum 0.120 mg/L).

In 1993 high levels of zinc and copper were discovered in a second stream draining the property. It was determined that the seepage from the waste rock piles were contributing to this contaminated runoff. Total zinc concentrations in this drainage into the lake averaged 8.1 mg/L, again mostly in the dissolved form. Dissolved copper concentrations were also elevated, 0.018 mg/L average and 0.274 mg/L maximum. This contaminated runoff was subsequently diverted for treatment in the main wetlands area as well.

6.6.4.2 Monitoring needs

Owen Lake has high fisheries capability and contains populations of Dolly Varden char, rainbow trout, mountain whitefish and burbot. There is good public access to Owen Lake and it is a popular recreational fishery. DFO is considering enhancement opportunities on Owen Creek to rebuild former stocks now that a culvert blocking fish passage has been replaced.

The criterion for the protection of aquatic life for zinc is 0.03 mg/L. The criterion for copper is dependent on hardness, but assuming hardness <50 mg $CaCO_3$/L, the criterion is ≤0.002 mg/L. The very high zinc and copper concentrations in drainage from the adit and waste rock dump are definitely within a range which would be expected to be highly toxic to aquatic life, if untreated. The data indicate that the diversion to wetlands only provided partial treatment, and the discharges to the lake in 1994 still exceeded criteria. It appears unlikely that diverting additional acidic drainages from the waste rock dump to the wetland will improve this situation.

A long-term remediation plan for this property should be developed. Although discharges from the property have been monitored, there has been no receiving environment monitoring in the two affected creeks or Owen Lake to determine effects, if any, from the discharge. Given the metals levels which apparently have occurred in the two streams, aquatic life may have been severely impacted already. The second question which needs to be addressed is if, and how, these discharges may have affected Owen Lake. The possibility and aquatic implications of contaminated lake bottom sediments in the vicinity of the mine discharges should also be addressed.

7. UPPER BULKLEY RIVER TO MORICE RIVER CONFLUENCE

The upper Bulkley River heads at Bulkley Lake and meanders along a broad floodplain to its confluence with the larger Morice River (Figure 7.1). Two major tributaries are Maxan Creek (draining Maxan Lake) which enters Bulkley Lake; and Buck Creek, which joins the Bulkley near the Morice confluence and within the District of Houston. The Bulkley River including tributaries is a Class II stream (see section 2.2.4 for explanation of classified waters). The Bulkley valley, a part of the rolling Nechako Plateau, has the highest agricultural capability in the Skeena region.

7.1 HYDROLOGY

A hydrometric station is located near the mouth of Buck Creek in Houston (Station 08EE013). Monthly mean, maximum and minimum discharge for Station 08EB013 are shown in Table 7.1 and Figure 7.2. On average, Buck Creek supplies about 19% of flows to the Bulkley River. Environment Canada is undertaking a review of the WSC hydrometric network, and this station may be subject to discontinuation is funding support is not found.

The second hydrometric gauge station is located at the North Road bridge downstream of Houston. This is a manual gauge rather than an automatic station and therefore low flows in the winter are not recorded because of icing conditions. Monthly mean, maximum and minimum discharge April to November for Station 08EE003, Bulkley River near Houston, are shown in Table 7.2 and Figure 7.3. This hydrometric station is scheduled for decommissioning in 1996 or 1997 if funding support from other agencies is not found.

7.2 LAND USE HISTORY

7.2.1 Settlements

The upper Bulkley River watershed is covered by overlapping First Nations land claim areas, including that of the Wet'suwet'en peoples. The District Municipality of Houston, on the Bulkley River floodplain near its confluence with the Morice River, is the major settlement in this reach, with an estimated 1994 population of 3720. The population of Houston has declined slightly in the past few years as a result of the closure of the Equity Silver Mine.

7.2.2 Agriculture

The Dominion Telegraph line was completed through the Bulkley Valley in 1902, followed by the first cattle ranch near the junction of the Morice River, called the Diamond D (Large 1957). The valley was wide and rolling here with semi-open expanses of grasslands alternating with clumps of pine, spruce and poplar. The open country was vegetated with wild pea-vine and red top grasses suitable for grazing. Other early settlements were at Bulkley Lake and at Pleasant Valley (later named Houston). The Grand Trunk Pacific Railway (now CNR) was completed through the valley in 1914.

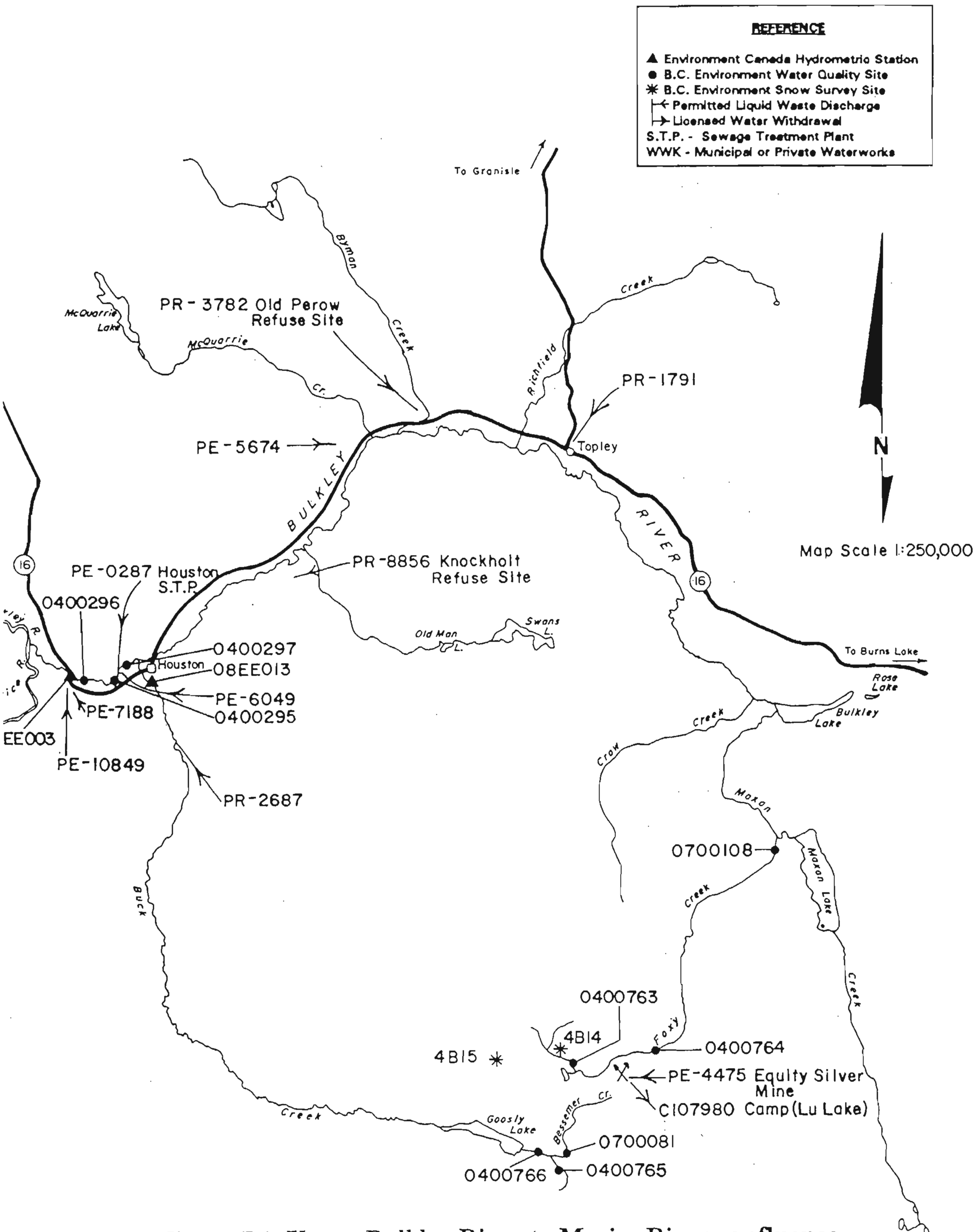


Figure 7.1 Upper Bulkley River to Morice River confluence

Table 7.1 Monthly discharge summary Buck Creek at Mouth, Station 08EE013

Latitude:	54 23 52 N
Longitude:	126 39 04 W
Drainage Area Gross:	580 km2
Period of Record	1973-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	1.42	1.06	6.49	18.8	41.6	29.9	6.71	3.72	3.01	2.79	4.18	3.94
Monthly Min.	0.063	0.025	0.206	0.558	14.1	2.74	0.389	0.138	0.177	0.526	0.292	0.087
Monthly Mean	0.52	0.441	0.76	5.91	21.9	11.2	3.09	0.987	0.801	1.37	1.65	0.779

Average 7-day, 10-year low flow is 0.090 m3/s with 95% confidence limits of 0.023 and 0.166.

Figure 7.2 Discharge envelope Buck Creek at Mouth, Station 08EE013

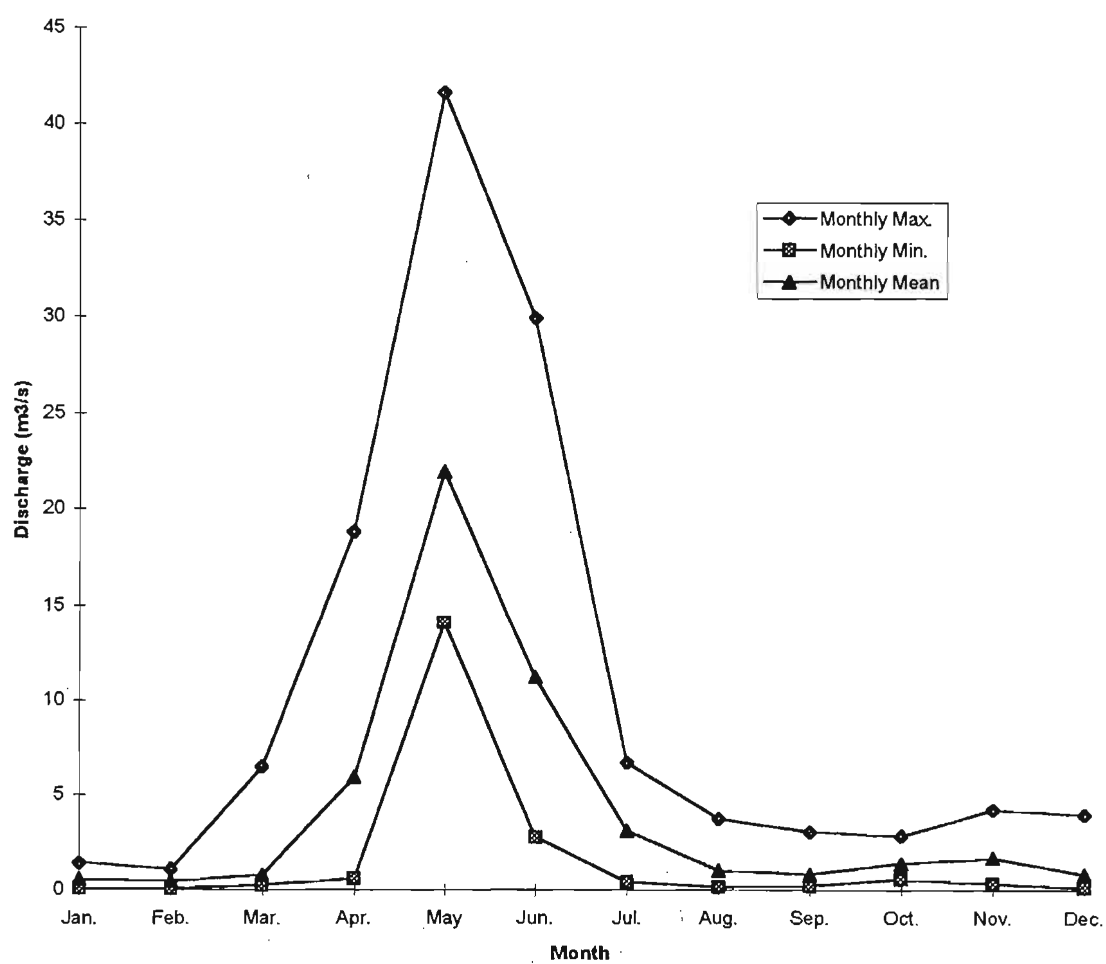


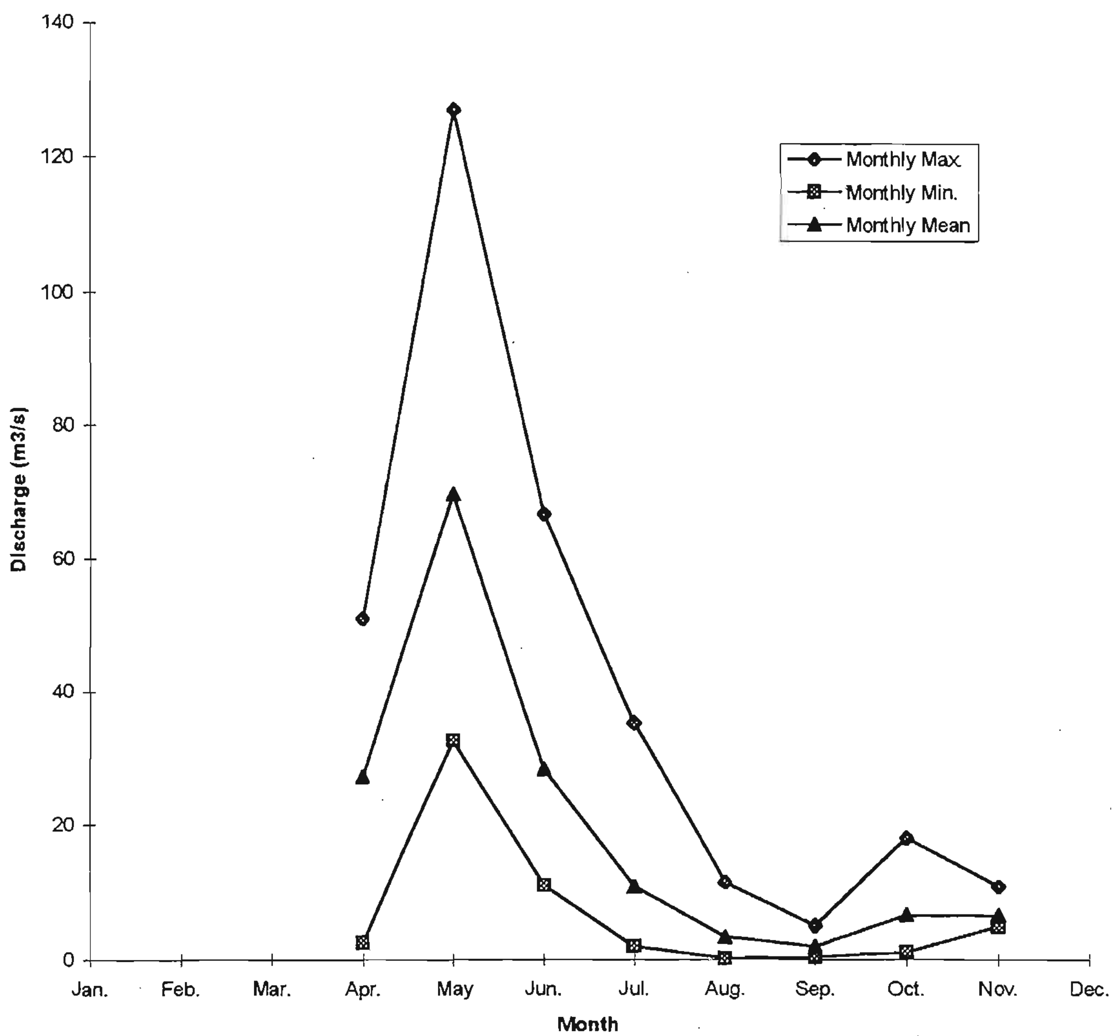
Table 7.2 Monthly discharge summary Bulkley River near Houston, Station 08EE003

Latitude: 54 23 45 N
Longitude: 126 42 30 W
Drainage Area Gross: 2380 km2
Period of Record 1930-1951, 1971, 1980-1993 (Ice-free periods only)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.				51.0	127	66.9	35.3	11.4	5.00	17.9	10.7	
Monthly Min.				2.49	32.5	10.9	1.92	0.206	0.371	1.14	4.87	
Monthly Mean				27.1	69.9	28.3	10.7	3.36	1.94	6.55	6.51	

Average 7-day, 10-year low flow is 0.216 m3/s with 95% confidence limits of -0.023 and 0.455 (1980-1994 April - September).

Figure 7.3 Discharge envelope Bulkley River near Houston, Station 08EE003



Early settlers were employed in tie-making for the railway, in conjunction with land clearing for agriculture. Today there are an estimated five ranches and 20 hobby farms running approximately 500 breeding cows in the upper Bulkley River drainage. Agricultural grazing on Crown land is administered by MOF through range units. In 1992 the Prince Rupert Forest Region range database showed 48 range tenures in the Morice Forest District and 9407 AUMs of authorized grazing. Grazing permits were issued for 3121 cattle and 48 horses in 1992. Most of this grazing was concentrated in the Bulkley valley portion of the district.

*7.2.3 **Forestry***

7.2.3.1 History

Early settlers to the upper Bulkley were employed in tie-making for the railway, in conjunction with land clearing for agriculture. The "Summit" area (Houston to Burns Lake) produced more hewn ties than any comparable section along the railway (Mould 1976). The hewn tie industry, based in the lodgepole pine stands along the upper Bulkley, flourished through the 1920's and 1930's. Usually the ties were hauled out of the woods by horse teams and sleighs along snow covered winter roads.

At one point Buck Creek was used for log driving, by dam construction in a meadow area at the headwaters, and the construction of flumes over canyon sections and the highway. Over 40,000 ties were brought down the creek through this method in the spring of 1930. The south side of Bulkley Lake produced large volumes of ties during the early years. The ties were hauled over the ice and then over the low pass to Rose Lake, in the Fraser watershed. Others were watered, towed to the foot of the lake and floated about a mile down the Bulkley River to the railway siding. (Mould recalls that in about 1925, the bark peelings from 60,000 to 70,000 ties were left in Rose Lake, causing total destruction of the fish population, which had included rainbow trout up to five pounds.)

Logging in the Bulkley watershed expanded from primarily small scale selective and strip logging operations in the late 1960's to primarily clearcut logging used today. At the time of construction in 1970, the Northwood Pulp and Timber mill located near the Morice River at Houston was the largest sawmill in British Columbia.

Northwood Pulp and Timber Ltd. and Houston Forest Products are the major forestry operators in the area today. The upper Bulkley watershed is networked with roads and major areas of forestry operation are in the upper Bulkley tributaries Maxan/Foxy Creeks, Dungate Creek and Buck Creek. A process to develop an LRMP for the entire Morice TSA is underway.

7.2.3.2 Stream protection practices

Stream protection practices in the interior of the Prince Rupert Forest Region (Bustard and Wilford 1986) is reviewed in section 1.3.4. Bustard (1986*b*) conducted an assessment of stream protection practices in the Morice and other TSAs, using a combination of interviews and field inspections. The author states there are more sensitive fisheries sites in active logging areas in the Morice TSA than in other interior districts in the region. Logging operations around tributaries of the Bulkley and Morice rivers encompass high value salmon and steelhead streams.

He found extensive logging in the vicinity of streams in the TSA, and many examples of different streamside treatments. There had been a shift away from total reserves along streams in recent years due to windthrow problems in the reserves that had been left (with forest companies going back into the reserve strips to remove the blowdown in subsequent years). As in other districts in the interior there had been a shift towards the use of machine reserves. Most forestry and fisheries personnel interviewed in the Morice TSA indicated that they were satisfied that machine reserves provided adequate streamside protection.

Sediment from roads (due to both construction and inadequate maintenance) was cited as the main impact from logging activities on streams in the Morice TSA. As well, blockage of fish movements due to poor culvert installation and maintenance was cited as a problem. These concerns were quite widespread due to the distribution of steelhead trout and coho salmon through many of the smaller tributaries in the district. Field investigations were not carried out in the upper Bulkley watershed.

7.2.4 Mining

The Equity Silver Mine, located between the headwaters of Maxan and Buck Creeks south of Houston was a major employer for the area from start-up of open pit mining in 1980 until mine closure in 1992 (see section 7.5.1).

7.3 WATER WITHDRAWALS

A summary of licensed water withdrawals from the upper Bulkley River is found in Table 7.3. There are 59 domestic and stock watering licenses and 11 irrigation licenses on the system. Eight domestic licenses are held by members of the Dungate Drive Water Utility at Houston. Although the District Municipality of Houston holds a water license on Mathews Lake, north of Houston, the present water supply for the municipality comes from shallow wells near the Bulkley River in the industrial section of town (P. James, District of Houston, personal communication). Equity Silver Mines utilizes Lu Lake at the headwaters of Foxy Creek (Maxan watershed) for treatment and storage of mining wastes. The Equity Silver Mines Ltd. license for 91 m^3/d for mining camp use may not be fully utilized since the mine has closed.

The 7 day average 10 year low flow is 0.216 m^3/s with 95% confidence limits of -0.023 and 0.455 (Table 7.2). The 7 day average low flow was calculated with data for the summer months, April to September, because Station 08EE003 is only a seasonal station. Data collection for this station has been somewhat sporadic over the years, therefore only years in which data was available through September (usually the low flow month) were used. The lowest flow reported at this station was 0.136 m^3/s in September 1992. The wintertime 7 day average low flow in the upper Bulkley at Houston may be considerably lower than 0.2 m^3/s. For example, the mean discharge in February in Buck Creek at Houston (Table 7.1) is about 50% of the mean August and September flows.

The licensed water withdrawals from the upper Bulkley total 0.10 m^3/s, which is about 46% of the summertime 7 day average 10 year low flow. The largest quantity of licensed water withdrawals are 11 irrigation licenses on tributaries of the upper Bulkley with an estimated consumption of

0.097 m^3/s. Most irrigation licenses are issued in acre-feet for the April to September growing season. The irrigation licenses have been converted from acre-feet to m^3/s by assuming 2 months of operation, 12 hours/day. There are no data available on the actual water utilization by licensees, however, maximum water utilization for irrigation would occur during hot, dry summers when streamflows are at their lowest. Most of these water withdrawals for irrigation are from smaller tributary streams to the upper Bulkley which are ungauged. Further investigation would be required to determine if in-stream flow requirements for fisheries are being compromised.

Table 7.3 Licensed water withdrawals upper Bulkley River to Morice River confluence

Input streams

Domestic/stock watering

GD	m3/d	m3/s
(56 licences)		
45000	204.6	2.37E-03

Irrigation*

AF	m3/d	m3/s
(11 licences)		
407	8367.1	9.68E-02

Bulkley River

Domestic/stock watering

GD	m3/d	m3/s
(3 licences)		
1500	6.8	7.87E-05

Work camp

License	Licensee	GD	m3/d	m3/s
C107980	Equity Silver Mines Ltd.	20000	90.9	1.05E-03
	(Also 14 434 m3/d storage)			
	(Lu Creek/Lake)			

* Irrigation licences have been converted from acre-feet to m3/s by assuming 2 months of operation, 12 hours/day in the summer.

7.4 WATER QUALITY AND AQUATIC RESEARCH

7.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly 1983 - 1987 from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Summary water quality data for 1983-1987 for the upper Bulkley River sample site 0400296 downstream of Houston (Figure 7.1) are found in Table 7.4. This site was generally sampled once per month for five years.

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

Table 7.4 Water quality summary upper Bulkley River, Site 0400296, 1983-1987

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	18	17	5	60	25.1	21.0	16
pH	52	52	7.0	8.1	7.62	0.22	7.6
Conductance (umhos/cm)	53	53	73	223	155.3	36.1	165
Total Residue (mg/L)	52	52	82	222	124.5	23.6	121
Filterable Residue (mg/L)	12	12	78	130	108.3	18.6	115
Non-filterable Residue (mg/L)	51	49	1	132	15.1	28.0	3
Turbidity (NTU)	51	51	0.9	45.0	6.49	9.51	2.0
Alkalinity (mg/L)	51	51	29.5	102.0	67.86	18.23	71.0
Hardness Total (mg/L)	4	4	40.0	76.6	57.28	15.46	56.3
Hardness Dissolved (mg/L)	8	8	55.8	80.4	69.78	8.67	70.8
Total N (mg/L)	15	15	0.17	0.56	0.350	0.130	0.33
T.K.N. (mg/L)	52	52	0.02	0.78	0.330	0.140	0.31
Ammonia (mg N/L)	52	45	0.006	0.488	0.0871	0.1072	0.024
NO2 + NO3 (mg N/L)	52	32	0.02	0.20	0.073	0.047	0.02
Total Carbon (mg/L)	36	36	19	33	24.4	3.2	25
Organic Carbon (mg/L)	16	16	2	13	5.9	2.9	5
Inorganic Carbon (mg/L)	51	51	8	31	17.9	5.7	18
Chloride (mg/L)	36	36	0.9	8.2	2.67	1.64	2.1
Ortho P (mg/L)	52	51	0.004	0.099	0.0247	0.0204	0.015
Silica (mg/L)	8	8	9.7	13.6	12.22	1.37	12.6
Sulfate (mg/L)	8	8	3.0	4.8	3.98	0.63	4.0
Fluoride (mg/L)	1	0					<0.1

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	48	45	0.01	3.71	0.466	0.813	
As	65	16	0.001	0.004	0.0018	0.0008	<0.001
Ca	51	51	9.76	28.10	18.340	4.200	19.70
Cd	66	0					<0.0005
Co	51	3	0.11	0.18	0.147	0.035	<0.1
Cr	51	2	0.01	0.02	0.015		<0.01
Cu	51	42	0.001	0.020	0.0034	0.0034	0.002
Fe	51	51	0.17	4.85	0.790	0.065	0.43
Mg	51	51	3.29	8.91	6.040	0.001	6.29
Mn	51	51	0.03	0.30	0.087	0.056	0.07
Mo	51	9	0.01	0.01	0.01		<0.01
Ni	51	0					<0.05
P	53	53	0.011	0.190	0.1560	0.0320	0.053
Pb	51	21	0.001	0.009	0.0029	0.0020	<0.001
V	51	5	0.01	0.03	0.016	0.009	<0.01
Zn	51	16	0.005	0.030	0.0125	0.0094	<0.005

Source:Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 7.4 (continued) Water quality summary upper Bulkley River, Site 0400296, 1983-1987

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	51	37	0.01	0.30	0.077	0.065	0.04
As	65	11	0.001	0.003	0.0014	0.0007	
B	51	0					<0.01
Ba	51	51	0.01	0.04	0.025	0.007	0.02
Ca	51	51	7.01	25.30	17.503	4.040	18.10
Cd	66	0					<0.0005
Co	51	0					<0.1
Cr	51	1	0.04	0.04	0.04		<0.01
Cu	66	30	0.001	0.010	0.0017	0.0017	0.001
Fe	55	51	0.03	0.53	0.221	0.090	0.20
K	8	8	0.80	1.20	1.010	0.160	1.05
Mg	51	51	2.55	7.96	5.710	1.360	6.23
Mn	51	50	0.01	0.23	0.057	0.043	0.04
Mo	51	2	0.01	0.01	0.01		<0.01
Na	8	8	3.60	9.40	5.920	1.690	5.90
Ni	51	0					<0.05
P	51	51	0.007	0.120	0.0320	0.0210	0.026
Pb	66	7	0.001	0.002	0.0013	0.0005	
V	51	0					<0.01
Zn	66	1	0.007	0.007	0.007		

Source:Wilkes and Lloyd 1990
[a] Minimum detectable concentration

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

This dataset is not a good representation of water quality for most of the upper Bulkley watershed because water quality at this site has been affected by the discharge from the District of Houston sewage treatment plant (STP) located 2.3 km upstream. Comparison of selected water quality parameters for seven rivers in the Skeena watershed (Table 1.3) shows that colour, hardness, total Kjeldahl nitrogen (ammonia + organic nitrogen), total phosphorus and total nitrogen are elevated at this site compared to the others. No parameters were found to exceed the maximum criteria for protection of aquatic life however.

Nijman (1986) and Maclean and Diemert (1987) noted that nutrient concentrations were relatively high at this site compared to upstream sites, attributable to the STP. More recent data for this site reported by Portman (1995) shows somewhat lower ammonia-N concentrations during 1993-1994 (mean=0.034 mg/L, n=12) as compared to the 1983-1987 period (mean=0.087 mg/L, n=52). Likewise, the mean total phosphorus concentrations for the 1993-1994 period reported by Portman of 0.088 mg/L (n=11) is about half the level reported for the 1983-1987 period of 0.16 mg/L. This is a reflection of improvements to the STP (including phosphorus removal) instituted in the early 1990's (see section 7.5.2).

Nijman (1986) reviewed the somewhat limited data available for the upper Bulkley River upstream of the Houston STP at three sites 1) the outlet of Bulkley Lake, 2) upstream from Buck Creek, and 3) 100 m upstream of the STP. The waters were found to be soft, with mean hardness ranging from 25.9 to 92 mg $CaCO_3$/L. Mean alkalinity, a measure of pH buffering capacity of a waterbody, ranged from 34 to 64.5 mg $CaCO_3$/L. The waters were slightly coloured and this was attributable to the presence of organic tannins and lignins from swamps and wetlands in the watershed. Colour may be aesthetically unappealing for drinking water but does not affect human health.

7.4.1.1 Nutrient loading to the upper Bulkley River

The District of Houston has raised concern over the degree of nutrient loading to the upper Bulkley River upstream of the municipality. Orthophosphate is the nutrient of concern because it represents the biologically available form of phosphorus which is usually limiting to algae growth in streams. Limited data from several upstream sites (Table 7.5) indicates that orthophosphate is elevated upstream of the municipality (mean=0.014 mg/L). Two tributaries, both of which join the Bulkley in Houston, also appear to have quite elevated orthophosphate concentrations, Avalon Creek (0.048 mg/L) and Buck Creek (0.027 mg/L). The reasons for this are not known, but nutrient loading from agriculture (and perhaps a subdivision on Avalon Creek) are suspected. In 1990-1991 the upper Bulkley had an average orthophosphate concentration of 0.016 mg/L, as compared to 1983-1987 mean or 50th % concentrations in the Morice, Telkwa, Kispiox and Lakelse rivers of <0.003 mg/L. The positive correlation between phosphorus concentrations and forestry and agriculture as land-use activities in watersheds is discussed in section 2.1.4.

Table 7.5 Comparison of total phosphorus and orthophosphate concentrations between upper Bulkley River sites and Morice River

	Site K[a] Bulkley R. U/S Houston mg/L 1991-1993	Site M[a] Avalon Creek mg/L 1991-1993	Site J[a] Bulkley R. U/S Buck Creek mg/L 1991-1993	Site L[a] Buck Creek mg/L 1991-1993	Site 0400295[b] U/S STP mg/L 1990-1991	Site 0400203[c] Morice River mg/L 1983-1988
Total phosphorus	0.057 (n=12)	0.071 (n=2)	0.036 (n=9)	0.056 (n=7)	0.033 (n=10)	0.017 (n=56)
Ortho-phosphate	0.014 (n=12)	0.048 (n=2)	0.023 (n=9)	0.027 (n=7)	0.016 (n=10)	<0.003 (n=50)

[a] Source: Portman 1995
[b] Source: Remington 1991
[c] Source: Wilkes and Lloyd 1990

7.4.2 Water quality assessment and objectives

Water quality objectives for the Bulkley River Basin are shown in Table 7.6 (Nijman 1986). Drinking water objectives for fecal coliform bacteria are applied upstream of Houston, while recreational water quality objectives are applied downstream.

Table 7.6 Provisional water quality objectives for the Bulkley and Morice Rivers

		Bulkley River			
Water Bodies	Morice River	Bulkley L. to Houston	Houston to Morice R.	Morice R. to Smithers	Smithers to Skeena R.
Designated Water Uses	Drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	Drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	Aquatic life, wildlife, recreation, livestock, irrigation, industrial use	Drinking water, aquatic life, wildlife, recreation, livestock, irrigation, industrial use	Aquatic life, wildlife, recreation, livestock, irrigation, industrial use
Fecal Coliforms [1]	≤ 10 MPN/100mL 90th percentile	≤ 10 MPN/100mL 90th percentile	≤ 200 MPN/100mL geometric mean ≤ 400 MPN/100mL 90th percentile	≤ 10 MPN/100mL 90th percentile	≤ 200 MPN/100mL geometric mean ≤ 400 MPN/100mL 90th percentile
Turbidity [2]	5 NTU maximum increase (upstream ≤ 50 NTU), 10% maximum increase (upstream > 50 NTU)				
Suspended Solids [3]	10 mg/L maximum increase (upstream ≤ 100 mg/L), 10% maximum increase (upstream > 100 mg/L)				
Total Chlorine Residual [3]	0.002 mg/L maximum				
Periphyton Standing Crop [4]	< 50 mg/m^2 chlorophyll a				
Un-ionized Ammonia - N [5]	≤ 0.007 mg/L average, 0.030 mg/L maximum				
Nitrite - N [5]	≤ 0.020 mg/L average, 0.060 mg/L maximum				
Dissolved Oxygen	7.8 mg/L minimum				

Note: the objectives apply to discrete samples from all parts of the water body except from initial dilution zones of effluents. These excluded dilution zones are defined as extending up to 100 m downstream from the discharge point and no more than 25 percent across the width of the stream, from the surface to the bottom.

1 the geometric mean and 90th percentile are calculated from a least 1 sample per week for 5 weeks in a period no longer than 30 days. The drinking water objective (10/100 mL) applies year-round and the recreation objective (200-400/100 mL) applies during the recreation season.

2 the increase (in NTU, % or mg/L) is over level measured at a site upstream from a discharge or a series of discharges and as close to them as possible, and applies to downstream levels.

3 since the objective is less than the minimum detectable concentration, it will be necessary to estimate the receiving water concentration using effluent loading and streamflow. The objective applies only if sewage effluent is chlorinated.

4 standing crop from natural substrate. Average of at least 10 samples collected at random from the streambed on one day.

5 the average is calculated from at least 1 sample per week for 5 weeks in a period no longer than 30 days.

7.4.1.1 Water quality objectives monitoring

A monitoring program was recommended for the Houston sewage treatment plant at the following sites: 0400287 (upstream control), PE 287 (outfall), 0400295 (100 m downstream), and 0400296 (3.2 km downstream) as shown in Figure 7.1. Monitoring to determine the attainment of the water quality objectives were carried out in 1988 - 1992. These are published in an annual MOELP report of objectives attainment in the province.

In 1988-92, the following parameters were monitored at Site 0400297 (upstream) and Site 0400295 (100 m downstream) for three to five consecutive weeks during summer low flows in most years: fecal coliforms, turbidity, suspended solids, chlorophyll *a*, ammonia-N and nitrite-N. The objectives were met with the exception of fecal coliforms at the upstream site, which exceeded the objective of <10/100 mL 90th percentile (np) in every year. Fecal coliform concentrations ranged from np=10/100 mL (1989) to np=120/100 mL (1990). It should be noted that the fecal coliform concentrations were similar at the downstream site, but the objectives have been set higher for this reach of the river (<200/100 mL geometric mean). As with nutrients, agricultural activities in the watershed are suspected to be the cause of elevated fecal coliform concentrations.

7.5 LIQUID WASTE DISCHARGES

7.5.1 Equity Silver Mines PE-4475

7.5.1.1 Background

The following information was taken from the Technical Report dated March 30, 1994 for the most recent permit amendment.

Equity Silver Mines Limited owns and operated a copper-silver mine located about 32 km southeast of Houston, and at about 1200 m elevation. It is located at the headwaters of Bessemer and Foxy Creeks. Bessemer Creek flows southward into Buck Creek, while Foxy Creek flows northward into Maxan Creek, both of which are major tributaries of the upper Bulkley River (Figure 7.4). Mining and milling operations ceased in early 1994 due to lack of economic ore.

Ore reserves are confined to four known mineralized zones: the Southern Tail, Main Zone, Waterline Zone and North Zone. Open pit mining of the Southern Tail ore body began in April 1980 and was completed in May 1984. Mining of the Main Zone began in March 1983 and was completed by the end of 1991. Development of the Waterline Zone for open pit mining began in 1988 with completion in early 1994. Underground mining began in August 1993 from the northern end of the Waterline Zone and was completed by early 1994. Stockpiled low grade ore was depleted by the fall of 1992.

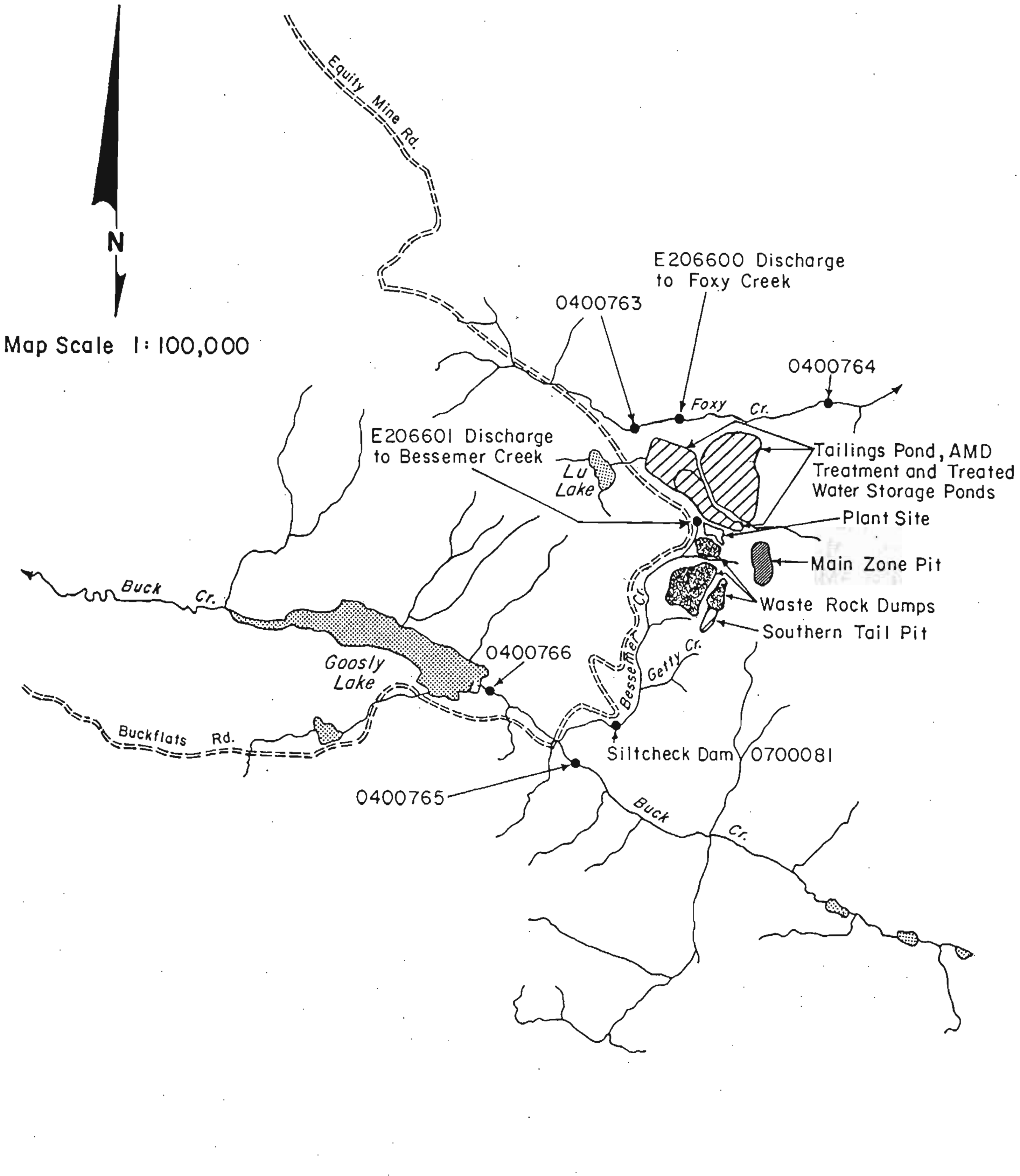


Figure 7.4 Main elements of Equity Silver Mine

In 1981 acidic drainage, commonly called either acid rock drainage (ARD) or acid mine drainage (AMD), was found to be occurring from the oxidation of sulfides contained in the mined waste rock. See section 2.1.3 for discussion of ARD generation at this mine and potential impacts on downstream aquatic life. To date waste rock dumps are comprised of approximately 85 million tonnes of waste. The AMD from the minesite is collected and processed in a lime treatment plant to neutralize acid and remove metals prior to discharging treated water back to the environment (Equity Silver Mines Ltd. 1994).

According to the technical report for the recently amended permit PE-4475 a $37.5 million security bond required in the amended MEMPR's Reclamation Permit M-114 was posted in 1991. Of this amount, $32 million is for financing the long-term AMD treatment cost upon completion of reclamation and $5.5 million is to ensure that the placement of compacted clay cover on the waste dumps and the plant site clean-up are completed.

Between 1990 and 1991, 73 ha of the total 120 ha Main Waste Dump were resloped, covered with 0.5 m of mechanically compacted clay, 0.3 m of loosely placed clay and then seeded with grass species. Between 1991 and 1992, another 19 ha of the dump were resloped and covered. Equity has been resloping and recovering their waste dumps since 1990. Also in 1992, Equity carried out some major projects such as reconstruction of the Main AMD Pumphouse, construction of the AMD sludge pipeline, installation of the AMD sludge booster pump, addition of a third reactor to the treatment plant, and upgrading of electrical and computer instrumentation of the plant.

Equity Silver Mines has been generally in compliance with its permit requirements. Other than seasonal spikes due to AMD discharges at freshet, in general there have been significant decreases in dissolved copper and zinc concentrations in the lower parts of Bessemer and Foxy Creeks since 1990.

At this time the tailings pond supernatant is left in the impoundment for natural degradation by sunlight. It is expected that at mine closure, excess effluent would be discharged to the AMD Treatment Plant.

Acid mine drainage from Bessemer Waste Dump, Main Waste Dump, Southern Tail Waste Dump, and plant site is collected by a collection system which includes the Main AMD Ditch, Secondary Ditch (back-up for Main Ditch), No.1 Dam AMD Seepage Pond, Getty Creek Ditch (SW corner drainage), Bone Yard Ditch (for Plantsite Drainage), a 16,000-m^3 Main AMD Pond, a 25,000-m^3 Surge Pond, a 4250-m^3 Getty Pond, and a 130,000-m^3 AMD Storage Pond. From these works, AMD is conveyed by 13 pumps to the AMD Storage Pond, and 2 pumps to the AMD Treatment Plant for neutralization with slaked lime to pH = 8.5. For 1992, about 818,000 m^3 of AMD was treated at an average acidity of 8,950 mg/L ($CaCO_3$ equivalent), using 5,164 tonnes of lime. This compares to 767,650 m^3 of AMD at an acidity of 11,475 mg/L using 5,916 tonnes of lime for 1991. Lime consumption seemed to have peaked to 6,500 tonnes in 1990 but has declined since then.

Treated effluent is discharged to two sludge settling ponds. Supernatant from the sludge ponds is discharged to the Treated Water Storage Pond west of the Diversion Dam for storage. From here, the treated effluent is discharged to Foxy Creek via No. 3 Dam at Lu Creek Diversion Canal, or to Bessemer Creek via a culvert located to the north side of the mine access road, depending on the available dilution in the creeks. For the past few years, treated AMD discharges have been occurring in the spring to take advantage of increased dilution.

Acid Mine Drainage from No. 1 Seepage Dam has been collected and pumped to the Tailings Pond in the past to control tailings pond pH and cyanide levels. In 1992, a return 8" pipeline and collection ditch beside the line were installed to recycle AMD from this source to the AMD Treatment Plant at mine closure.

Since February 1993, about 17,500 m^3 of sludge has been pumped from the settling ponds to the lower elevations of the Main Zone Pit under Approval No. AE-11974, which expired on October 31, 1993. Two 75-HP sludge pumps, a surge tank, and a pipeline were built in the last part of 1992 for this operation.

Southern Tail Pit water is currently discharged to Bessemer Creek. As sampling is currently carried out weekly at the Silt Check Dam outlet, the discharge can be re-routed to the AMD Collection System to avoid exceeding permit limits in the creek. The discharge has been diverted on occasions for treatment.

7.5.1.2 Permitted discharge

Permit PE-4475, which was amended on March 30, 1994, allows discharges to the environment from four different sites. They are as follows:

1. Discharge of Runoff, Excess Tailings Pond Supernatant, Treated Acid Mine Drainage, and Treated Sewage from the Silt Check Dam Facility to Bessemer Creek (SEAM Site No. 0700081).— This discharge consists of treated acid mine drainage and treated sewage effluent discharged from the Diversion Pond, excess tailings pond supernatant, and surface runoff from outside the confines of the acid mine drainage collection system. The maximum and average authorized rates of discharge are 422,092 m^3/day and 3,575,000 m^3/yr, respectively. The works authorized are a settling pond (also known as the Silt Check Dam Facility) on lower Bessemer Creek and related appurtenances.

The characteristics of the effluent at the last point of control (Silt Check Spillway as the compliance point) shall be equivalent to or better than:

Dissolved As = 0.05 mg/L	Dissolved Cu = 0.05 mg/L
Nitrite/Nitrate (as N) = 20 mg/L	Dissolved Fe = 0.30 mg/L
Dissolved Al = 0.50 mg/L	pH = 6.5 - 8.5
Total Suspended Solids = 75* mg/L	Dissolved Sb = 0.25 mg/L
Dissolved Cd = 0.01 mg/L	Dissolved Zn = 0.20 mg/L

Toxicity (rainbow trout 96-hr LC50 static bioassay) = 100%

* Total Suspended Solids = 75 mg/L until August 31, 1995 and 50 mg/L thereafter.

2. Discharge of Excess Tailings Pond Supernatant, Treated Acid Mine Drainage and Treated Sewage from the Diversion Pond to Foxy Creek (SEAM Site No. E206600).— This discharge consists of treated acid mine drainage, treated sewage effluent, and excess tailings pond supernatant from the Diversion Pond.

The maximum rate at which effluent may be discharged from the Diversion Pond to Lu Creek Diversion Channel, thence to Foxy Creek, is 400,000 m^3/year. The discharge rate is subject to the measured dissolved copper concentration of the effluent dilution ratios as follows:

(Cu) mg/L	Dilution Ratio Foxy Creek: Discharge
0.05	20:1
0.04	16:1
0.03	12:1
0.02	7:1
0.01	3:1

The dilution ratio is to be based on flow measurement on Foxy Creek upstream of the point of discharge.

The characteristics of the effluent shall be equivalent to or better than:

Dissolved As = 0.05 mg/L	Dissolved Cu = 0.05 mg/L
Nitrite/Nitrate (as N) = 20 mg/L	Dissolved Fe = 0.30 mg/L
Dissolved Al = 0.50 mg/L	pH = 6.5 - 9.0
Total Suspended Solids = 50 mg/L	Dissolved Sb = 0.25 mg/L
Dissolved Cd = 0.01 mg/L	Dissolved Zn = 0.20 mg/L

Toxicity (rainbow trout 96-hr LC50 static bioassay) = 100%

In addition to satisfying the above water quality requirements, effluent with pH in the range 8.5 - 9.0 must have characteristics being equivalent to or better than:

Total As = 0.05 mg/L
Total Cd = 0.01 mg/L
Total Cu = 0.05 mg/L
Total Sb = 0.25 mg/L
Total Zn = 0.20 mg/L

The works authorized are a sewage treatment lagoon, an acid mine drainage collection system, an acid mine drainage treatment plant, sludge settling ponds, a treated effluent storage pond (known as the Diversion Pond), pumps, pipes and related appurtenances.

3. Discharge of Excess Tailings Pond Supernatant, Treated Acid Mine Drainage and Treated Sewage from the Diversion Pond to Bessemer Creek, thence to Buck Creek (SEAM Site No. E206601).— This discharge consists of treated acid mine drainage, treated sewage effluent, and excess tailings pond supernatant from the Diversion Pond. The maximum rate at which effluent may be discharged from the Diversion Pond to Bessemer Creek, thence to Buck Creek, is 800,000 m^3/year.

The discharge rate is subject to the measured dissolved copper concentration of the effluent and dilution ratios as follows:

(Cu) mg/L	Dilution Ratio Bessemer Creek: Discharge
0.05	33:1
0.04	26:1
0.03	19:1
0.02	12:1
0.01	5:1

The dilution ratio is to be based on flow measured on Buck Creek upstream of the point of discharge.

The characteristics of the effluent shall be equivalent to or better than:

Dissolved As = 0.05 mg/L
Dissolved Cu = 0.05 mg/L
Nitrite/Nitrate (as N) = 20 mg/L
Dissolved Fe = 0.30 mg/L
Dissolved Al = 0.50 mg/L
pH = 6.5 - 9.0
Total Suspended Solids = 50 mg/L
Dissolved Sb = 0.25 mg/L
Dissolved Cd = 0.01 mg/L
Dissolved Zn = 0.20 mg/L
Toxicity (rainbow trout 96-hr LC50 static bioassay) = 100%

In addition to satisfying the above water quality requirements, effluent with pH in the range 8.5 - 9.0 must have characteristics being equivalent to or better than:

Total As = 0.05 mg/L
Total Cd = 0.01 mg/L
Total Cu = 0.05 mg/L
Total Sb = 0.25 mg/L
Total Zn = 0.20 mg/L

The works authorized are a sewage treatment lagoon, an acid mine drainage collection system, an acid mine drainage treatment plant, two sludge settling ponds, a treated effluent storage pond (also known as the Diversion Pond), a settling pond (also known as Silt Check Dam Facility) on lower Bessemer Creek, pumps, pipes and related appurtenances.

4. Discharge of AMD Sludge to Main Zone Pit (SEAM Site E220237).— This discharge consists of acid mine drainage sludge from two sludge settling ponds associated with the Acid Mine Drainage Treatment Plant. There is no restriction on discharge rate for acid mine drainage sludge. The characteristics of the effluent shall be acid mine drainage lime treatment plant sludge (complexes of calcium sulphate and metal hydroxides). The works authorized are two sludge settling ponds, a sludge booster pump, a sludge conveyance pipeline and related appurtenances.

7.5.1.3 Receiving environment monitoring

In addition to the current Receiving Environment Monitoring Program outlined in Table 7.7, the permittee is also required to carry out the following:

- Annual fish study - peamouth chub and rainbow trout to be collected from Goosly Lake and rainbow trout from Foxy Creek above Maxan Creek, in sufficient numbers to obtain 5 analyzable samples of each species at Goosly Lake and of rainbow trout at Foxy Creek. Analyze axial muscle tissue for concentrations of Cu, Zn, and Cd.

- Fish, water quality, invertebrate, periphyton, sediment and sediment core analysis studies to be completed every 4 years or as directed by the Regional Waste Manager. Terms of Reference to be approved by the Regional Waste Manager prior to commencement.

The EPP report *Equity Silver Mines Ltd. Permit Amendment - Receiving Environment Assessment July 1993* provides the following summary of receiving environment monitoring (Sharpe 1993). Data found in Table 7.8, Table 7.9, Table 7.10 and Table 7.11 correspond with the following summary given by Sharpe.

- Since 1990, dissolved copper levels have trended downward at the Lower Foxy Creek site, and remained relatively constant at or near the 0.005 mg/L Water Quality Objective (WQO) at the Buck Creek/Goosly Lake site. The WQO of 0.05 mg Cu/L, which was proposed by Equity and accepted by EPP, is higher than the MOELP criteria for the protection of aquatic life. Higher peaks (0.007 - 0.018 mg/L) correspond with high runoff periods in March, April, September, and October. Dissolved copper levels have remained high at the Silt Check Dam site since 1990 (0.0115 - 0.0157 mg/L). Much of this copper is being removed by organic ligands in the swamps between this station and Goosly Lake. The estimated copper complexing capacity of Buck Creek waters has been shown to be between 0.0286 and 0.0479 mg/L (Godin 1992).

- Dissolved cadmium levels in Buck Creek have been at or above 0.0002 mg/L consistently since 1990. Lower Foxy Creek site has experienced high dissolved cadmium in 1991, despite the fact there was no discharge of treated ARD that year. The Upper Foxy Creek control site has experienced high cadmium sporadically since 1984.

- The MOELP criteria for the protection of aquatic life for zinc (0.03 mg/L) has not been exceeded since 1986 at Buck Creek/Goosly Lake and since 1990 at Lower Foxy Creek stations.

- The Buck Creek/Goosly Lake station has averaged between 3.9 and 10.7 mg/L TSS, with maxima not exceeding 25 mg/L since 1982 (cf. estimated maximum criteria of 22 mg/L). The additional loading of TSS at freshet (57 mg/L in 1992 and especially 309 mg/L in June 1993) would not result in a significant rise at this station due to wetlands between it and the Silt Check Dam. However there may be some impact on the biotic resources of Buck Creek due to the smothering effects of additional sediments.

Table 7.7 Receiving environment monitoring program Equity Silver Mines PE-4475

	pH	Spec. Cond.	TSS	Ca CO3	SO4	Cu(t)	Zn(t)	Cd(t)	Cu(d)	An(d)	Al(d)	Cd(d)	Flow	LC50
0400763 Foxy Cr. above Lu diversion	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	CM	
0400764 Foxy Cr. below Berzelius Div.	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M		
0400765 Buck Cr above Bessemer Cr	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	CM	
0700081 Bessemer at Siltcheck	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	CM	
E206600 Treated ARD to Foxy Cr	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	CM	(d)
E206601 Treated ARD to Bessemer Cr	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	CM	(d)
0700108 Foxy Cr at Maxan Cr	M	M	M	M	M	M	M	M	M	M	M	M		
0400766 Buck Cr at Goosly Lk inlet	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M	W/M		

W/M - Weekly while discharging/monthly otherwise
CM - continuous flow monitoring
(d) - Two 96-hr rainbowtrout LC50 bioassays per year - one prior to discharge the other approximately half way through the discharge period.

Table 7.8 Water quality summary upper Foxy Creek (0400763), Equity Silver Mines PE-4475, 1990-1993

mg/L		Zn(d)	Zn(t)	Al(d)	Al(t)	Cd(d)	Cd(t)	pH	SO4	CaCO3	Cu(d)	Cu(t)
1990	AVG	0.005	0.005	0.109	0.252	0.001	0.002	7.04	1.9	23.8	0.001	0.002
	STD	0	0	0.081	0.213			0.52	4.5	5.3	0	0.002
	MAX	0.005	0.005	0.31	0.65	0.001	0.002	7.7	6.3	30.2	0.002	0.008
	MIN	0.005	0.005	0.012	0.023	0.001	0.002	5.63	1	11.6	0.001	0.001
1991	AVG	0.005	0.007	0.143	0.447			7.11	1.3	23.1	0.002	0.005
	STD	0.001	0.004	0.074	0.575			0.22	0.5	5.8	0.002	0.006
	MAX	0.008	0.017	0.23	2.3			7.46	2.5	32.4	0.009	0.023
	MIN	0.005	0.005	0.033	0.08			6.81	1	12.2	0.001	0.001
1992	AVG	0.005	0.005	0.19	0.357			7.06	1.4	21.2	0.001	0.002
	STD			0.091	0.162			0.05	0.7	4.9	0.001	0.002
	MAX	0.005	0.005	0.32	0.683			7.59	3	27.4	0.004	0.01
	MIN	0.005	0.005	0.039	0.133			6.09	1	11.7	0.001	0.001
1993	AVG	0.007	0.009	0.157	0.321			7.01	1.9	23	0.001	0.001
	STD	0.004	0.01	0.107	0.219			0.37	0.9	6.1	0.0004	0.0004
	MAX	0.015	0.039	0.449	0.899			7.6	3.7	30.5	0.002	0.002
	MIN	0.005	0.005	0.016	0.124			6.3	1	11.5	0.001	0.001

Average Cadmium levels 1984 to 1993

	Cd(d)
1984	0.0007
1985	0.0005
1986	0.0005
1987	0.0005
1988	0.0002
1989	0.0002
1990	0.0002
1991	0.0005
1992	0.0002
1993	0.0002

Table 7.9 Water quality summary lower Foxy Creek (0400764), Equity Silver Mines PE-4475, 1990-1993

mg/L		TSS	pH	SO4	CaCO3	Cu(d)	Cu(t)	Fe(d)	Zn(d)	Zn(t)	Al(d)	Al(t)	Cd(d)
1990	AVG	7.7	7.29	53.7	40.1	0.005	0.007	0.073	0.009	0.01	0.065	0.329	0.0002
	STD	12.7	0.36	18.5	11.4	0.005	0.01	0.053	0.012	0.02	0.065	0.388	0.0001
	MAX	46	7.94	85.6	60	0.017	0.037	0.21	0.048	0.07	0.25	1.23	0.0004
	MIN	1	6.57	28.6	18.4	0.001	0.001	0.03	0.005	0.01	0.005	0.029	0.0002
1991	AVG	15	7.39	54	42.3	0.003	0.008	0.086	0.007	0.03	0.09	1.059	0.0005
	STD	36.4	0.26	47.9	18.5	0.002	0.013	0.053	0.004	0.06	0.075	2.71	0.001
	MAX	133	7.96	190	89.3	0.007	0.05	0.21	0.02	0.22	0.22	10	0.0037
	MIN	1	6.9	12.7	16.5	0.001	0.001	0.03	0.005	0.01	0.012	0.016	0.0002
1992	AVG	7.8	7.24	49.6	36.6	0.004	0.004	0.111	0.006	0.01	0.132	0.322	0.0002
	STD	12.4	0.26	66.4	10.9	0.002	0.003	0.052	0.002	0.01	0.116	0.307	
	MAX	47	7.56	267	60.7	0.008	0.011	0.222	0.012	0.03	0.44	1.16	0.0003
1993	AVG	3.4	7.14	28.5	58.8	0.002	0.003	0.091	0.005	0.01	0.092	0.231	0.0002
	STD	3.6	0.33	11.4	60.6	0.002	0.002	0.044	0.001	0	0.084	0.272	
	MAX	12	7.73	48.5	257	0.008	0.008	0.169	0.007	0.02	0.3	0.917	0.0002
	MIN	1	6.65	13	18.9	0.001	0.001	0.035	0.005	0.01	0.015	0.026	0.0002

Table 7.10 Water quality summary Buck Creek at Goosly Lake (0400766), Equity Silver Mines PE-4475, 1990-1993

mg/L		TSS	pH	SO4	CaCO3	Nitrate	Cu(d)	Cu(t)	Fe(d)	Fe(t)	Zn(d)	Zn(t)	Al(d)	Al(t)	Cd(d)	Cd(t)
1990	AVG	6	7.27	109.4	65.15	0.57	0.0038	0.0062	0.464	0.984	0.007	0.01	0.0836	0.313	0.0002	0.0002
	STD	4.8	0.32	81.7	16.43	0.64	0.0015	0.0034	0.216	0.52	0.002	0.004	0.0913	0.231		
	MAX	16	8.02	352	85.2	2.46	0.007	0.016	0.99	2.49	0.011	0.018	0.37	0.85	0.0003	0.0003
	MIN	1	6.72	32.6	29.4	0.01	0.001	0.001	0.22	0.49	0.005	0.005	0.005	0.042	0.0002	0.0002
1991	AVG	3.9	7.32	97	68.55	0.32	0.003	0.0036	0.443	1.29	0.006	0.01	0.0482	0.1583	0.0002	0.0002
	STD	1.9	0.33	68.1	16.91	0.43	0.002	0.0025	0.185	0.436	0.002	0.01	0.078	0.2031		0.0001
	MAX	8	8.02	220	84.2	1.3	0.003	0.008	0.749	2.17	0.012	0.04	0.29	0.7	0.0002	0.0006
	MIN	1	6.9	23.7	33.5	0.01	0.001	0.001	0.1	0.678	0.005	0.005	0.005	0.019	0.0002	0.0002
1992	AVG	5.3	7.29	50.5	64.88	0.04	0.0039	0.0044	0.671	1.334	0.006	0.01	0.0833	0.2271	0.0002	0.0002
	STD	4.1	0.18	43.9	22.44	0.04	0.0024	0.0027	0.299	0.459	0.003	0.008	0.0884	0.1609		
	MAX	18	7.58	171	102	0.13	0.009	0.01	1.4	2.11	0.014	0.029	0.25	0.54	0.0002	0.0002
	MIN	2	6.93	11.1	25.6	0.01	0.001	0.001	0.228	0.642	0.005	0.005	0.01	0.055	0.0002	0.0002
1993	AVG	5.9	7.18	32.4	64.81	0.07	0.0043	0.0099	0.665	1.603	0.007	0.018	0.0987	0.3504	0.0002	0.0003
	STD	5.2	0.2	51.9	22.66	0.15	0.0034	0.0106	0.286	0.458	0.003	0.021	0.1641	0.4438		0.0001
	MAX	20	7.4	203	92.3	0.57	0.011	0.039	1.28	2.28	0.017	0.078	0.63	1.55	0.0002	0.0005
	MIN	1	6.85	9.2	30.7	0	0.001	0.001	0.309	0.985	0.005	0.005	0.008	0.052	0.0002	0.0002

Average Zinc and TSS levels 1982 to 1993

	Zn(t)	TSS
1982	0.024	8.9
1983	0.012	5.5
1984	0.019	7.7
1985	0.007	4
1986	0.006	13.9
1987	0.006	8
1988	0.005	4.3
1989	0.005	10.7
1990	0.006	6
1991	0.007	3.9
1992	0.01	5.3
1993	0.021	5.9

Table 7.11 Water quality summary Bessemer Creek at the Siltcheck (0700081), Equity Silver Mines PE-4475, 1990-1993

mg/L		TSS	pH	SO4	CaCO3	Nitrate	Cyanide	As(d)	As(t)	Cu(d)	Cu(t)
1990	AVG	11.8	7.68	754.3	92	5.11	0.005	0.0029	0.0046	0.0157	0.0234
	STD	16.6	0.29	279.5	25.8	3.86	0	0.0043	0.0049	0.0088	0.0149
	MAX	85.3	8.26	1880	118	14.1	0.005	0.015	0.016	0.039	0.074
	MIN	1	7.06	185	38.6	0.5	0.005	0.007	0.0011	0.001	0.006
1991	AVG	8.2	7.77	629.5	91.1	5.76	0.005	0.0012	0.002	0.0115	0.0184
	STD	12.8	0.36	281.1	25.2	8.71	0	0.0006	0.0018	0.0071	0.0136
	MAX	61	8.35	1520	119	29.7	0.005	0.0021	0.0075	0.04	0.064
	MIN	1	6.57	165	43.3	0.4	0.005	0.0003	0.0004	0.001	0.006
1992	AVG	10.4	7.6	505.2	29.8	0.55	0.017	0.0007	0.0016	0.0128	0.0189
	STD	14.2	0.6	324.1	14	0.64	0.014	0.0005	0.0013	0.0079	0.0145
	MAX	57	9.46	1270	70	1.85	0.04	0.0021	0.0049	0.037	0.076
	MIN	1	6.25	104	23.5	0.01	0.005	0.0001	0	0.005	0.006
1993	AVG	13.4	7.24	205.6	45.2	0.06	0.01	0.0008	0.0045	0.0162	0.0251
	STD	43.7	0.33	237.6	13.4	0.06	0.005	0.0003	0.0087	0.0066	0.0229
	MAX	309	7.97	1100	71.9	0.19	0.015	0.0011	0.0324	0.035	0.156
	MIN	1	6.38	51.1	17	0	0.005	0.0003	0	0.007	0.007
		Fe(d)	Fe(t)	Sb(d)	Sb(t)	Zn(d)	Zn(t)	Al(d)	Al(t)	Cd(d)	Cd(t)
1990	AVG	0.1	0.33	0.047	0.0488	0.039	0.049	0.06	0.22	0.0007	0.0008
	STD	0.15	0.39	0.022	0.0215	0.019	0.027	0.04	0.24	0.0004	0.0004
	MAX	0.53	1.09	0.13	0.13	0.087	0.12	0.16	0.91	0.0017	0.0015
	MIN	0.03	0.05	0.014	0.016	0.01	0.014	0.02	0.05	0.0002	0.0002
1991	AVG	0.04	0.28	0.092	0.097	0.039	0.059	0.05	0.33	0.0009	0.0009
	STD	0.02	0.48	0.074	0.0777	0.022	0.042	0.03	0.54	0.0004	0.0005
	MAX	0.1	1.9	0.32	0.32	0.096	0.21	0.12	1.91	0.0016	0.0019
	MIN	0.03	0.04	0.013	0.014	0.013	0.018	0.01	0.02	0.0003	0.0004
1992	AVG	0.06	0.33	0.012	0.013	0.036	0.05	0.09	0.44	0.0005	0.0006
	STD	0.07	0.29	0.007	0.0075	0.03	0.04	0.07	0.43	0.0003	0.0004
	MAX	0.37	1.11	0.03	0.032	0.135	0.173	0.23	1.32	0.0013	0.0015
	MIN	0.03	0.03	0.001	0.0016	0.005	0.005	0.02	0.05	0.0002	0.0002
1993	AVG	0.09	0.95	0.007	0.008	0.028	0.048	0.11	1.5	0.0004	0.0005
	STD	0.06	2.58	0.003	0.0023	0.024	0.047	0.06	3.02	0.0004	0.0004
	MAX	0.23	17.6	0.012	0.0142	0.098	0.244	0.24	10.9	0.0015	0.0015
	MIN	0.02	0.04	0.003	0.0051	0.005	0.005	0.03	0.11	0.0002	0.0002

Sharpe concludes that some impacts to the receiving waters of Foxy and Buck Creeks may have already occurred. Although fish populations in both Buck and Foxy Creek drainages are apparently numerous and healthy, an unexplained reduction in steelhead trout fry densities in Buck Creek occurred in 1992 (Bustard 1994). The decline in steelhead fry densities was more severe than in other tributaries in the vicinity of Equity. Godin (1992) found that rainbow trout in Goosly Lake were not accumulating metals in muscle, gill or liver tissues. Peamouth chub from Goosly Lake, on the other hand, tended to accumulate higher metal levels.

Godin stated that a shift to more pollution-tolerant invertebrate species had occurred in Goosly Lake, but that the presence of large numbers of Cladocerans, which have been shown to be susceptible to heavy metal contamination, indicated relatively good conditions for aquatic life. These impacts remain within the bounds of acceptability given the current regime of discharges. Further study is necessary to ensure that impacts can be closely monitored, and judgments as to their acceptability can be made.

Since treated ARD volumes are projected by Equity to increase over a period of years by up to 350,000 m^3 (>30% increase), it may be necessary to reduce metal contaminant concentrations in effluent by a corresponding amount. The most recent hydrology study for Equity has revised the unit monthly streamflow forecast for Foxy and Buck Creeks. The previous value of 14 $L/s/km^2$ used for predictive purposes has been revised downward by 22% to 10.6 $L/s/km^2$. This new value may make a difference in calculating maximum annual discharges to treated AMD to the two creek systems.

Sharpe's recommendations regarding future consideration of the site are summarized as follows:

- An AMD discharge plan should be prepared by Equity to establish new permitted treated AMD discharge volume limits. This plan should use dilution to minimize toxic effects of metals during periods of high creek flows. If effluent quality begins to stabilize in terms of the variability in the concentrations of the suite of metals found in it, then mesocosm and fish toxicity studies similar to those carried out previously by Richardson and Perrin (1990) and Carrier (1991) should be conducted. In addition, the most recent hydrological studies (revising the streamflow forecast for Foxy and Buck Creeks downward by 22%), as well as a system of daily streamflow monitoring should be considered in any new efforts to fine-tune effluent discharge rates.

- Since treated AMD volumes are predicted to increase by over 30% in the next few years, a review of current discharge quality limits should occur, based on the concept of "no net increase" in total loading to the two watersheds. In addition to copper, cadmium should be factored into any dilution rate scale that might accompany a new set of effluent quality requirements.

- Equity be required to permanently divert the Southern Tail Pit discharge to the AMD collection and treatment system, since this flow contains dissolved cadmium at least 20 times the treated ARD discharge and 200 times the MOELP criteria for the protection of aquatic life (0.0002 mg/L). According to Carrier (1991), aquatic organisms are highly sensitive to cadmium as a toxicant. Low concentrations over narrow range cause both chronic and acute toxicity.

- Cadmium should be added to the list of water quality analyses for all present monitoring sites. Cadmium in Buck Creek and Foxy Creek drainages is already at the MOELP water quality objective concentration of 0.0002 mg/L for the protection of aquatic life.

- Fish studies should be completed annually to maintain the ability to detect and attribute meaningful changes in the health of populations to the appropriate causes. Peamouth chub and rainbow trout axial muscle metal concentrations should be used as an index of trends in metal contamination in fish in Goosly Lake. Five specimens of each species would be a suitable sample size.

- For both Foxy and Buck Creek watersheds, fish, benthic invertebrate, periphyton, sediment and sediment core analysis studies should occur once every 3 - 5 years, depending on trends identified in the fish studies. These studies should include a risk rating similar to that used by Godin (1992), to document changes in aquatic ecosystems in the zone of influence for Equity's discharges.

7.5.1.4 Discussion

It is difficult to assess contaminant loadings from the Equity minesite at this time because: 1) the discharge regime (quantity, quality, timing, and site) has varied considerable over the past several years; 2) AMD quantity and quality is changing as the reclamation of the minesite is carried out; and 3) a recent hydrology study has revised the predicted unit monthly streamflow forecast for Foxy and Buck Creeks downwards by 22%. The strategy suggested by Sharpe of continued detailed monitoring in order to further refine the bounds of acceptable changes in the abundance and health of aquatic life in the Buck and Foxy Creek drainages during the course of mine reclamation appears to be the only option. In the author's opinion, development of water and sediment quality objectives for the Buck Creek/Goosly Lake and the Foxy Creek/Maxan Creek/Bulkley Lake watersheds is necessary in order to set discharge criteria and to focus monitoring during the prolonged period of AMD generation and management from this mine. Datasets critical to the development of water quality objectives for these systems is discussed in section 7.6.6.

7.5.2 District of Houston Sewage Treatment Plant PE-0287

7.5.2.1 Background

The Houston STP is situated on the dyked south bank of the upper Bulkley River about 1.2 km downstream of the confluence of Buck Creek and about 5 km upstream of its confluence with the Morice River. PE-0287 was issued on July 30, 1969 when the plant consisted of two aeration cells, chlorination plant and outfall to the center of the river.

Anadromous fish present in this section of the upper Bulkley include coho and chinook salmon and steelhead trout. Chinook salmon spawn in the immediate vicinity of the STP during late August and early September. Juvenile coho rear in the river for at least one summer and winter following emergence. Steelhead juveniles remain in the river for up to four years prior to leaving the system as smolts, while some chinook may drop downstream out of the upper Bulkley prior to their first winter.

An EPP receiving environment study conducted in 1986 (Maclean and Diemert 1987) found elevated nutrients, particularly orthophosphate, downstream of the STP. This was correlated to increased periphyton biomass accumulation on artificial and natural substrates 850 m downstream of the STP. Algal biomass was lowest 100 m downstream of the outfall, which was attributed to residual chlorine acting as an algaecide. Taxonomic analysis also indicated a shift in periphyton community structure consistent with eutrophication. An increase in fecal coliforms downstream of the STP during low flow periods was also noted. Subsequently a third storage cell was added to provide effluent storage during periods of extremely low flows.

7.5.2.2 Receiving environment monitoring 1990

A receiving environment monitoring program consisting of monthly water quality and annual biological monitoring was required by EPP in November 1989. The District of Houston initiated monthly receiving water sampling and analysis on September 17, 1990. Receiving environment biological monitoring commenced during summer low flows September 7-14, 1990 (Remington 1991).

Four monthly monitoring sites were established by EPP as follows:

Site 1 (SEAM 0400297) 400 metres upstream of the outfall

Site 2 (SEAM E212484) 400 metres downstream of the outfall and downstream of the #3 Cell. The decision was made not to use EPP Site 0400295 located 100 m downstream of the outfall. Site 2 E212484 was established in order to assess the possibility of exfiltration from the #3 Cell. Cross-stream sampling was required at this site, Site 2E (east bank), Site 2C (center) and Site 2W (west bank).

Site 3 (SEAM E212891) 850 metres downstream. This was the site (Derek CN Station) of maximum periphyton accumulation reported in 1986 by Maclean and Diemert.

Site 4 (SEAM 0400296) 3.2 km downstream of the outfall. This is the site sampled by EPP 1983-1987 (Table 7.4). It is also the location of a public picnic site on the Bulkley River which is a popular swimming spot in warm weather.

Results of the 1990 biological monitoring are summarized below:

- Periphyton standing crop on the natural substrate equaled or exceeded the Bulkley River Objective for protection of aesthetics (50 mg/m^2 chlorophyll *a*) at all sites, and increased downstream of the STP. Periphyton standing crop was shown to be significantly greater at Site 3 as compared to Site 1 by Student's *t* test ($P<0.0000007$). The Objective level for protection of aquatic life of <100 mg/m^2 chlorophyll *a* was exceeded at Site 3 which had a standing crop of 320 mg/m^2. (Sampling for fish at this site was impeded by thick mats of algae which sloughed off the bottom when disturbed.) These are similar to the results of Maclean and Diemert, with greatest periphyton biomass found at Site 3, 850 m downstream, and the lowest biomass 100 m downstream. This was thought to be the result of residual chlorine inhibiting the growth of algae at the site immediately downstream of the STP, despite elevated nutrient concentrations.

  Benthic invertebrate density was high at all sites and increased downstream of the plant. A Student's *t* test indicated a significant difference in density between Site 1 and downstream Sites 2 and 4. The average species density (number of taxa/m^2) was least at Site 1 and greatest at Site 3. Species richness (Margalef's diversity index) was least at Site 2 and greatest at Site 3. Chironomid (midge) larvae were the dominant invertebrate at all sites, and were particularly abundant at Site 3. Ephemeroptera (mayflies) and Tricoptera (caddisflies) were sub-dominant at all sites except Site 3 where Tricoptera were depressed compared to the other sites.

Fish enumeration was carried out at Sites 1 and 3. The predominant species were longnose dace (76.5%) and steelhead fry (18.8%). Juvenile chinook and coho salmon each comprised 1.1% of the overall catch. Sample results suggested that juvenile salmonid densities (excluding one school of mountain whitefish) were slightly higher at Site 1 than at Site 3. However, habitat differences between sites, sampling difficulties, and small number of sample sites could have resulted in this slight variation. Juvenile salmonid densities were within ranges reported previously for the upper Bulkley River.

7.5.2.3 Permitted discharge

A major upgrading of the sewage treatment plant was completed during the summer of 1991. This included a phosphorus removal facility (alum injection system and flocculation chamber), reconstruction of the chlorination/dechlorination system, upgrading of electrical power supply works, the installation of emergency overflow gate from Cell #3, and a new raker bar screen and flow meter. The phosphorus removal facility was not put into full time use until March, 1992.

PE-0287 was last amended October 23, 1991. Permitted discharge to the Bulkley River is as follows:

- The maximum authorized rate of discharge shall be 3200 m^3/day.

- The characteristics of the effluent shall be equivalent to or better than:

Biochemical Oxygen Demand (BOD_5)	30 mg/L
Total Suspended Solids (TSS)	40 mg/L
Total Phosphorous	1.50 mg/L
Chlorine Residual (after dechlorination)	Non-detectable
Toxicity (96-hour LC50)	100% (non-toxic)

7.5.2.4 Receiving environment monitoring 1992

Results of the 1992 biological monitoring (Remington and others 1993) are summarized below:

Water quality.— One way ANOVA was run on data for each water quality parameter to see if differences by site were apparent. Ammonia-N was the only parameter for which there was a significant difference indicated between sites. A series of Student's *t* tests was then run to examine the differences in mean ammonia-N concentrations between Site 1 (control) and each of the downstream sites. A significant ($P<0.05$) increase in mean ammonia-N concentrations was indicated for Sites 2E, Site 2C, and Site 3 downstream of the sewage treatment plant (indicating entrainment of the discharge along the left bank looking downstream). A maximum ammonia-N concentration of 0.385 mg/L was recorded at Site 2E on September 2, 1992 during a period of extreme low flows. Although elevated, total ammonia-N concentrations were less than the Bulkley River Objective level for the protection of aquatic life. As a result of the new phosphorus removal facility, no significant difference in orthophosphate was found between sites.

Periphyton standing crop.— Periphyton biomass as chlorophyll *a* was near or below the 50 mg/m^2 Objective at Sites 1, 3 and 4, but equaled the Objective level for the protection of aquatic life at Site 2E, with a biomass of 100 mg/m^2. This increase in chlorophyll *a* biomass at Site 2 was significant using the Student's *t* test (P=0.0014). Diatoms dominated the algal community at all sites and diversity and richness appeared unaffected by location. Two diatom taxa were found to decrease significantly at Site 2, with recovery at Site 3 and/or Site 4. Other changes in periphyton community structure, although not statistically significant, were consistent with nutrient enrichment. A high degree of disturbance to the substrate was observed during the September 1992 sampling period due to redd building activities of large numbers of spawning chinook salmon.

Nutrient limitation to algal growth.— Calculation of growing season N:P ratios at Site 1 upstream of the plant indicated that the upper Bulkley River is either nitrogen limited or co-limited (that is, either biologically available nitrogen or phosphorus could contribute to excessive stream algal biomass). Nordin (1985) considered that biologically available phosphorus >0.003 mg/L or inorganic nitrogen >0.025 mg/L contributed to high risk of excessive algal biomass. Thus it appears that the Bulkley River upstream of the sewage treatment plant with a mean orthophosphate concentration of 0.016 mg/L, and mean dissolved inorganic nitrogen concentration of 0.033 mg/L, is at high risk for excess and nuisance algae growth. The algal biomass at Site 1 upstream of the plant is already at or near the Objective level for protection of aesthetics and recreation of 50 mg/m^2 chlorophyll *a*. An investigation of non-point sources of nutrients to the upper Bulkley River (e.g. from septic systems and agriculture) was suggested.

Benthic invertebrates.— There was no statistically significant spatial change found in benthic invertebrate density, diversity or richness in the September 1992 sampling, although invertebrate density was nearly doubled at sites 1 and 4 as compared to Site 2E. The general recovery of the benthic community and in many cases an increase in densities suggests that changes which may have occurred at Site 2E were localized, with a general recovery at Sites 3 and 4.

Fish.— Fish species composition in the upper Bulkley is dominated by longnose dace and to a lesser extent longnose suckers (together accounting for about 90% of all fish in the study area). This pattern occurred upstream and downstream of the sewage treatment plant and was thought to reflect a combination of low stream velocities, warm temperatures, (and perhaps eutrophication) in this section of the upper Bulkley, providing longnose dace with a competitive feeding advantage over steelhead and salmon juveniles. Juvenile steelhead and salmon densities combined were in the 0.2 to 0.3 fish/m^2 range at all sites. This density is similar to that measured in 1990 and is relatively low compared to those found in Buck Creek and Foxy Creek, upstream in the Bulkley watershed.

It should be emphasized that the sites selected for comparison were simple sections of stream and that complex debris sites with deeper pool habitat typically utilized by juvenile coho salmon were avoided. Although overall fish biomass (g/m^2) was lower at the two downstream sites, the combined salmon and steelhead biomass was similar upstream and downstream of the STP. Steelhead fry lengths were larger upstream of the treatment plant than downstream. This occurred in the 1990 study also and may reflect more favorable growing conditions upstream of the treatment plant. Overall fry lengths at both locations were large relative to other steelhead producing streams further upstream in the watershed.

7.5.2.5 Receiving environment monitoring 1994

A modified receiving environment monitoring program was conducted in August 1994 and a review of 1993-1994 monitoring data was presented (Remington 1994).

Ammonia-N.— Ammonia-N was the only parameter for which there was a significant difference indicated between sites upstream and downstream of the STP. The average ammonia-N concentration at Site 2 is about 10 times greater than at the upstream sites. A significant increase in ammonia-N concentrations at Sites 2E, 2C and Site 3 was also noted previously. Studies have shown that the un-ionized ammonia molecule is the form of ammonia toxic to fish. The concentration of un-ionized ammonia increases with increasing temperature and pH. Criteria for protection of aquatic life from un-ionized ammonia have been calculated using total ammonia-N concentrations at varying temperature and pH (Nagpal 1994). The maximum ammonia-N concentrations recorded at Site 2 occurred December 1993 through February 1994. The maximum ammonia-N concentration was 0.200 mg/L on 15 December, 1993. At temperatures ranging from 0-1° C and pH ranging from 7.2-7.3 (on that date) the criteria for average 30-day concentration for total ammonia-N is 2.05-2.08 mg/L, which is an order of magnitude greater than concentrations observed.

Elevated ammonia concentrations were measured in the effluent during the winter of 1993-1994, and may be the cause of the less than 100% survival of rainbow trout in 96-hr LC50 toxicity tests of the effluent during this period.

Nitrite.— Nitrite is highly toxic to fish. The provisional objective for nitrite-N in this section of the Bulkley is <0.020 mg/L average, and 0.060 mg/L maximum. The average nitrite-N concentrations were 0.004 mg/L or less at all sites. The maximum nitrite-N concentration recorded was 0.019 mg/L at Site 2 on 13 October, 1993.

Aluminum.— Because aluminum is a by-product of the alum phosphate removal treatment at the plant, dissolved aluminum was added to the monitoring program in 1993. Relatively few samples have been analyzed to date and Single-Factor ANOVA does not indicate a significant change in dissolved aluminum concentrations at sites downstream of the STP. However, all sites had an average dissolved aluminum concentration in exceedance of the criteria for 30-day average dissolved aluminum (0.05 mg/L dissolved Al at pH ≥6.5). Site 3 had an average dissolved aluminum concentration of 0.1 mg/L which is equal to the criterion for maximum dissolved aluminum for the protection of aquatic life.

Periphyton standing crop.— Average periphyton biomass (chlorophyll *a*) at three sites sampled on August 22-23, 1994 is shown in Table 7.12. A Student's *t* test was conducted to examine differences in mean chlorophyll *a* between sites. A statistically significant increase in mean chlorophyll *a* biomass at Site 3 compared to Site 1 was indicated

(P=0.014). The Objective for the Bulkley River is 50 mg/m² chlorophyll *a* to protect recreation (Nijman 1986). The MOELP criteria value is less than 50 mg/m² chlorophyll *a* for the protection of uses related to aesthetics and recreation and less than 100 mg/m² chlorophyll *a* to protect against undesirable changes in aquatic life (Nordin 1985). In 1994 periphyton biomass at all sites was less than the criteria for protection of aquatic life but not recreation.

Table 7.12 Periphyton biomass as chlorophyll *a* (mg/m²) at three sites in upper Bulkley River, August 22-23, 1994

Location	Date Sampled	Rep	Biomass mg/m2	Average/Site
Site 1	22-Aug-94	1	13.3	32.4
		2	44.1	
		3	31.3	
		4	23.9	
		5	29.5	
		6	52.0	
Site 2	22-Aug-94	1	71.4	54.5
		2	63.2	
		3	10.0	
		4	84.7	
		5	84.5	
		6	13.0	
Site 3	22-Aug-94	1	89.9	64.4
		2	44.6	
		3	37.6	
		4	74.2	
		5	87.7	
		6	52.5	

Benthic invertebrates.— For each taxon, summary statistics were determined to examine the importance of taxonomic groups down to the genus level. Statistics were also determined for total numbers, number of taxa (richness), and the Margalef's diversity index. It was clear from these statistics that 11 taxa were most abundant at all sites (cumulatively >90% of the community) despite the large number of taxa found. All other taxa were relatively rare or were found only incidentally. From these rare taxa, those which were found at one or more sites but not at others were identified as they may have been important indicators of site specific differences in community composition. A one way ANOVA was then run on data for each of the dominant taxa to determine if differences in abundance, by site, were apparent.

The mean density of organisms per sample increased from 578/sample at Site 1 to >2500/sample at Sites 2 & 3. Analysis of the data with one way ANOVA indicates a statistically significant site effect (P=0.009). An increase in number of taxa/sample and Margalef's Diversity index were also significant to the P<0.05 level. A comparison of differences in abundance by site of the major taxa (making up 90% of the community), with application of the Bonferroni correction, did not indicate a significant difference in density of any individual organism. Chironomids (particularly Orthocladini) were the most abundant insect group with a large increase in density at Site 2. The most abundant Plecoptera (*Sweltza/Triznaka* sp) and the most abundant Ephemeroptera (*Rhithrogena* sp) also increased downstream of the STP. Given that diversity and numbers of sensitive animals did not decline, but rather increased, there was probably no toxic effect related to the effluent from the STP. The increase in densities was thought to be a response to nutrient enrichment.

Effluent rainbow trout LC50 toxicity during winter.— Portman (1995) of EPP prepared a review of the District of Houston STP outfall data. Rainbow trout 96-hour LC50 toxicity testing indicated effluent acute toxicity during the winter months of 1993 and 1994. Ammonia concentration in the effluent was elevated during the winter months as well, and the toxicity failures were correlated to increased ammonia concentrations. In general, rainbow trout toxicity began to be exhibited when ammonia-N concentration exceeded 10 mg/L in effluent. There was no correlation found between toxicity and the other parameters routinely monitored for STPs, that is, TSS and BOD. Nor was there a demonstrable correlation between toxicity and dissolved aluminum concentrations in effluent, although dissolved aluminum concentrations consistently exceed the criteria for the protection of aquatic life. See section 7.6.5 for further discussion and monitoring recommendations.

7.5.3 Regional District of Bulkley Nechako (Knockholt) PR-8856

7.5.3.1 Background

The Regional District of Bulkley Nechako applied for a permit to discharge municipal refuse from the community of Houston on June 22, 1990. The landfill which was operating at that time (PR-2687) on the edge of Houston was running out of space and the land lease was set to expire on November 17, 1990. After searching for many years, Knockholt was finally chosen for its location and soils.

The site is located 8 km east of Houston in the Knockholt CN Station area. The land is gently sloping to the north with the Bulkley River about 875 meters away at the nearest point. Soil samples from the area were analyzed and found to be 60% clay and 40% sand indicating a fairly low permeability, allowing retention of leachates and remediation of the water through adsorption of nutrients and ions on the clay. The application was approved and the permit issued on August 31, 1990.

7.5.3.2 Permitted discharge

The permit allows a maximum discharge rate of 2015 tonnes/year of refuse and a maximum discharge rate of 400 m^3/year of sewage waste disposal. Both trench and ramp methods are permitted with cover and compaction at least once every day. The frequency of covering may vary when freezing conditions adversely affect normal operation.

The site has consistently been out of compliance for insufficient compaction, infrequent covering and insufficient leachate control due to ponded water. A warning letter was sent by EPP in August 1995 citing non-compliance with Waste Management Permit PR-8856 and seven others.

During the winter of 1994 the Regional District attempted to build a trench for winter use but found that during construction a considerable amount of water entered the trench making it unacceptable for landfilling refuse. It was difficult to ascertain whether the water was from surface or groundwater. As a result the Regional District will hire a consultant to undertake a geotechnical study of the site. The Knockholt site has been designated as a possible Regional Landfill site under the Solid Waste Management Plan and as a result would expand to accept refuse from the entire Bulkley Nechako Regional District.

7.5.4 Regional District of Bulkley Nechako (Topley) PR-1791

7.5.4.1 Background

The Topley Landfill is located on a level site 2.5 km north of Topley on the Topley Landing Road.

7.5.4.2 Permitted discharge

Permit PR-1791 for a municipal landfill serving the community of Topley and surrounding area was issued December 11, 1972. In 1988 the permit was amended to allow open regulated burning of municipal type waste including putrescibles. This was amended in 1992 to allow open burning of only selected non-putrescible refuse (such as woodwaste). The maximum authorized rate of discharge is 66 tonnes/year. An open trench method with compaction and soil cover at least once per month is required.

The site has been in and out of compliance with the permit requirements frequently over the years due to a lack of maintenance. Permit inspection in 1991 noted that there was only room for one more trench on the site. The permittee informed EPP that they would be decommissioning this site in the fall of 1993 but failed to provide a Closure Plan.

Complaints from the public and an inspection in early 1994 indicated that the Topley site 1) was still road accessible to the public and had no closure sign, 2) was still being used by the public, and 3) was not receiving regular maintenance (cover and compaction). In August 28 1995 a warning letter was sent to the Regional District concerning non-compliance with Waste Management Permit PR-1791 and seven other sites.

7.5.5 Minor Discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PE-6049	Chevron Canada Ltd.	Houston	Oil/Water separator discharge to ground	Average 15 m^3/day
PE-7188	Gerry's Trailer Court	Houston	Septic tank effluent discharge to ground	Average 21 m^3/day
PE-10849	Finning Tractor	Houston	Oil/Water separator discharge to ground	Average 19 m^3/day
PE-5674	Lund Creek Development	Perow	Septic Tank effluent to ground	Average 74 m^3/day
PR-3782	Regional District of Bulkley Nechako (RDBN) Old Perow site	Perow	Municipal refuse to ground - Site is now closed	
PR-2687	RDBN - Old Houston site	Houston	Municipal refuse to ground - Site is now closed	

7.6 SUMMARY AND REVIEW OF MONITORING NEEDS

The upper Bulkley River may be the reach of the Skeena watershed which has been most impacted by human activities. Some of the first permanent settlement occurred in the upper Bulkley, with settlers employed in tie-making and land clearing for agriculture. The railway was constructed paralleling the length of the Bulkley River in the early 1900's, followed by Highway 16, and later construction of the natural gas pipeline. Forestry expanded into the major tributaries with a shift to primarily clear-cut logging in the early 1970's. Equity Silver Mine was built south of Houston in 1980 and operated until mine closure in 1992. The District Municipality of Houston is located near the mouth of Buck Creek on the floodplain of the Bulkley River.

7.6.1 Hydrometric data needs

Environment Canada is undertaking a review, with the goal of reducing the WSC hydrometric network. Both the year-round hydrometric station on Buck Creek and the summertime station on the upper Bulkley are subject to discontinuation if funding support from other agencies is not found. Rather than remove these stations, this author considers it essential to keep both stations in place and, in addition, to upgrade the station at Houston to a year-round station. The reasons are as follows:

- The discharges of treated ARD from the Equity Silver Mine into Foxy and Buck Creeks are based on available dilution. These discharges will continue for centuries, according to current knowledge, and long-term hydrometric data are important to the management of these discharges.
- Water withdrawals, mainly for agriculture, are estimated to be about 46% of the 7 day average 10 year low flow at Houston. Hydrometric data is necessary to the assessment of these withdrawals. The District of Houston obtains its municipal water supply from shallow wells in the floodplain next to the river, and there are 59 other domestic water use licenses in the watershed. Excessive water withdrawals, coupled with climate variation, could result in water shortages and insufficient in-stream flows for fish.
- It is presently difficult to assess the dilution of discharge from the District of Houston STP because year-round streamflow data is not available.
- It has been suggested by several researchers (Coulson 1989, McBean and others 1992) that a potential effect of climate change (warming) may be reduced summer and early autumn flows in streams of the Interior Plateau hydrologic regions, such as the upper Bulkley basin.

7.6.2 Land use activities and nutrient/bacterial loading

Water quality in the upper Bulkley River appears to be moderately affected by land-use activities in the watershed. Available data indicates that considerable nutrient enrichment occurs upstream of the main known nutrient point source, the sewage treatment plant at Houston. Orthophosphate concentrations upstream of Houston are approximately 0.016 mg/L. This is by far the highest orthophosphate concentration of any of the seven Skeena River watershed sites monitored 1983-1987. The nearby Morice River, for example, has an orthophosphate concentration of less than the detection limit (<0.003 mg/L). Limited sampling of Avalon Creek, at its junction with the

Bulkley, found orthophosphate concentrations about three times greater than in the Bulkley (mean=0.048 mg/L). Avalon Creek is a small intermittent creek which passes through several farms and then a small housing subdivision (utilizing septic tanks). Buck Creek was found to have a mean orthophosphate concentration of 0.027 mg/L. Again, there are several farms in this watershed.

An increase in total phosphorus and orthophosphate loadings to streams draining agricultural areas has been demonstrated elsewhere (see section 2.1.4). Orthophosphate represents the dissolved biologically available form of phosphorus which is usually the nutrient limiting the growth of algae (periphyton) in streams. A calculation of growing season nitrogen:phosphorus ratios indicated that the upper Bulkley River is either nitrogen limited or co-limited (that is, either biologically available nitrogen or phosphorus could contribute to excessive stream algal biomass). This is because there was an abundance of orthophosphate available (suspected to be from anthropogenic non-point sources). Nordin (1985) considered that biologically available phosphorus >0.003 mg/L or inorganic nitrogen >0.025 mg/L contributed to a high risk of excessive algal biomass. Thus it appears that the Bulkley River upstream of the sewage treatment plant with a mean orthophosphate concentration of 0.016 mg/L, and mean dissolved inorganic nitrogen concentration of 0.033 mg/L, is at risk. The algal biomass upstream of the STP is already at or near the objective level for protection of aesthetics and recreation of <50 mg/m^2 chlorophyll *a*.

Fecal coliform bacteria concentrations upstream of the sewage treatment plant at Houston have often exceeded the water quality objective for this section of Bulkley. Livestock may be a contributor to elevated fecal coliform concentrations in a watershed if careful waste management practices are not followed.

Juvenile fish enumeration conducted in 1990 and 1992 found fish species composition in the upper Bulkley at Houston to be dominated by longnose dace and to a lesser extent longnose suckers. This pattern occurred upstream and downstream of the STP, and was thought to reflect a combination of low stream velocities, warm temperatures, and possibly eutrophication, providing longnose dace with a competitive feeding advantage over steelhead and salmon juveniles.

Monitoring needs.— Identification of the sources of nutrient loading to the upper Bulkley is a research priority. Sampling should be conducted in all major tributaries and related to soil type and land-use activities within the watershed. These should include forestry, agriculture and the subdivisions around Houston which are served by septic tanks.

7.6.3 Interaction of agriculture and water quality

There are an estimated five ranches and 20 hobby farms running approximately 500 breeding cows in the upper Bulkley drainage. It is believed that most of this activity is focused on private lands along the mainstem Bulkley River. There were grazing permits for about 3100 cattle and 48 horses issued in the Morice Forest District in 1992. Most of this grazing occurs in tributaries to the upper Bulkley, with some along the Morice.

Unless careful stream protection practices are followed, runoff from winter feedlots and uncovered manure piles can affect water quality by direct toxic effects (ammonia and nitrite), by the addition of nutrients and bacteria, and by creating oxygen demand. Improper livestock grazing can also result in a decline in streambank vegetation and stability. All animal wastes contain microorganisms, and more than 100 diseases are transmissible between animals and humans.

Monitoring needs.— An assessment of agricultural interactions with water quality is an important research need for this reach of the Skeena watershed. Agriculture is the most wide-spread land-use activity, as well as the activity most likely to lead to nutrient enrichment of streams. Runoff of nutrients and bacteria from winter feeding and calving areas near the mainstem Bulkley and tributaries is a particular concern. In addition, an assessment of range use practices in the watershed is needed.

A second concern is water withdrawal for irrigation, which is estimated to be 46% of 7 day average 10 year summer low flow. Low in-stream flows can cause problems for fish because of higher temperatures and lack of dilution for nutrients and waste discharges. At present, there are no data on the actual volumes of water utilized for irrigation, or to what extent instream flows in smaller tributaries may be affected. See further discussion in section 12.4.

7.6.4 Interaction of forestry and water quality

A number of practices from the early part of the century, such as log driving down Buck Creek and log handling in Bulkley Lake, undoubtedly had negative impacts on water quality and fisheries. Forestry is now centered in the major tributaries of Maxan/Foxy Creeks, Dungate Creek and Buck Creek.

An assessment of stream protection practices in the Morice TSA, conducted in the mid-1980's, noted that extensive logging operations around tributaries of the Bulkley encompass high value salmon and steelhead streams. There had been a shift away from total reserves towards the use of machine reserves along streams due to windthrow problems in the reserves. Most forestry and fisheries personnel interviewed in the Morice TSA indicated that they were satisfied that machine reserves provided adequate streamside protection.

Sediment from roads (due to both construction and inadequate maintenance) was cited as the main impact from logging activities on streams in the Morice TSA. As well, blockage of fish movements due to poor culvert installation and maintenance was cited as a problem. These concerns were quite widespread due to the distribution of steelhead trout and coho salmon through many of the smaller tributaries in the district.

7.6.4.1 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is a major land-use activity in this reach. The FPC is expected to improve compliance with stream protection guidelines and the Watershed Restoration Program is intended to address problems such as lack of road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring is also necessary to ensure that LRMP management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.3.

7.6.5 Interaction of mining and water quality

7.6.5.1 Equity Silver Mine

Equity Silver Mines Limited owns and operated a copper, gold and silver mine/mill complex, located about 32 km southeast of Houston, in the headwaters of Bessemer and Foxy Creeks. Bessemer Creek flows southward into Buck Creek and Goosly Lake, while Foxy Creek flows northward into Maxan Creek, then into Bulkley Lake, the head of the Bulkley River. Mining and milling operations ceased in early 1994 due to lack of economic ore.

In 1981 acidic drainage, commonly called either acid rock drainage (ARD) or acid mine drainage (AMD) was found to be occurring from the oxidation of sulfides contained in the approximately 85 million tonnes of mined waste rock. Within a few years, elevated levels of acidity, copper, zinc and iron were discovered in seepages from the tailings pond, waste rock dump and waste rock used as plant site and road foundation materials. The company had to start excavating a system of deep trenches around the site to collect the drainage. Later a lime treatment plant to neutralize acid and remove metals prior to discharging treated water to Bessemer and Foxy Creeks was added.

In 1986, it was estimated that 800,000 m^3 of AMD was produced per year from the minesite, with mean concentration 88 mg/L copper, 58 mg/L zinc, 16 mg/L arsenic, 775 mg/L iron and a pH of 2. Bioassay results indicated a 11,000:1 dilution ratio would be required to protect water quality and fisheries in the nearby creeks. See section 2.1.3 for further discussion.

A $37.5 million security bond was required in the mine's reclamation permit, which was posted in 1991. Of this amount, $32 million is for financing the long-term AMD treatment cost upon completion of reclamation and $5.5 million is to ensure that the placement of compacted clay cover on the waste dumps and the plant site clean-up are completed.

AMD from the waste rock piles and plant site is collected and conveyed to a storage pond and treatment plant for neutralization with slaked lime to pH of 8.5. For 1992, about 818,000 m^3 of AMD was treated at an average acidity of 8,950 mg/L ($CaCO_3$ equivalent), using 5,164 tonnes of lime. This compares to 767,650 m^3 of AMD at an acidity of 11,475 mg/L using 5,916 tonnes of lime for 1991. Lime consumption seemed to have peaked at 6,500 tonnes in 1990 but has declined since then.

Treated effluent is discharged to two sludge settling ponds. From here, the treated effluent is discharged to Foxy or Bessemer Creek depending on the available dilution in the creeks. For the past few years, treated AMD discharges have been occurring in the spring to take advantage of increased dilution. The maximum rate at which effluent may be discharged is subject to the measured dissolved copper concentration of the effluent and dilution ratios based on flow measurement in the creeks upstream of the point of discharge. The maximum permitted rate of discharge of treated AMD to Foxy Creek is 400,000 m^3/year, with a dilution ratio calculated to achieve a maximum instream dissolved copper concentration ≤0.003 mg/L. The maximum permitted rate of discharge of treated AMD to Bessemer Creek, thence to Buck Creek, is 800,000 m^3/year, with a dilution ratio calculated to achieve a maximum instream dissolved copper concentration ≤0.002 mg/L.

Since February 1993, about 17,500 m^3 of AMD sludge has been pumped from the settling ponds to the lower elevations of the largest open pit remaining from mining. Water from a smaller open pit (Southern Tail Pit) is discharged to Bessemer Creek. Sampling is carried out weekly and the discharge is occasionally re-routed to the AMD collection system to avoid exceeding permit limits in the creek. Most of the drainage from outside the confines of the AMD collection system drains directly to Bessemer Creek. The last point of control and compliance point on Bessemer Creek is a Silt Check Dam facility just upstream of Buck Creek.

Equity Silver Mines has been generally in compliance with its permit requirements.

Copper.— The dissolved copper water quality objective (WQO) of 0.005 mg/L was proposed by Equity and accepted by EPP for this drainage. Although higher than the MOELP criterion, this was justified by background levels occurring occasionally in Buck and Foxy Creeks. Since 1990, dissolved copper levels have trended downward at the lower Foxy Creek monitoring site, and remained relatively constant at or near the 0.005 mg/L WQO at the Buck Creek/Goosly Lake site.

Dissolved copper levels have remained high at the Silt Check Dam site since 1990 (0.011-0.016 mg/L). It is evident that much of this copper is being removed by organic ligands in the swamps between this station and Goosly Lake. It appears that complexing capacity in this drainage (0.029-0.048 mg Cu/L) is sufficient to protect the aquatic resources in Goosly Lake from copper toxicity at current discharge rates.

Cadmium.— CCME and MOELP water quality criterion for the protection of aquatic life for total cadmium is 0.0002 mg/L at hardness=60 mg $CaCO_3$/L. Dissolved cadmium levels in Buck Creek have been at or above 0.0002 mg/L consistently since 1989. Lower Foxy Creek experienced high dissolved cadmium levels in 1991, despite the fact there was no discharge of treated AMD that year. This may result from seepage from the minesite and runoff from areas of high mineralization. The Upper Foxy Creek control site has experienced high cadmium levels sporadically since 1984.

Zinc.— The MOELP criterion for the protection of aquatic life for zinc (0.03 mg/L) has not been exceeded since 1986 at Buck Creek/Goosly Lake and since 1990 at Lower Foxy Creek stations.

A review by EPP indicates that some impacts to the receiving waters of Foxy and Buck Creeks may have already occurred (Sharpe 1993). However, these impacts remain within the bounds of acceptability given the current regime of discharges. Further study is necessary to ensure that impacts can be closely monitored, and judgments as to their acceptability can be made.

Since treated ARD volumes are projected by Equity to increase over a period of years by up to 350,000 m^3 (>30% increase), it may be necessary to reduce metal contaminant concentrations in effluent by a corresponding amount. The most recent hydrology study for Equity has revised the unit monthly streamflow forecast for Foxy and Buck Creeks downward by 22%. This new value may make a difference in calculating maximum annual discharges of treated AMD to the two creek systems.

Sharpe's recommendations are summarized as follows:

- An AMD discharge plan should be prepared by Equity to establish new permitted treated AMD discharge volume and quality limits based on the concept of "no net increase" in total loading to the two watersheds. This plan should use dilution to minimize toxic effects of metals during periods of high creek flows. In addition to copper, cadmium should be factored into any dilution rate scale that might accompany a new set of effluent quality requirements. If effluent quality begins to stabilize in terms of the variability in the concentrations of the suite of metals found in it, then mesocosm and fish toxicity studies similar to those carried out previously at the site should be conducted. In addition, the most recent hydrological studies, as well as a system of daily streamflow monitoring should be considered in any new efforts to fine-tune effluent discharge rates.
- Equity be required to permanently divert the Southern Tail Pit discharge to the AMD collection and treatment system, since this flow contains dissolved cadmium at least 20 times the treated ARD discharge and 200 times the MOELP water quality criterion for the protection of aquatic life of ≤0.0002 mg/L.
- Cadmium should be added to the list of water quality analyses for all present monitoring sites. Cadmium in Buck Creek and Foxy Creek drainages is already at the criterion concentration.
- Fish studies should be completed annually to maintain the ability to detect and attribute meaningful changes in the health of populations to the appropriate causes. Peamouth chub and rainbow trout axial muscle metal concentrations should be used as an index of trends in metal contamination in fish in Goosly Lake and Foxy Creek.
- For both Foxy and Buck Creek watersheds, fish, benthic invertebrate, periphyton, sediment and sediment core analysis studies should occur once every 3-5 years, depending on trends identified in the fish studies. These studies should include a risk rating similar to that used by Godin (1992) to document changes in aquatic ecosystems in the zone of influence for Equity's discharges.

Discussion and additional monitoring needs.— It is difficult to assess contaminant loadings from the Equity minesite at this time because: 1) the discharge regime (quantity, quality, timing, and site) has varied considerably over the past several years; 2) AMD quantity and quality is changing as the reclamation at the minesite is carried out; and 3) a recent hydrology study has revised the predicted unit monthly streamflow forecast for Foxy and Buck Creeks downwards by 22%. The strategy suggested by Sharpe of continued detailed monitoring in order to further refine the bounds of acceptable changes in the abundance and health of aquatic life in the Buck and Foxy Creek drainages during the course of mine reclamation appears to be the only option.

Suggested modifications/additions to Sharpe's monitoring recommendations are as follows:

- The monitoring requirements for the Buck Creek/Goosly Lake and Foxy Creek above Maxan Creek should include analysis of humic acid, dissolved organic carbon and "free copper", to further develop the relationship between these parameters, as was recommended in water quality assessment and objectives for Tsolum River basin, Vancouver Island (Deniseger and Pommen 1995).
- Receiving environment complexing capacity for cadmium should be determined to help develop the relationship between complexing capacity and cadmium bioavailability.
- Bulkley Lake should be added to the receiving environment monitoring program. EPP conducted several surveys of this lake in 1987 which can be considered as background data. The Foxy Creek/Maxan Creek/Bulkley Lake system will be a long term receptor of the treated ARD discharge, and fisheries resources are high in this system. In addition there are other mining prospects in the Foxy Creek drainage which could result in cumulative loadings.
- According to Bustard (Equity Silver Mines Ltd. Environmental Report 1994), there were no peamouth chub found in Goosly Lake in 1994 and there has never been a record of peamouth chub in Goosly Lake. Godin (1992) may have mistaken largescale suckers for peamouth chub, leading to some confusion as to appropriate monitoring species. It is suggested that largescale suckers be used instead as a fish monitoring species for Goosly Lake.
- At present, the fish studies in Goosly Lake and Foxy Creek call for analysis of axial muscle only. It is suggested that analysis be conducted on fish livers, rather than or in addition to axial muscle, for both metals and metallothionein. The data collected by Equity for the past several years has been for fish livers. Musculature has been proven not to be the most suitable body part for determining the extent of heavy metal accumulation of the entire organism (Förstner and Wittmann 1981). Organs with the greatest affinity to heavy metals were recommended for evaluation, particularly liver, gill or kidney. The BC Acid Mine Drainage Task Force review of biological monitoring for heavy metals (EVS 1990) recommends using fish bone metals levels to indicate chronic exposure levels, and gill, liver or kidney levels to illustrate recent metabolic activity.

7.6.5.2 Datasets critical to the development of water and sediment quality objectives for the Buck Creek/Goosly Lake and Foxy Creek/Maxan Creek/Bulkley Lake watersheds

It is a recommendation of this study that water and sediment quality objectives be developed for both the Buck Creek/Goosly Lake and Foxy Creek/Maxan Creek/Bulkley Lake watersheds. Watershed specific objectives are necessary in order to set discharge criteria and to focus monitoring during the prolonged period (centuries) of ARD generation and management from this mine and perhaps additional mines in the watershed.

Acute and chronic toxicity of treated ARD to stream and lake biota.— When reclamation of the site is complete, and the treated ARD discharge has stabilized considering the suite of metals present, mesocosm and bioassay fish and benthic invertebrate studies similar to those carried out previously could be utilized in establishing both discharge limits and Water Quality Objectives.

Both acute and chronic toxicity data will be required for objectives setting, utilizing a battery of biological assessment tests. Factors such as the multiple metals found in the treated ARD and the organic complexing capacity of the waterbodies need to be addressed. Therefore, *in-situ* bioassays are suggested using varying dilutions to represent the range of metal concentrations in proposed discharges and to establish dose/response relationships.

Water quality objectives have recently been developed for the ARD impacted Tsolum River watershed on Vancouver Island (Deniseger 1995). Deniseger recommends monitoring for "free" copper, which is an estimate of the amount of dissolved copper which is not organically bound and proposes an analytical method. In addition to detailed analysis of total and dissolved metals concentrations, analysis should include humic acid, dissolved organic carbon and "free" copper to further develop the relationship between these parameters.

The most promising and proven biological monitoring techniques (EVS 1990) are benthic community responses and growth and reproductive parameter of fish populations. The benthic invertebrate community may be particularly useful in lake situations, since benthic response may relate both to changes in water and sediment quality. The use of mesocosm studies, such as conducted at the minesite previously, is suggested as the most direct means of measuring benthic and fish community responses to a gradient of ARD additions.

Sediment quality objectives.— The establishment of lake sediment quality objectives is deemed particularly important, since it is assumed that the bottom sediments of Goosly and Bulkley lakes will be the long term receptor sites of heavy metal contamination. Sequential extractions have been performed on recently deposited sediments in Goosly Lake. Cadmium content in the sediments showed a large proportion in the easily exchangeable fraction, indicating that this was a metal of concern.

The minimum toxicological dataset requirements for derivation of freshwater sediment quality guidelines for the protection of aquatic life (CCME 1995) are:

- At least four studies are required on two or more sediment-resident invertebrate species that occur in North American waters. There must include at one benthic crustacean species and one benthic arthropod species other than a crustacean.
- At least two of these studies must be partial or full life-cycle test that consider ecologically relevant end points (e.g., growth, reproduction, developmental effects).

The Sediment Quality Triad approach (Chapman and others 1987) consists of three components: sediment chemistry which measures contamination, sediment bioassays which measure toxicity, and biological community structure (in situ or field parameters) which measures alteration. Sediment toxicity bioassays ideally would include a range of test including acute lethal, acute sublethal and chronic tests. Tests and test organisms recommended for ARD (EVS 1990) are:

- *Daphnia magna*: both acute (48 hr) and chronic (7 day);
- *Hyallela azteca*: sublethal acute (10 day) lethality; and
- *Chironomus tentans*: chronic (10 day) partial life-cycle.

Spiked-sediment toxicity tests may be necessary to further refine dose/response relationships. Consideration should be given to conducting all bioassays over a longer timeperiod than 10 days. In an assessment of hardness and humic concentration effect on the bioaccumulation and toxicity of copper, Winner (1985) noted that, in bioassays using *Daphnia spp.*, a 21 day exposure period was not long enough for determining an ecologically relevant no effect concentration. Previous studies have shown that copper concentrations which cause mortality beyond a 21-day exposure also cause a reduction in filtration rate, growth and negative phototactic behavior. See further discussion in section 12.6.

7.6.6 Interaction of urban developments and water quality

7.6.6.1 District of Houston STP

The Houston STP is situated on the dyked south bank of the upper Bulkley River about 1.2 km downstream of the confluence of Buck Creek and about 5 km upstream of its confluence with the Morice River. In 1986 the plant consisted of two aeration cells, chlorination plant and outfall to the center of the river.

An EPP study conducted in 1986 found elevated nutrients, particularly orthophosphate, correlating to increased periphyton biomass downstream of the STP. Taxonomic analysis also indicated a shift in periphyton community structure consistent with eutrophication. An increase in fecal coliforms downstream of the STP during low flow periods was also noted. Subsequently a third storage cell was added to provide effluent storage during periods of low flows.

A receiving environment monitoring program, including monthly water sampling and periodic biological sampling, was initiated in 1990 using four monitoring sites. Site 1 was 400 m upstream of the STP outfall, Site 2 was 400 m downstream, Site 3 was 850 m downstream, and Site 4 was 3.2 km downstream. Biological data collected during the summer low flow period 1990 are summarized as follows:

Periphyton standing crop.— Periphyton standing crop on the natural substrate equaled or exceeded the Bulkley River Objective for protection of aesthetics (50 mg/m^2 chlorophyll *a*) at all sites, and increased downstream of the STP. Periphyton standing crop was shown to be significantly greater at Site 3, as compared to Site 1. The criterion level for protection of aquatic life of <100 mg/m^2 chlorophyll *a* was exceeded at Site 3 which had a standing crop of 320 mg/m^2.

Benthic invertebrates.— Benthic invertebrate density was high at all sites and increased downstream of the plant. Chironomid (midge) larvae were the dominant invertebrate at all sites, and were particularly abundant at Site 3. Ephemeroptera (mayflies) and Tricoptera (caddisflies) were sub-dominant at all sites except Site 3 where Tricoptera were depressed compared to the other sites.

Fish.— Fish enumeration was carried out at Sites 1 and 3. The predominant species were longnose dace (76.5%) and steelhead fry (18.8%). Juvenile chinook and coho salmon each comprised 1.1% of the overall catch. Sample results suggested that juvenile salmonid densities were slightly higher at Site 1 than at Site 3. However, habitat differences between sites, sampling difficulties, and the small number of sample sites could have resulted in this slight variation.

Installation of phosphorus removal facility and subsequent monitoring.— A major upgrading of the sewage treatment plant was completed during the summer of 1991. This included installation of a phosphorus removal facility (alum injection system and flocculation chamber), reconstruction of the chlorination/dechlorination system and other improvements. The phosphorus removal facility was not put into full time use until March, 1992.

Water quality.— Subsequent to the improvements, ammonia-N was the only parameter for which there was a significant difference indicated between upstream and downstream sites, with an increase in mean ammonia-N occurring at Sites 2 (east bank), Site 2(center), and Site 3 downstream of the sewage treatment plant (indicating entrainment of the discharge along the left bank looking downstream). Although elevated, total ammonia-N concentrations were within Bulkley River Objective levels for the protection of aquatic life. Elevated ammonia concentrations were measured in the effluent during the winter of 1993-1994, and may be the cause of the less than 100% effluent rainbow trout in 96 hr LC50 bioassay results during this period.

As a result of the new phosphorus removal facility, a there was no significant difference found in total phosphorus or orthophosphate concentrations between sites.

Because aluminum is a by-product of the alum phosphate removal treatment at the plant, dissolved aluminum was added to the monitoring program in 1993. The limited dataset indicated no change in dissolved aluminum concentrations at sites downstream of the STP. However, sites upstream and downstream had an average dissolved aluminum concentration in exceedance of the criterion for 30-day average dissolved aluminum.

Results of late summer biological monitoring 1992 and 1994 are summarized below:

Periphyton standing crop.— In 1992 periphyton biomass as chlorophyll *a* was below the 50 mg/m^2 objective at Sites 1, 3 and 4, but equaled the objective level for the protection of aquatic life at Site 2, with a biomass of 100 mg/m^2. Diatoms dominated the algal community at all sites and diversity and richness appeared unaffected by location. Two diatom taxa were found to decrease significantly at Site 2, with recovery at Site 3 and/or Site 4. Other changes in periphyton community structure, were consistent with nutrient enrichment. In 1994 periphyton biomass downstream of the plant slightly exceeded the <50 mg/m^2 aesthetics objective, but the 100 mg/m^2 criterion for protection of aquatic life was not exceeded. See discussion on nutrient limitation to algal growth in section 7.6.2.

Benthic invertebrates.— In 1992 and 1994 the mean density of benthic organisms per sample increased from Site 1 upstream to Sites 2 & 3 downstream. Chironomids were the most abundant insect group with a large increase in density at Site 2, thought to be the result of nutrient enrichment. The most abundant Plecoptera (stoneflies) and the most abundant Ephemeroptera (mayflies) also increased downstream of the STP. Given that diversity and numbers of sensitive animals did not decline, there was probably no toxic effect related to the effluent.

Fish.— Fish species composition, sampled in 1992, was dominated by longnose dace and to a lesser extent longnose suckers (together accounting for about 90% of all fish in the study area).

This pattern occurred upstream and downstream of the sewage treatment plant and probably reflected a combination of low stream velocities, warm temperatures, (and perhaps eutrophication) in this section of the upper Bulkley, providing longnose dace with a competitive feeding advantage over steelhead and salmon juveniles.

Effluent rainbow trout LC50 toxicity during winter.— Rainbow trout 96-hour LC50 toxicity testing during the winter months of 1993 and 1994 demonstrated acute 100% effluent toxicity. The toxicity failures were correlated to elevated ammonia concentrations during the winter months. In general rainbow trout toxicity began to be exhibited when ammonia concentration exceeded 10 mg/L in effluent. There was no correlation found between toxicity and TSS or BOD. Nor was there a demonstrable correlation between toxicity and dissolved aluminum concentrations in effluent, although dissolved aluminum concentrations consistently exceed the criteria for the protection of aquatic life.

Discussion and monitoring needs.— The phosphorus removal facility, installed in 1992, has been demonstrated to reduce phosphorus concentrations in effluent and receiving environment, resulting in a substantial reduction in periphyton biomass downstream, as compared to previous levels. Studies conducted in 1992 and 1994 indicate periphyton standing crop is still elevated downstream of the STP and may be aesthetically undesirable but, in general, biomass does not exceed the criterion for the protection of aquatic life. While phosphorus removal may not be necessary for the winter months, it should be continued for the entire summer growing season.

Relatively high orthophosphate concentrations are found in the upper Bulkley River compared to other Skeena tributaries (section 7.6.2, Table 7.5). Calculation of N:P ratios indicates that algae growth in the upper Bulkley is either nitrogen-limited or co-limited by nitrogen and phosphorus. With orthophosphate concentrations in upstream waters in the order of 0.016 mg/L, the addition of biologically available nitrogen compounds by the STP (ammonia and nitrate) would be expected to result in an increase in algal biomass. This effect is seen in increased algal standing crop and a shift in the benthic invertebrate community indicative of nutrient enrichment (increased density of chironomids). Fish studies indicate that the Bulkley River in this reach may be suffering from eutrophication, both upstream and downstream from the STP. The sources of nutrient and bacterial loading in the upper Bulkley watershed upstream of the STP need to be identified.

The question of toxicity due to elevated concentrations of dissolved aluminum in the effluent due to alum use in phosphorus removal has been raised. Research on dissolved aluminum toxicity of fresh STP alum sludge (Ramamoorthy 1988) would indicate that this is not likely a problem because of the high organic complexing capacity of sewage effluents. A laboratory simulation of an aquatic ecosystem was used, placing rainbow trout directly in tanks with alum sludge (covered with nylon mesh). Aluminum in water quantitatively speciated as a function of pH and toxic and nontoxic aluminum species were identified from fish mortality data. In 96 hours, there were no fish mortalities at pH 7.65 and 9, with corresponding aluminum concentrations of 28 and 307 mg/L in tank waters. Aluminum is known to form strong coordinate water soluble complexes with organic and inorganic ligands. At pH 7-9, aluminum in water was present essentially as filterable nonexchangeable complexes with dissolved organic matter (such as sulphate, humic and fulvic acids) and was not lethal to fish.

Effluent toxicity correlated to elevated wintertime ammonia concentrations is similar to the findings of municipal effluent toxicity studies in other northern Canadian communities. In the absence of a high proportion of industrial discharges to wastewater entering a municipal sewage treatment plant, effluent toxicity is commonly the result of elevated concentrations of un-ionized ammonia. A review of data from Ontario and Western Canada (MISA 1990) found that in plants having secondary treatment, and in spite of high BOD removal efficiencies, effluents were frequently toxic if the total ammonia-N concentration exceeded 10 mg/L. This was very often the case during winter operation, due to reduced nitrification at lower wastewater temperatures.

Maximum permitted discharge at this plant is 3200 m^3/day, or 0.051 m^3/s. The 7 day average 10 year low flow for the upper Bulkley (Table 7.2) is 0.216 m^3/s with 95% confidence limits of 0.023 and 0.455 m^3/s. The maximum permitted discharge during a 10 year return low flow would result in a dilution ratio of 4.2:1, which would be unacceptable according to Pollution Control Objectives. The permit further requires that flows in the river be monitored and dilution ratios calculated. At the request of EPP, the current practice at the plant is to reduce the discharge as much as possible during periods of low river flows, utilizing storage capacity in the third cell.

The mean daily discharge April 1992-December 1994 was 1050.76 m^3/s. During the low flow period of September 1993 to March 1994, the discharge was reduced to an average of 0.009 m^3/s. This lower rate of discharge resulted in dilution ratios in the 500:1 to 1200:1 range. In the winter of 1993-1994, the river remained free of ice and it was possible to gauge the river flows and thus calculate dilution ratios. In most winters, icing conditions prevent flow measurement at this type of hydrometric station.

The criterion for maximum ammonia-N concentration, for temperature 0-1 °C and 7.2-7.3 pH, is 18.8 mg NH_3-N/L. The 30-day average ammonia criterion is 2.05 mg NH_3-N/L. Ammonia concentrations in the winter of 1993-1994 ranged from 3.8 to 18.5 mg/L NH_3-N which would be predicted to produce chronic/acute toxicity within the mixing zone. Acute toxicity was demonstrated in the associated effluent samples (96-hr LC50 75%) over the winter.

The lowest dilution ratio calculated during December 1993 to March 1994 time period was 386:1, which would result in a theoretical ammonia-N concentration of 0.048 mg/L following complete mixing. It should be noted that this was an unusually mild winter, with high flows and little ice.

The worst case theoretical ammonia concentration, assuming 18.5 mg/L NH_3-N in effluent at a discharge rate of 0.009 m^3/s (the 1993-1994 winter discharge rate) and the 7 day average 10 year low flow of 0.216 m^3/s (24:1 dilution ratio), would result in 0.77 mg/L ammonia-N, after complete mixing.

The above analysis indicates that, given the 1993-1994 wintertime discharge rate, acute and/or chronic toxicity from ammonia would be predicted in the mixing zone, but that, following complete mixing, neither acute nor chronic toxicity would be predicted from this discharge. The areal extent of the mixing zone at this site is not known, but entrainment of effluent along the left bank for over 250 m downstream has previously been noted.

Monitoring needs.— The question of acute and chronic toxicity within the mixing zone is somewhat problematic here. There are key fisheries resources immediately downstream of the discharge; chinook salmon spawn and their eggs and alevins overwinter in the gravels, and juvenile chinook, coho and steelhead rear in this area. The use of this reach of the upper Bulkley by overwintering adult or juvenile fish which might be attracted to the warmer temperatures of the wastewater is unknown. The section of river from upstream of the STP to about 200 m downstream of the outfall has been dyked, forming a relatively deep water channel which might be attractive to overwintering fish. A research need is to clarify fisheries usage of the portion of the river which may be experiencing the discharge mixing zone, and to assess possible effects on fish.

An evaluation of the causes of toxicity and methods for toxicity reduction at this plant should be undertaken. While observed ammonia-N concentrations are within a range which could be toxic, there may be other toxicants contributing, for example, metals, chlorine residuals, surfactants, organics. Many of these toxicants can be removed, if detected and traced back to the source. Aluminum speciation in this discharge should be determined as well, to help determine potential biological availability.

The present maximum permitted discharge rate could result in a 4.2:1 dilution ratio during periods of extremely low flows. The Bulkley River Objectives (Nijman 1986) call for no less than a 10:1 dilution ratio at this plant. It is suggested that the permitted maximum discharge rate be reviewed and that discharge rate at this plant be subject to the measured ammonia concentration and dilution ratios based on instream flow measurement (similar to Equity). Again, the need for a year-round hydrometric station and for accurate discharge monitoring is emphasized. As the population of Houston increases and portions of the municipality which are not presently tied to the sewer system are connected, there is a need for long term planning for expansion and/or improved wastewater treatment. Further discussion of research needs in the area of municipal sewage treatment plants is found in section 12.5.

8. BULKLEY RIVER TO SKEENA RIVER CONFLUENCE

Below the confluence of the Morice River, the Bulkley River drains in a northwesterly direction past the communities of Telkwa, Smithers and Moricetown to its confluence with the Skeena at Hazelton (Figures 8.1 and 8.2). The topography is broad and rolling between Houston and Moricetown. The Bulkley valley has the highest agricultural capability in the watershed. The gradient steepens after Moricetown and the Bulkley enters a deeply incised canyon downstream of the Suskwa River. Major tributaries in this reach include the Telkwa River (draining the Bulkley Ranges of the Hazelton Mountains), and Canyon Creek, Reiseter Creek and the Suskwa River (draining the Babine Ranges of the Skeena Mountains). The Bulkley River including tributaries is a Class II angling stream. See section 2.2.4 for explanation of classified waters.

8.1 HYDROLOGY

The hydrometric station at Quick has one of the longest periods of record in the region. The drainage area of the Bulkley at Quick is 7360 km^2. The monthly discharge summary for the Bulkley River at Quick, Station 08EE004, is shown in Table 8.1 and Figure 8.3. One of the major gauged tributaries in this reach is the Telkwa River, which drains the Bulkley Ranges and joins the Bulkley at Telkwa. Monthly mean, maximum and minimum discharge for Station 08EE020, the Telkwa River below Tsai Creek, are shown in Table 8.2 and Figure 8.4. Both of these stations show a discharge peak in late May or early June due to snowmelt in high elevation headwaters, followed by a gradual decline in flows to late winter minima. In many years there is a minor peak in October-November due to fall rains.

The discharge summary for a smaller tributary which drains the main agricultural portion of the valley, Canyon Creek near Smithers, Station 08EE014, is presented in Table 8.3 and Figure 8.5. The drainage area of Canyon Creek is 256 km^2, draining the McKendrick Pass. Flows in Canyon Creek drop off sharply following maximum flows during freshet and, in some years, August-September flows are almost as low as the wintertime low flows, reflecting the lower elevation headwaters of this interior stream.

Environment Canada is undertaking a review and reduction of the hydrometric network, and a number of stations in this reach may be affected. Station 08EE020 Telkwa River is on a list of stations which require funding support from other agencies or it may be discontinued. Station 08EE014 Canyon Creek, Station 08EE012 Simpson Creek, and Station 08EE025 Two-Mile Creek will be decommissioned in 1996 or 1997 if funding support is not found.

8.2 LAND USE HISTORY

8.2.1 Settlements

In earliest recordings, the Wet'suwet'en village of 'Kyah Wiget (later named Moricetown) was located on either side of a narrow gorge of the Bulkley River (Cassidy and Cassidy 1980). The Wet'suwet'en are the western-most branch of the Athapascan Carrier people. The estimated 1992 population of the Moricetown band was 1144 people.

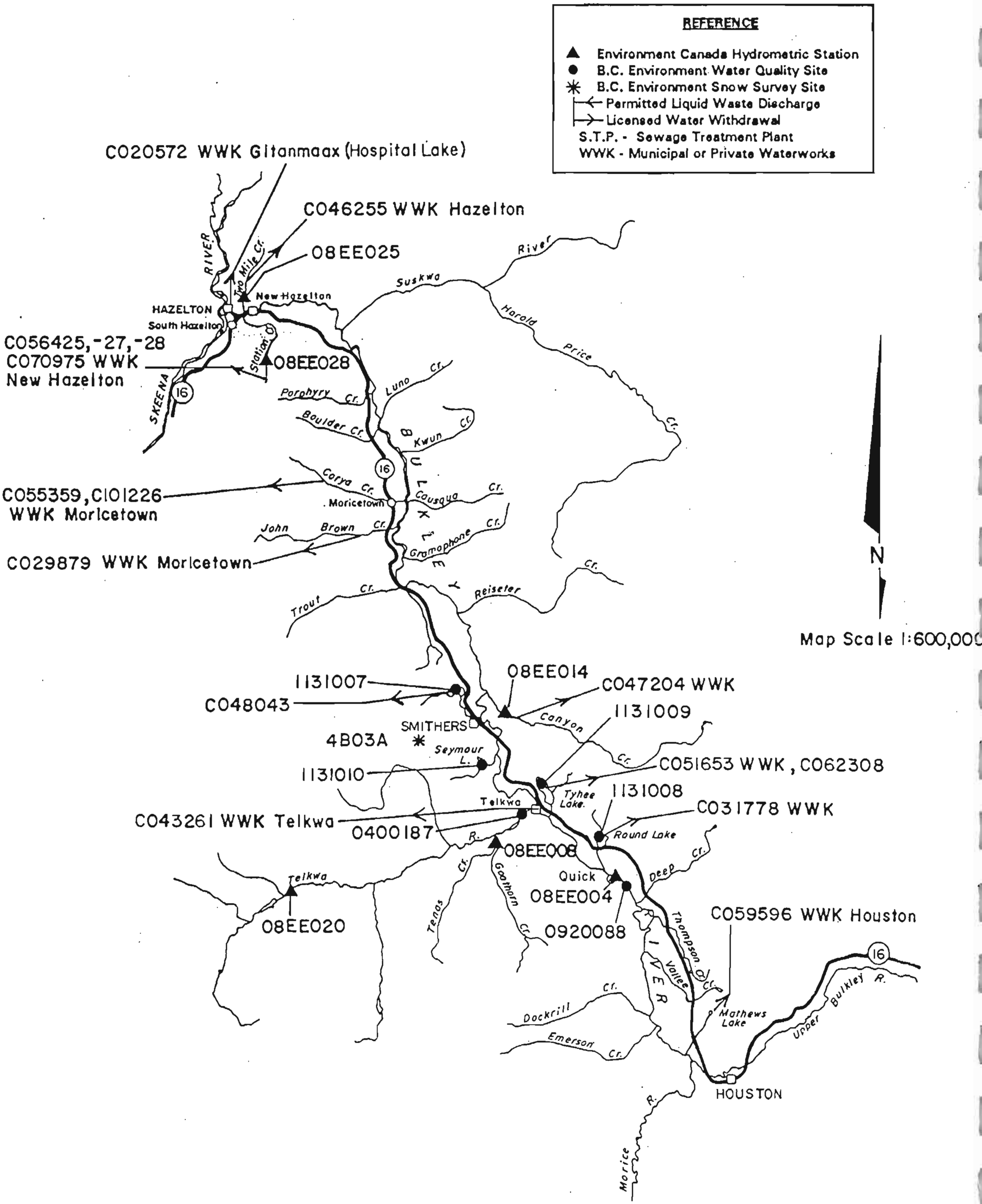


Figure 8.1 Bulkley River to Skeena River confluence (hydrometric sites and licensed water withdrawals)

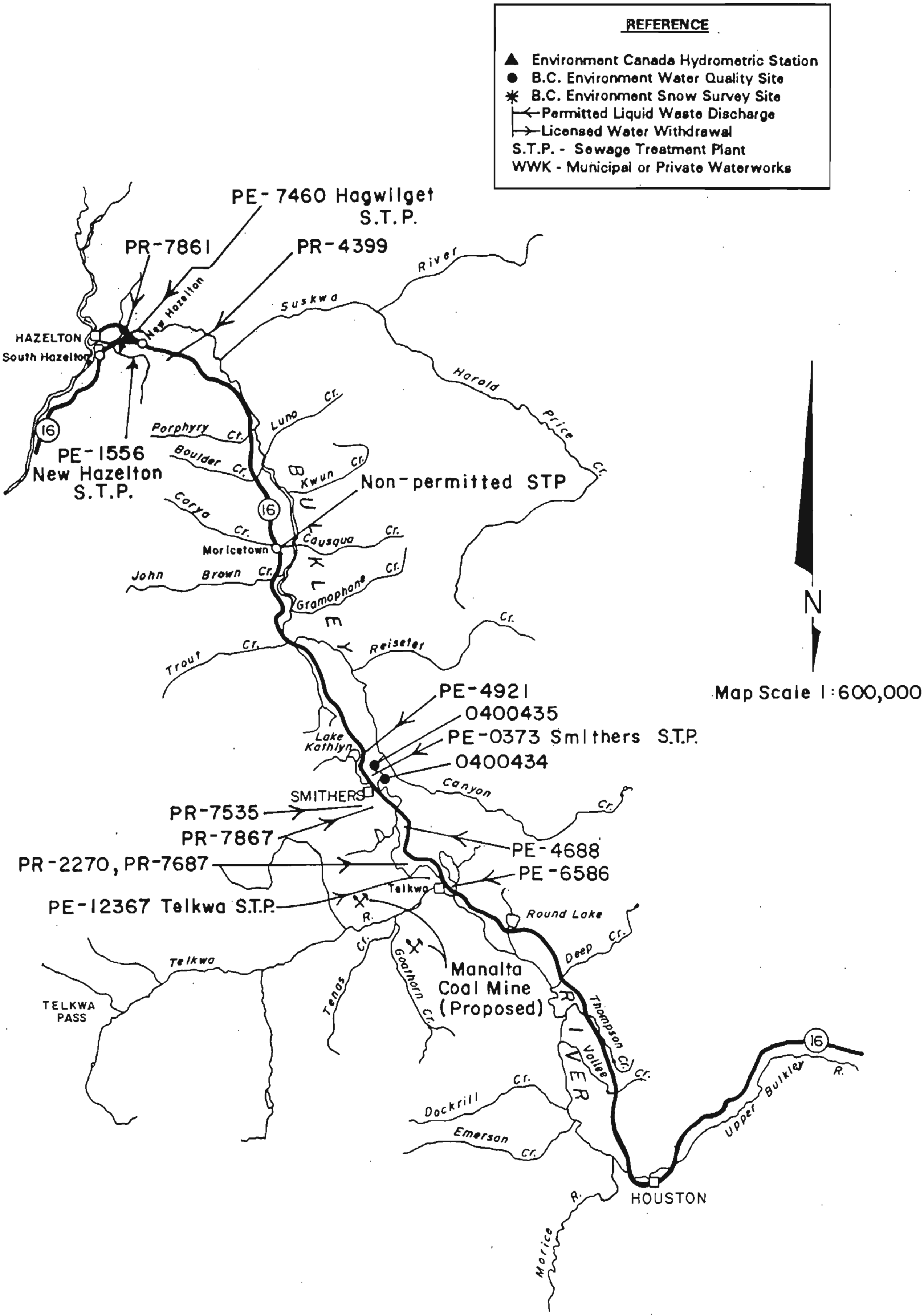


Figure 8.2 Bulkley River to Skeena River confluence (permitted waste discharges)

Table 8.1 Monthly discharge summary Bulkley River at Quick, Station 08EE004

Latitude:	54 37 05 N
Longitude:	126 53 55 W
Drainage Area Gross:	7360 km2
Period of Record	1930-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	86.7	76.3	105	247	450	594	424	280	164	285	293	176
Monthly Min.	15.3	12.2	15.8	22.4	112	223	154	102	65.9	37.3	31.4	17.7
Monthly Mean	39.9	32.0	28.8	81.2	303	366	233	148	103	113	106	62.7

Average 7-day, 10-year low flow is 14.4 m3/s with 95% confidence limits of 12.8 and 16.2.

Figure 8.3 Discharge envelope Bulkley River at Quick, Station 08EE004

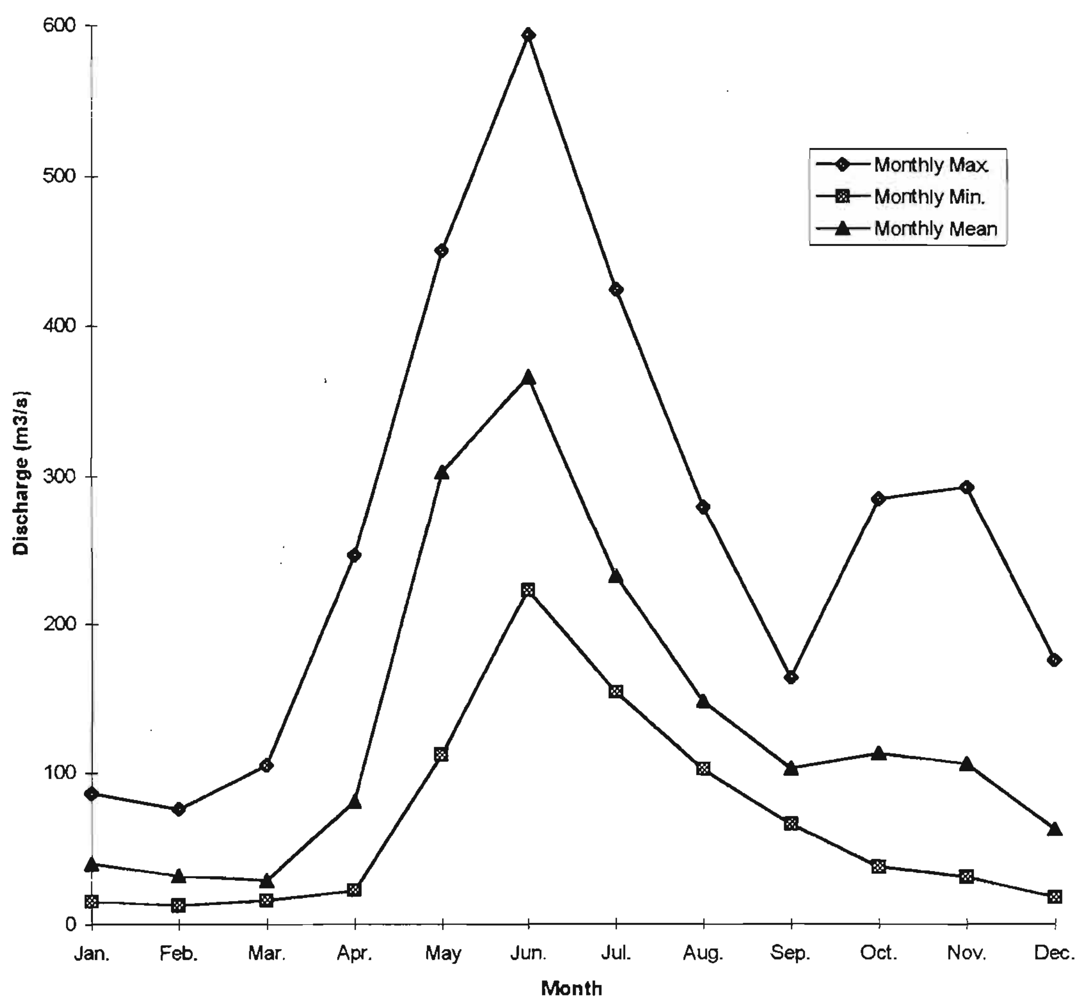


Table 8.2 Monthly discharge summary Telkwa River below Tsai Creek, Station 08EE020

Latitude:	54 36 10 N
Longitude:	127 29 42 W
Drainage Area Gross:	368 km2
Period of Record	1975-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	4.43	3.46	5.57	11.3	43.1	61.4	50.8	34.9	27.6	37.7	18.7	7.29
Monthly Min.	1.59	1.02	1.13	1.16	13.5	30.0	21.4	16.1	11.1	5.86	2.31	1.16
Monthly Mean	2.53	2.18	2.15	4.84	25.4	40.3	31.1	22.2	15.4	13.8	7.93	3.53

Average 7-day, 10-year low flow is 1.09 m3/s with 95% confidence limits of 0.757 and 1.40.

Figure 8.4 Discharge envelope Telkwa River below Tsai Creek, Station 08EE020

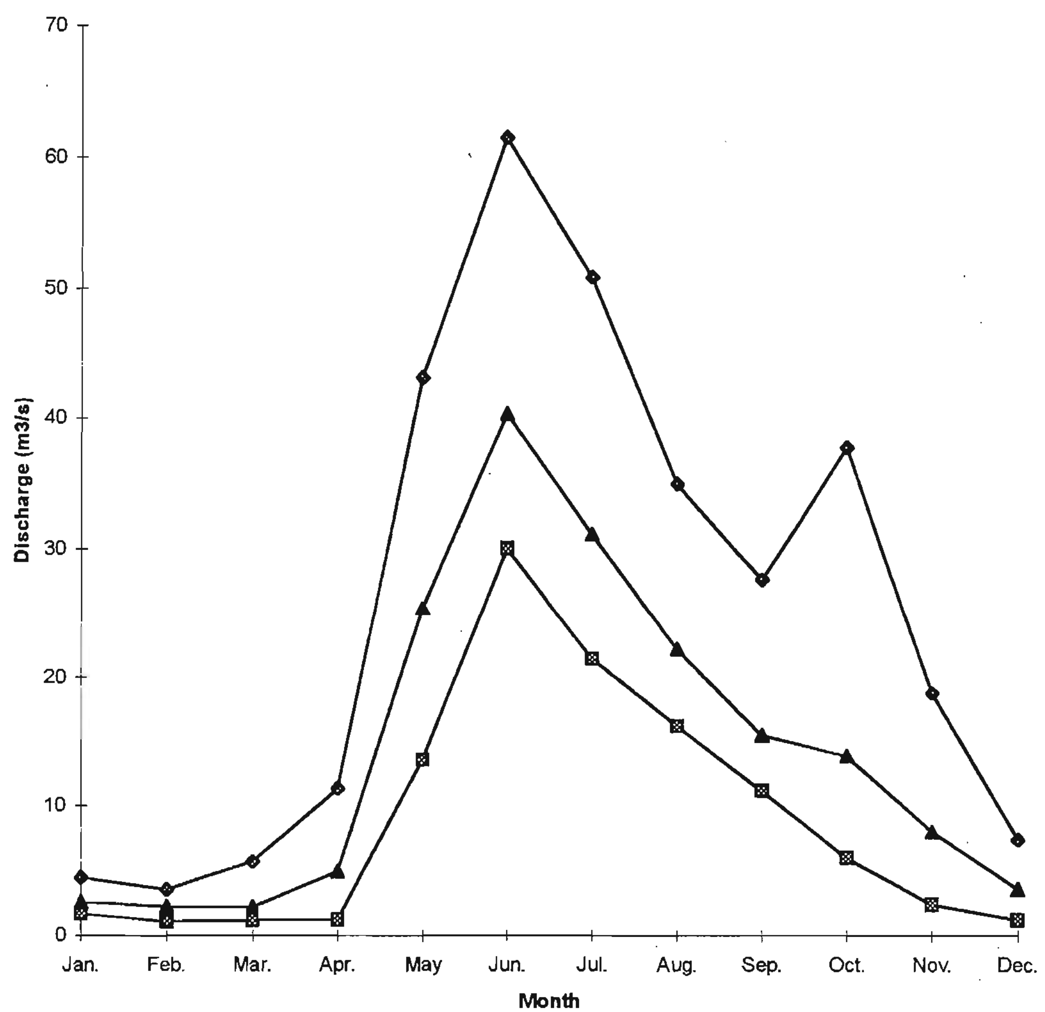


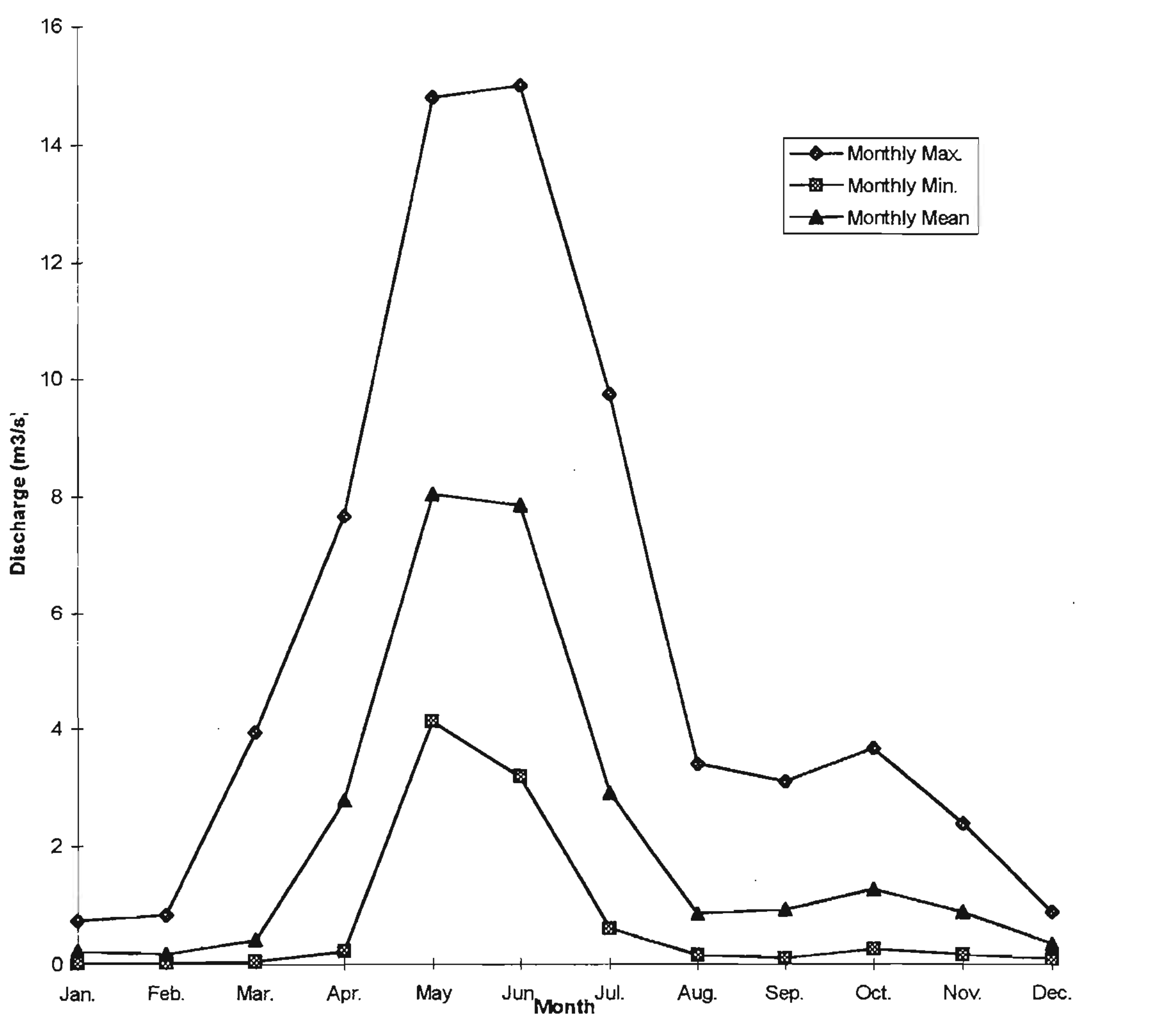
Table 8.3 Monthly discharge summary Canyon Creek near Smithers, Station 08EE014

Latitude:	54 47 54 N
Longitude:	127 06 41 W
Drainage Area Gross:	256 km2
Period of Record	1973-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	0.742	0.839	3.92	7.67	14.8	15.0	9.74	3.38	3.09	3.65	2.38	0.873
Monthly Min.	0.017	0.021	0.038	0.221	4.11	3.17	0.59	0.146	0.099	0.253	0.161	0.07
Monthly Mean	0.225	0.18	0.409	2.77	8.05	7.86	2.89	0.844	0.922	1.26	0.88	0.33

Apr-Sep average 7-day, 10-year low flow is 0.090 m3/s with 95% confidence limits of 0.011 and 0.191.
(except when icing conditions noted in April)

Figure 8.5 Discharge envelope Canyon Creek near Smithers, Station 08EE014



There were two villages close to the junction of the Skeena and Bulkley Rivers. The Gitksan and Wet'suwet'en village of Hagwilget was located on a small flat below the cliffs at Hagwilget canyon on the Bulkley. This village was later moved uphill to the top of the bank overlooking the canyon. The estimated 1992 population at Hagwilget was 481 people. The Gitksan village of Gitanmaax was situated on the banks of the Skeena, a few kilometers above the junction (see section 5.2).

The Dominion Telegraph line was completed through the valley in 1902, and soon there were settlers located around Round Lake, along Deep Creek and at Glentanna on the Telkwa High Road. The village of Aldermere began along the shores of Aldermere Lake, now known as Tyhee Lake, on a ridge between it and the Bulkley River. In 1907 a village called Telkwa was surveyed adjoining Aldermere, on the banks of the Bulkley opposite the confluence of the Telkwa River. Aldermere was eventually abandoned and Telkwa flourished. Telkwa's estimated 1994 population was 1084.

When the Grand Trunk Pacific Railway (now CNR) was built through the valley during 1907-1914, two new townsites became established, Smithers and New Hazelton. Smithers, located on a swampy area at the base of Hudson Bay Mountain, got its start as a divisional point on the railway. It is now the largest community in the area with an estimated 1994 population of 5476. The District Municipality of New Hazelton (estimated 1994 population 819) is located just upstream of the confluence of the Bulkley and Skeena Rivers.

8.2.2 Agriculture

The first attempt to farm in the Bulkley valley was made by the Hudson's Bay Company, when they established a ranch in the neighborhood of Driftwood Creek in 1898 (Large 1957). The terrain was rolling and semi-open, with grasslands alternating with clumps of pine, spruce and poplar. Native peavine and red topped grasses were naturally suitable for grazing. When the railway was completed through the valley in 1914, dairy and cattle farming were already established.

Cattle and dairy ranching are still major economic sectors in this reach of the Bulkley River. An estimated 150 ranches are located between Houston and Moricetown, with an approximate total of 4000 breeding cows. Agricultural grazing on Crown land is administered by MOF through range units. In 1992 the Prince Rupert Forest Region range database showed 39 range tenures in the Bulkley Forest District and 6866 AUMs of authorized grazing. Grazing permits were issued for 2245 cattle, 36 horses, and 1647 sheep in 1992. The number of sheep is up dramatically from previous years as the result of the use of sheep for deciduous brush control on newly reforested lands. Many of these sheep are brought in by contractors and are not wintered in the valley.

8.2.3 Forestry

8.2.3.1 History

Early settlers to the Bulkley valley were employed in hewn tie-making for the railway, in conjunction with land clearing for agriculture (Mould 1976). The hewn tie industry, based in the lodgepole pine stands in the valley, flourished through the 1920's and 1930's.

The first large scale mill in the area, near the present site of Eddy Park at Telkwa, was established in 1920. Logs were often transported to this mill by river. In 1924 a new sawmill was established on the edge of Smithers. With the introduction of portable sawmills, lumber production in the valley was another source of employment, and in the 1940's there were hundreds of independently owned small scale selective and strip logging operations in the valley. The small bush mills were gradually phased out and replaced with large mills at Houston and Smithers. Logging and milling operations have expanded rapidly since the 1960's, with expanded road systems and a shift to primarily clearcut logging. The main forestry operators in the valley today are West Fraser Mills Ltd. PIR division and REPAP (Skeena Cellulose Inc.), both with mills at Smithers.

8.2.3.2 Bulkley LRMP

The Bulkley watershed is within the Bulkley TSA, with district forest office at Smithers. Presently a community-based group, the Bulkley Valley Community Resources Board, is preparing a Land and Resource Management Plan for the Bulkley TSA. The board, formed in 1993, has reached a Consensus Management Direction for the LRMP, but is conducting an additional socio-economic study prior to release of the plan. In addition to recommending areas for protected status under PAS, the LRMP is expected to prescribe management practices for the many Community Watersheds found in this reach.

8.2.3.3 Stream protection practices

Stream protection practices in the interior of the Prince Rupert Forest Region (Bustard and Wilford 1986) is reviewed in section 1.3.4. Bustard (1986*b*) conducted an assessment of stream protection practices in the Bulkley and other TSAs using a combination of interviews and field inspections. Recent harvesting priorities in the Bulkley TSA had been directed at salvaging blowdown and beetle infested timber from the Harold Price Creek area of the Suskwa River watershed.

Each streamside treatment in the Bulkley TSA was assessed individually and varied depending on values being protected, topography, streamside vegetation, and the type of equipment available. Logging was taking place to the edge of streams when feasible. A number of larger streams, such as tributaries of the Telkwa River, have distinct topographic breaks and timber was being left from the break to the stream edge. Directional felling away from creeks was normally used on fish streams and any leaning or immature trees and deciduous vegetation was left along the streamside. Top skidding was not normally used, and equipment operated to the stream edge. Most logging along streams was conducted in the winter, and ground disturbance was minimal. Forest Service staff suggested that operators had good success with the use of feller-bunchers along streams with very little disturbance to the streambank. There are a number of examples of logging to the stream edge in the Harold Price Creek watershed.

Industry and Forest Service staff indicated that their main concerns for streamside treatments were in the small streams that were being winter logged. There is some difficulty in deciding which small creeks should be identified and marked and when skid bridges should be required. Areas such as the upper Harold Price Creek have numerous small creeks transecting the cutblocks. One forester indicated that there were very few small creeks that did not get debris in them during logging operations.

Field inspections revealed inconsistent treatment of the smaller creeks, particularly in the Harold Price Creek area. The problems seem to stem from lack of good inventory information and a breakdown in supervision of operators along these small streams. Since the area was developed over a short period in response to windthrow and spruce beetle infestations, stream protection had not been emphasized.

Road building and lack of road maintenance, particularly in the vicinity of culvert and bridge crossings, were identified as the main source of sediment to streams in the district. The timing of construction had a major influence on the amount of sediment generated. Following logging, roads and drainage structures were generally left "as is" to enable future access for silvicultural needs.

Rate of cut and its implications to streamflow channel integrity was not cited as a concern. An analysis of rate of cut suggested little reason for concern in Harold Price Creek, one system where a detailed analysis had been undertaken. The comment was made that with the mosaic of age classes and species present in the Bulkley TSA, it was unlikely that more than 30% of a watershed would be logged during any pass.

8.2.3.4 Assessment of forest hydrology in the Telkwa River watershed

Beaudry and Schwab (1989) prepared an analysis of possible changes to flow regimes in the Telkwa River as a result of forest harvesting activities. The authors estimate that >50% of the peak streamflow volume is generated in the upper 1/3 of the watershed (the Telkwa Pass area of high elevation and coastal influence, which had not yet been affected by clear-cutting). Logging activities had been concentrated in the middle and lower section of the watershed. Only 5% of the middle and 4.5% of the lower sections had been clear-cut over the past 20 years, which the authors state would have produced no detectable effect on peak flows.

At that time the five year development plan called for an additional 2%, 2.3% and 1.1% of the lower, middle and upper sections of the watershed to be clear-cut. This would bring the total 25 year harvest to 6.5%, 7.3% and 1.2% for the lower, middle and upper sections respectively. Modeling indicated this could represent a theoretical increase of 2% in peak streamflow (which would not be detectable even in a watershed with sophisticated flow gauges). However, the authors cautioned that on a smaller scale, within some of the smaller sub-basins, certain sites may be highly erodible, or have intrinsically higher fisheries or recreation values and site specific protection measures might be necessary.

8.2.3.5 Assessment of suspended sediments in the Telkwa River watershed

A suspended sediment monitoring program was conducted in the Telkwa River watershed to determine the timing of suspended sediment transport and to isolate sediment sources in the watershed (Beaudry and others 1991). It was found that natural sediment sources from landslides, gully erosion, and streambank erosion dominated the sediment input in all the major tributaries of the Telkwa River during the 1990 freshet. Pine Creek was found to be the most important chronic sediment source to the lower Telkwa during spring runoff. The peak concentration of sediment in Pine Creek occurs several weeks earlier than in the mainstem because naturally unstable terrain in the canyon section of the creek is influenced by early spring snow melt.

Suspended sediment levels in the Telkwa reached a high of 900 mg/L on May 28, 1990, and the dark colour lingered for about a month with concentrations in the range of 25-50 mg/L. The generally milky colour of the Telkwa river during summer and early fall is caused by high elevation glacier melt. Sediment levels gradually reduced to less than 1 mg/L in the main stem and all tributaries with the onset of cooler temperatures during the fall.

Land use activities no doubt produce erosion and subsequent sediment to the Telkwa River. However, no direct link could be made to logging activities, and natural sediment sources were thought to dominate the sediment profile. The authors cautioned that small amounts of sediment introduced into the Telkwa during the summer/fall period could substantially alter turbidity and thus the recreational opportunity of the river. Therefore, there must be an active program to prevent and mitigate erosion and sediment transport in the watersheds. This will become particularly important with the movement of harvesting activities into the steeper and wetter areas within the watershed.

8.3 WATER WITHDRAWALS

8.3.1 Bulkley River

A summary of licensed water withdrawals from the Bulkley River in this reach is found in Table 8.4. There are 387 domestic and stock watering licenses in this reach, with 1493 m^3/day licensed consumption. In addition, there are 93 irrigation licenses, with estimated water withdrawals of over 240,000 m^3/day in the summer months.

In addition, there are numerous licenses for waterworks for communities and rural settlements on tributary streams and the Bulkley River. Watersheds which supply domestic water for community distribution systems or utilities are considered by Water Management to be Community Watersheds. Watersheds with community waterworks in this reach include: Mathews Lake, Seymour Lake, Tyhee Lake, Kathlyn Lake, Round Lake, Hospital Lake, Canyon Creek, Station Creek, Two Mile Creek, Corya Creek, and John Brown Creek. Although the District of Houston holds a waterworks license on Mathews Lake, this has not been developed, and Houston currently withdraws water from shallow wells in the Bulkley River floodplain within the District boundaries.

The 7 day average 10 year low flow for the Bulkley River at Quick is 14.4 m^3/s with 95% confidence limits of 12.8 and 16.2 (Table 8.1). The minimum flows generally occur in February. Licensed water withdrawals for the Bulkley and tributaries in this reach total 2.76 m^3/s, or about 19% of 7 day average 10 year low flow. Of this total licensed withdrawal, 2.66 m^3/s are for irrigation, which would only take place in the summertime. It can be seen in Table 8.1 that mean monthly minimum flows during the April to September irrigation season are in the range of 66-223 m^3/s.

Table 8.4 Licensed water withdrawals Bulkley River to Skeena River confluence

Input streams

Domestic/stock watering

GD	m3/d	m3/s
(380 licences)		
323950	1472.7	1.70E-02

Irrigation*

AF	m3/d	m3/s
(81 licences)		
3494	71829.7	8.31E-01

Waterworks

License	Licensee	GY	m3/d	m3/s
C059596	Houston D.M. (Mathews Lk)	10950000	136.4	1.58E-03
C051653	Hidber, J.A. & L. E. (Tyhee Lake)	2190000	27.3	3.16E-04
C047204	Goble, R.J. (Canyon Cr)	1460000	18.2	2.10E-04
C056425	New Hazelton D. M. and three others (Station Cr.)	88750000	1105.4	1.28E-02
C046255	Village of Hazelton (Two Mile Cr.)	273750000	3409.5	3.95E-02
		GD	m3/d	m3/s
C031778	Karelis N.C. & L. (Round Lk)	8000	36.368	4.21E-04
C062308	Beaubien R.H. (Tyhee Lake)	6000	27.276	3.16E-04
C048043	Burdett, E.M. (Kathlyn Lake)	5000	22.73	2.63E-04
	Moricetown Indian Band			
C055359	(Corya Cr.)	125000		
C101226	(Corya Cr.)	140000		
C029879	(John Brown Cr)	20000		
	total	285000	1295.6	1.50E-02
C020572	Gitanmaax Indian Band (Hospital Lk)	30000	136.38	1.58E-03

Canyon Creek (also included in above figures for input streams)

Domestic/stock watering

GD	m3/d	m3/s
(29 licenses)		
31750	144.3	1.67E-03

Irrigation*

AF	m3/d	m3/s
(6 licences)		
365	7503.7	8.68E-02

Waterworks

License	Licensee	GY	m3/d	m3/s
C047204	Goble, R.J. (Canyon Cr)	1460000	18.2	2.10E-04

Bulkley River

Domestic/stock watering

GD	m3/d	m3/s
(7 licences)		
4500	20.5	2.37E-04

Irrigation*

AF	m3/d	m3/s
(12 licences)		
7685.5	157999	1.83E+00

Waterworks

License	Licensee	GY	m3/d	m3/s
C043261	Village of Telkwa	73000000	909.2	1.05E-02
		GD	m3/d	m3/s
C055785	Marandy Holdings Water hauling (various locations)	20000	90.9	1.05E-03

* Irrigation licences have been converted from acre-feet to m3/s by assuming 2 months of operation, 12 hours/day in the summer.

8.3.2 Canyon Creek

Canyon Creek is the only gauged tributary stream in the agricultural portion of the Bulkley valley. Canyon Creek has 29 domestic and stock watering licenses, a waterworks license, and 6 irrigation licenses (Table 8.4). The April to September 7 day average 10 year low flow for Canyon Creek is 0.090 m^3/s with 95% confidence limits of 0.011 and 0.191 (Table 8.3). The licensed water withdrawals, including irrigation, for this reach total 0.089 m^3/s which approximately equals the 7 day average 10 year low flow. There are a number of assumptions made in the above analysis which will be discussed below. However, it appears that a very high percentage of the water in Canyon Creek could be removed under license during a dry summer, which could result in downstream water shortages and/or insufficient in-stream flows for fish.

There were several assumption made in the above analysis of water utilization in Canyon Creek: 1) Irrigation licenses have been converted from acre-feet to m^3/s by assuming 2 months of operation, 12 hours/day in the summer. Actual utilization by licensees is unknown. 2) The gauge station is located on a lower reach of the creek and may be downstream of licensed withdrawals, affecting the low flow estimate. The hydrometric data indicates that summertime 7 day average low flows have decreased from an average of 0.449 m^3/s in the late 1970's to 0.183 m^3/s in the early 1990's. It is not known if this decrease is the result of climate variation or the result of increased water utilization upstream of the gauge station. In either case there may be some cause for concern for fisheries resources.

8.4 WATER QUALITY AND AQUATIC RESEARCH

8.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Summary water quality data for the Telkwa River at the mouth, Site 0400187, and the Bulkley River at Quick, Site 0920088, are found in Tables 8.5 and 8.6. These stations were generally sampled once per month for five years 1983-1987.

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

Table 8.5 Water quality summary Bulkley River at Quick, Site 0920088, 1982-1987

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	19	10	5	75	23.5	22.1	5
pH	55	55	6.6	7.7	7.33	0.24	7.4
Conductance (umhos/cm)	56	56	47	112	63.4	14.5	61
Total Residue (mg/L)	56	56	28	176	61.6	34.8	47
Filterable Residue (mg/L)	14	14	33	84	48.7	16.1	42
Non-filterable Residue (mg/L)	50	44	1	91	13.4	21.8	3
Turbidity (NTU)	51	51	0.6	37.0	5.19	7.93	1.7
Alkalinity (mg/L)	55	55	20.0	46.7	28.06	6.38	27.3
Hardness Total (mg/L)	4	4	20.6	29.2	26.47	4.02	28.1
Hardness Dissolved (mg/L)	13	13	18.7	31.4	24.81	4.06	24.8
Total N (mg/L)	21	21	0.04	0.61	0.200	0.150	0.15
T.K.N. (mg/L)	56	56	0.02	0.52	0.140	0.120	0.10
Ammonia (mg N/L)	56	25	0.005	0.063	0.0137	0.0130	<0.005
NO2 + NO3 (mg N/L)	56	39	0.02	0.09	0.044	0.022	0.03
Total Carbon (mg/L)	34	34	4	20	9.5	4.4	8
Organic Carbon (mg/L)	21	18	1	11	3.4	3.5	1
Inorganic Carbon (mg/L)	55	55	3	13	6.8	2.0	7
Chloride (mg/L)	18	7	0.5	1.2	0.77	0.24	<0.5
Ortho P (mg/L)	51	12	0.003	0.018	0.0048	0.0042	<0.003
Silica (mg/L)	13	13	3.3	7.5	4.98	1.37	4.4
Sulfate (mg/L)	14	13	2.2	3.9	2.91	0.50	2.9
Fluoride (mg/L)	1	0					<0.01

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	50	47	0.02	2.90	0.426	0.682	
As	73	5	0.001	0.029	0.0072	0.0123	<0.001
Ca	54	54	6.79	15.00	9.110	1.800	8.82
Cd	73	0					<0.0005
Co	54	2	0.10	0.15	0.125		<0.1
Cr	54	1	0.01	0.01	0.01		<0.01
Cu	53	37	0.001	0.090	0.0046	0.0145	0.001
Fe	54	54	0.03	3.48	0.530	0.810	0.18
Mg	54	54	0.76	2.94	1.500	0.630	1.38
Mn	54	36	0.01	0.15	0.039	0.038	0.01
Mo	54	4	0.01	0.05	0.020	0.020	<0.01
Ni	54	1	0.06	0.06	0.06		<0.05
P	56	55	0.003	0.138	0.0226	0.0265	0.010
Pb	53	31	0.001	0.011	0.0029	0.0023	0.001
V	54	1	0.01	0.01	0.01		<0.01
Zn	53	17	0.005	0.020	0.0095	0.0046	<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 8. 5 (continued) Water quality summary Bulkley River at Quick, Site 0920088, 1982-1987

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	53	38	0.01	0.26	0.060	0.047	0.03
As	71	2	0.001	0.001	0.001		<0.001
B	54	0					<0.01
Ba	54	53	0.01	0.03	0.020	0.004	0.02
Ca	54	54	6.15	15.00	8.670	1.780	8.28
Cd	72	0					<0.0005
Co	54	0					<0.1
Cr	54	0					<0.01
Cu	72	16	0.001	0.003	0.0014	0.0007	
Fe	58	56	0.01	0.22	0.066	0.054	
K	13	13	0.30	0.60	0.370	0.100	0.30
Mg	54	54	0.65	2.79	1.320	0.550	1.19
Mn	54	7	0.01	0.04	0.021	0.014	<0.01
Mo	54	0					<0.01
Na	13	13	1.00	3.60	1.670	0.710	1.40
Ni	54	0					<0.05
P	56	45	0.003	0.027	0.0069	0.0046	0.005
Pb	72	7	0.001	0.002	0.0016	0.0005	<0.001
V	54	0					<0.01
Zn	72	2	0.005	0.005	0.005		<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 8.6 Water quality summary Telkwa River, Site 0400187, 1983-1987

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	17	10	5	50	22.2	16.4	5
pH	59	59	6.9	7.8	7.50	0.22	7.5
Conductance (umhos/cm)	60	60	46	435	91.3	28.9	89
Total Residue (mg/L)	60	60	48	364	87.3	51.7	74
Filterable Residue (mg/L)	14	14	33	86	61.0	17.4	67
Non-filterable Residue (mg/L)	52	49	1	316	23.9	54.5	6
Turbidity (NTU)	56	56	0.7	180.0	12.38	26.64	4.8
Alkalinity (mg/L)	59	59	20.2	62.2	41.99	12.59	41.2
Hardness Total (mg/L)	8	8	24.2	56.4	38.82	13.99	32.5
Hardness Dissolved (mg/L)	11	11	20.6	56.7	42.95	13.00	46.5
Total N (mg/L)	23	22	0.03	0.31	0.152	0.008	0.13
T.K.N. (mg/L)	59	58	0.01	0.32	0.090	0.070	0.06
Ammonia (mg N/L)	59	19	0.005	0.044	0.0102	0.0094	<0.005
NO2 + NO3 (mg N/L)	59	42	0.02	0.13	0.074	0.030	0.06
Total Carbon (mg/L)	36	36	5	20	12.5	4.6	14
Organic Carbon (mg/L)	24	17	1	9	2.8	2.7	1
Inorganic Carbon (mg/L)	60	60	5	16	10.6	3.9	11
Chloride (mg/L)	14	7	0.5	0.8	0.59	0.12	0.5
Ortho P (mg/L)	54	3	0.003	0.005	0.0037	0.0012	<0.003
Silica (mg/L)	14	14	3.8	8.2	6.39	1.59	7.1
Sulfate (mg/L)	14	14	2.2	6.2	4.46	1.16	4.9
Fluoride (mg/L)	1	1	0.01	0.01	0.01		

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	58	52	0.03	14.70	0.913	2.176	
As	84	6	0.001	0.029	0.0057	0.0114	<0.001
Ca	60	60	7.38	21.90	13.590	4.150	13.40
Cd	84	0					<0.0005
Co	60	3	0.10	0.13	0.117	0.015	<0.1
Cr	60	3	0.01	0.02	0.013	0.006	<0.01
Cu	59	45	0.001	0.040	0.0042	0.0070	0.002
Fe	60	60	0.11	13.80	0.990	1.930	0.44
Mg	60	60	1.20	4.84	2.530	0.790	2.72
Mn	60	53	0.01	0.54	0.050	0.082	0.02
Mo	60	7	0.01	0.03	0.013	0.008	<0.01
Ni	60	0					<0.05
P	59	57	0.003	0.585	0.0315	0.0797	0.013
Pb	59	35	0.001	0.007	0.0026	0.0016	0.001
V	60	4	0.01	0.03	0.015	0.010	<0.01
Zn	59	21	0.005	0.080	0.0137	0.0183	<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 8.6 (continued) Water quality summary Telkwa River, Site 0400187, 1983-1987

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	59	43	0.01	0.22	0.067	0.050	0.04
As	84	3	0.001	0.002	0.0017	0.0006	<0.001
B	60	0					<0.01
Ba	60	59	0.01	0.07	0.032	0.011	0.03
Ca	60	60	6.74	20.30	12.910	4.073	12.70
Cd	83	0					<0.0005
Co	60	1	0.12	0.12	0.12		<0.1
Cr	60	0					<0.01
Cu	83	23	0.001	0.003	0.0015	0.0007	
Fe	65	62	0.03	0.94	0.143	0.132	
K	14	14	0.20	0.40	0.300	0.039	0.30
Mg	60	60	0.92	3.36	2.180	0.800	2.20
Mn	60	32	0.01	0.02	0.014	0.005	0.01
Mo	60	2	0.01	0.01	0.01		<0.01
Na	14	14	0.90	3.10	2.020	0.680	2.20
Ni	60	0					<0.05
P	59	47	0.003	0.011	0.0051	0.0019	0.004
Pb	84	9	0.001	0.002	0.0012	0.0004	<0.001
V	60	0					<0.01
Zn	80	0					<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

8.4.1.1 Bulkley River at Quick

The Bulkley River at Quick has soft water (mean hardness=26.5 mg/L), with near neutral pH (mean=7.3). The waters have moderate colouration due to organic substances contributed by swamps and wetlands in the drainage area. While colouration may be aesthetically unpleasant for drinking water, it is not harmful to human health. Moderately low conductance and low dissolved solids (filterable residue) in the water are a reflection of the rapid rate of runoff in the region and are an indication of good water quality. While TSS is fairly low for most of the year, values can be high during freshet, particularly during flood years. Alkalinity, a measure of pH buffering capacity of a waterbody, is moderate (mean=28.1 mg $CaCO_3$/L). Nutrient concentrations are generally low, with orthophosphate concentration of <0.003 mg/L (50th %). The range of total metals concentrations often exceed MOELP criteria for protection of aquatic life at the hardness levels present. Mean total metals concentrations are generally very close the MOELP criteria. Dissolved metals levels are often less than or equal to their respective detection limits.

8.4.1.2 Telkwa River

Compared to the Bulkley River, the Telkwa has harder water (mean=38.8 mg/L), although still within the range considered to be soft. Colouration is similar to the Bulkley at Quick. The Telkwa has slightly more alkaline pH (mean=7.5) and higher alkalinity (mean=42.0 mg $CaCO_3$/L). Conductance (mean=91.3 μmhos/cm) and dissolved solids (filterable residue mean=61 mg/L) are both higher in the Telkwa than in the Bulkley River at Quick, perhaps reflecting higher mineralization in the Telkwa basin. One of the most noticeable characteristics of the Telkwa River is higher mean TSS than other Bulkley River tributaries (mean=23.9 mg/L, with a range of

1 to 316 mg/L). The Telkwa River is often more turbid than the Bulkley River at their confluence. This is partly due to the presence of glacial silt from the high elevation headwaters in the Telkwa Pass. (Further discussion of suspended sediments in the Telkwa River is found in section 8.2.3.5.) Nutrient levels are low, with a mean orthophosphate concentration of <0.003 mg/L (50th %). Like other Skeena tributaries, mean total metals concentrations are generally very close the MOELP criteria for protection of aquatic life at the hardness levels present. Total metals concentrations exceeding MOELP criteria are often observed. Mean dissolved metals levels are generally less than or equal to their respective detection limits.

8.4.2 Water quality assessment and objectives - Bulkley River

The water quality assessment and objectives for this reach (Nijman 1986) are presented in Table 7.6. Characteristics of concern were nutrients and fecal contamination from the Houston and Smithers sewage treatment plants.

A monitoring program was recommended for the Smithers STP at Site 0400434 (upstream control) and 0400435 (100 m downstream) as shown in Figure 8.2. Monitoring to determine the attainment of the water quality objectives was carried out in 1988-1992. These data are published in an annual report of objectives attainment in the province. In 1988-1992, the following parameters were monitored for three to five consecutive weeks during summer low flows in most years: fecal coliforms, turbidity, suspended solids, chlorophyll *a*, ammonia-N and nitrite-N. The objectives were met with the exception of fecal coliforms at the upstream site, which exceeded the objective of <10/100 mL 90th percentile (np) in 1990.

8.4.3 Water quality assessment and objectives-Kathlyn, Seymour, Round & Tyhee Lakes

Water quality assessment and objectives prepared for four small lakes in the Smithers/Telkwa area are presented in Table 8.7 (Boyd and others 1985). Kathlyn and Seymour Lakes had the highest flushing rates expressed as lake volumes per year (0.9/year and 1.1/year, respectively), while Tyhee and Round Lake had much lower flushing rates (0.2/year and 0.3/year).

The lakes are important for recreation, domestic water supply and irrigation. Seymour Lake had the most water licenses (26) all of which were for domestic use. Kathlyn Lake had 17 domestic licenses, 2 irrigation, and 2 industrial licenses. MOF holds the largest industrial license on Kathlyn Lake (455m^3/yr) for mixing fire retardant at the airport. Tyhee Lake had 6 domestic licenses, 2 waterworks licenses (50 m^3/d) and 1 industrial license (27 m^3/d for a trailer park). Round Lake had the fewest licenses with only 2 domestic licenses and 1 waterworks license (36 m^3/d).

Kathlyn and Tyhee Lakes receive the greatest recreation pressure. There is a public beach on the west side of Kathlyn Lake, while Tyhee Lake has a Provincial Park, with bathing beach, boat launch and campground.

The concern was that the spread of agricultural and residential development around the lakes was contributing to eutrophication. A second concern was that fecal coliform objectives be met for drinking water and recreation.

Table 8.7 Provisional water quality objectives for Kathlyn, Seymour, Round and Tyhee Lakes

Water Bodies		Kathlyn, Round, and Tyhee Lake	Seymour Lake
Designated Water Uses		Drinking water, aquatic life, recreation, irrigation and industrial use	
Fecal Coliforms [1]	Near water intakes	≤10 MPN/100 mL 90th percentile	
	At bathing beaches	≤200 MPN/100 mL geometric mean ≤400 MPN/100 mL 90th percentile	
Turbidity[2]		≤1 NTU average 5 NTU maximum	
Total Phosphorus[3]		≤0.015 mg/L average at spring overturn	not applicable
Colour[4]		15 TCU maximum, near water intakes	not applicable

Source: Boyd and others 1984

1 the geometric mean and 90th percentile are calculated from at least 5 weekly samples taken in a period of 30 days. The drinking water objective (10/100 mL) applies year-round and the recreation objective (200-400/100 mL) applies during the recreation season.

2 the average is calculated from at least 5 weekly samples taken in a period of 30 days and applies to any point of the lake. These are long-term objectives, to be met in the future.

3 the average is calculated from a set of at least 3 samples, including near the surface, at mid-depth and near the bottom, all three at mid-lake. This is a long term objective to be met in the future.

4 this is a long-term objective to be met in the future.

8.4.3.1 Lake eutrophication

The lakes had similar dissolved oxygen conditions, high in the surface waters throughout the year. Anoxic conditions persisted below the thermocline except for brief periods following spring or fall overturn when oxygen was mixed throughout the water column. Based on nutrient concentrations, all four lakes were considered eutrophic, Kathlyn Lake being the least eutrophic, Round Lake the most. Planktonic algal communities were typical of eutrophic lakes, with high biomass and noxious species being recorded. These contributed to taste and odor, slime formation or unattractive appearance. Reduction in spring overturn phosphorus concentrations would lower the algal biomass and result in less noxious algae dominating the phytoplankton community.

The major source of phosphorus (the key nutrient causing eutrophic conditions) for Kathlyn Lake was thought to be the drainage of fire retardant (diammonium phosphate) used by the MOF air tanker base. This opinion was disputed by MOF. This discharge has since been diverted away from the Kathlyn watershed. It was thought the major source of phosphorus in Round and Tyhee Lakes was internal loading during anoxic periods from lake sediments. A follow-up study by EPP (Maclean 1985) confirmed that internal loading from sediments was the principal source of phosphorus in Seymour Lake as well.

8.4.3.2 Watershed management recommendations

Recommendations were to freeze watershed development in all four watersheds until the eutrophic conditions are controlled by a restoration technique. When additional development is permitted, stringent emphasis should be placed on the control of phosphorus movement to the lake. Control would be necessary on the correct setback of septic tank tile field and the number of residences and hobby farms. In addition, installation of aeration systems (either destratification or hypolimnetic) in Round and Tyhee Lakes was suggested. The methods of 1) hypolimnetic water withdrawal (by a siphon during July to September), or 2) hypolimnetic aeration were suggested for Seymour Lake by Maclean (1985).

8.4.3.3 Objectives monitoring

A monitoring program was recommended, concentrating on Kathlyn and Tyhee Lakes. The monitoring entailed testing drinking water intakes for fecal contamination, turbidity and colour. Annual nutrient monitoring at spring overturn was recommended to determine the phosphorus budget of each lake. Monitoring to determine the attainment of the water quality objectives were carried out in 1988 - 1992. These are published in an annual report of objectives attainment in the province. Monitoring results are summarized as follows:

- Kathlyn: Total phosphorus objectives $\leq$0.015 mg/L average at spring overturn were not met in any year. The average total phosphorus concentration at spring overturn (n=4) was 0.020 mg/L. The objectives for fecal coliforms and turbidity were also not met in one of the 3 or 4 domestic outlets sampled in most years.

- Seymour: There was no spring overturn total phosphorus data collected 1988-92. Colour and turbidity objectives often were not met at the domestic outlets sampled.

- Round: Spring overturn total phosphorus data was inconclusive because stratification had often occurred at the time of sampling. Turbidity usually exceeded the objective at the domestic outlets sampled.

- Tyhee: Spring overturn total phosphorus data was inconclusive because stratification had often occurred at the time of sampling. Occasionally fecal coliform concentrations exceeded the objective at the domestic outlets sampled.

8.5 LIQUID WASTE DISCHARGES

8.5.1 Village of Telkwa STP PE-12367

8.5.1.1 Background

Historically the Village of Telkwa has experienced problems with septic tank failures due to poor clay soils. In September 1991 the Village proceeded with a feasibility study for a sewage disposal system. It was initially proposed that sewage be treated via a facultative lagoon and thence to wetlands prior to construction of the final three phases of the system; however, many concerns were raised by both federal and provincial agencies regarding the possible impacts to both fish and wildlife resources. In November 1992 the Village was informed of the need for an aerated lagoon prior to discharge to the wetland. As a result an application was submitted to EPP on July 23, 1993 requesting a permit to discharge treated sewage effluent to an exfiltration lagoon recharging to land.

The treatment system includes 3 aeration cells, the third discharging to an exfiltration lagoon with 45 day holding capacity. The treated effluent filters through the gravel down to an impermeable layer approximately 6 meters below the surrounding ground. Once filtered effluent reaches this depth, it follows the natural ground water flow east and north to existing wetlands for final polishing before entering the Bulkley River.

8.5.1.2 Permitted discharge

Permit PE-12367, issued July 4, 1994, authorizes the discharge of effluent from a 3-cell anaerobic-aerated lagoon system at a maximum rate of 850 m^3/day to the ground. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. Discharge monitoring as well as receiving environment monitoring are required. The discharge monitoring program is as follows:

One grab sample of effluent from the aerated lagoon (also known as Cell #3) going to the exfiltration lagoons must be taken monthly. This site is intended to be the point of compliance with effluent quality limits for the parameters of concern.

Parameters to be sampled are as follows:

- Biochemical oxygen demand, total suspended solids, total nitrogen, ammonia nitrogen, nitrate, nitrite, total phosphorus, orthophosphate, temperature (field parameter), dissolved oxygen (field parameter), and pH (field parameter).
- The Permittee must provide and maintain a suitable continuous flow measuring device following the outlet of the last aerated lagoon (also known as Cell #3). Effluent volume entering the exfiltration lagoon system must be monitored to provide the average and maximum daily discharge rates.

8.5.1.3 Receiving environment monitoring

The Telkwa wetlands are located on the south side of the Bulkley river approximately 4 km east of Telkwa and comprise an area of approximately 2.1 ha (Bustard 1993*a)*. The wetlands have developed in an old channel of the Bulkley River that was cut off from the mainstem river when the railroad was built along the river floodplain in the early 1900's. Wetlands such as these often provide important off-channel rearing areas for salmonid species such as coho and cutthroat trout depending upon suitable access from the mainstem river and adequate water quality conditions during critical periods.

Fish and water quality sampling was carried out during the summer of 1993 to determine the existing and potential use of these wetlands by salmonids and to provide baseline information representative of pre-development conditions. The report concluded that salmonid species such as coho salmon and cutthroat trout were not present in the Telkwa wetlands, but peamouth chub, redside shiners and longnose suckers were abundant. Increased flows into the wetland associated with the sewage project, in conjunction with the removal of the beaver dam at the CN rail culvert creating easier access into the wetlands, may encourage salmonid use of the lower portions of the wetlands. This will be dependent upon the quality of the effluent.

Receiving environment monitoring required under Permit PE-12367.— One grab sample at each of 2 monitoring sites as follows:

1. Groundwater sampling well #1, 150 m northwest of the northwest corner of the exfiltration lagoons. Depending on water level, surface grab sampling may be substituted at this site. The intent of this site is to be representative of the exfiltrate as it enters the wetland.
2. First intersection of a wetland channel and the CN railway. The intent of this site is to be representative of effluent polishing afforded by the wetland.

Sampling is to be carried out monthly for the following parameters: total nitrogen, ammonia nitrogen, nitrate, nitrite, total phosphorus, orthophosphate, temperature (field), dissolved oxygen (field), and pH (field).

The Permittee must also carry out a baseline receiving environment monitoring study prior to any discharges from the sewage treatment system as follows:

A floristic survey of the wetland which receives exfiltrate shall be undertaken. The study will focus on cover and abundance of wetland flora, including the seasonally inundated wetland fringe. The intent of the study is to provide an initial indication of the extent and health of vegetation communities within the zone of influence of treated sewage effluent discharged to the wetland. This survey shall be repeated at intervals of several years at the discretion of the Regional Waste Manager to reassess the health of the vegetation communities and so that changes in the value of the wetland as wildlife habitat can be assessed.

8.5.1.4 Discussion

The dilution ratio for this discharge, calculated using the 7 day average 10 year low flow in the Bulkley River at Quick and the daily permitted discharge rate to the exfiltration cell, is >1000:1. It is believed that both filtration through gravel and wetland polishing will remove nutrients from this discharge, further improving quality. The discharge and receiving environment monitoring programs for this permit are very comprehensive. Bioassay monitoring has not been required for this effluent, but this considered reasonable, given the discharge pathway at this site.

8.5.2 Manalta Coal Ltd. - Telkwa Coal

8.5.2.1 Background

Coal was initially discovered in the Telkwa area in about 1900. Coal production did not commence in the Goathorn Creek area until 1918. On the north bank of the Telkwa River, the Aveling (Telkwa) Mine produced from 1921 to 1922 and again from 1940 to 1945. Telkwa Colliery (McNeil Mine), on the south side of the Telkwa River, began producing in 1923. Initial mining production in the Telkwa area was mainly for local consumption until after 1930 when underground operations and later surface mining were initiated at Bulkley Valley Collieries near Goathorn Creek. All significant surface and underground mining operations ceased by the mid 1970's although some limited mining carried on until 1986.

Manalta Coal Ltd. (MCL) now holds the coal reserves at Telkwa. MCL plans to construct and operate a mine which will produce export thermal coal. If approved, mining at Telkwa would be by conventional open pit methods using diesel powered mining equipment. The project area under Mine Development Certificate Application consists of the proposed Pit 3 south of the Telkwa River, and Pits 7 & 8 north of the Telkwa River. Pits 1, 2, 4 & 5, identified by the previous owner, Crows Nest Resources Ltd., are not considered economic, and are not part of the current application. Coal will be delivered from the open pits to the crusher or stockpiles, located adjacent to the preparation plant where it will be washed to produce a marketable product for thermal coal sales. Waste rock will be deposited in waste dumps located near the ultimate limit of the pits.

Surface water runoff from the waste dump or pit areas will be directed into one of two surface water collection systems, the East and West interceptor ditch systems. Each system will transport runoff water to larger water control structures (settling ponds or tailings pond) where treatment can be performed if required. The interceptor ditches may be lined with coarse limestone as a back-up measure for any ARD runoff and to dissipate flows.

8.5.2.2 Receiving environment monitoring

Manalta Coal Ltd. is currently in the application stage. The outstanding issue at this time is the assessment of potential ARD production and how it will be mitigated. Manalta, in conjunction with government, have contracted a consultant to assess the potential for ARD and are awaiting the final report. Once this report has been reviewed and if it is accepted, the company would then go to public consultation.

In terms of potential impacts to aquatic resources and water quality in the receiving environment, Manalta is relying on past studies, many of which were carried out by Crows Nest Resources Ltd. Preparatory to its Stage II submission, Crows Nest undertook a baseline monitoring program of the Telkwa project area (MacLaren Plansearch Services Ltd. 1985). Starting in June 1983, surface water samples were collected on a monthly basis from twelve locations for 15 consecutive months. Groundwater and sediments were also sampled at a number of locations once during the study period.

This study concluded that:

- the overall water quality of the area was typical of natural conditions in a pristine aquatic environment and did not reflect the presence of pollution from anthropogenic sources;
- present alkaline conditions within the region as well as the nature of surrounding geology provided considerable buffering capacity against potential acid inputs should they arise;
- present physical and chemical levels posed no health problem for even the most sensitive aquatic organisms;
- toxic level occurrences of certain heavy metals were local and transitory in nature and could be explained by elevated erosional processes associated with heavy precipitation;
- in terms of nutrients, the overall fertility of the rivers and streams was relatively low.

Studies were undertaken in 1984 to evaluate aquatic resources in the study area (Bustard 1985). Stream periphyton, invertebrates and fish population were assessed in Goathorn and Tenas Creeks and the lower Telkwa River. As well potential impacts associated with the proposed coal mine and rail access, and means of mitigating impacts or enhancing fish populations in the area were evaluated.

Conclusions were as follows:

- Stream periphyton were measured above and below the proposed mining operation in Goathorn Creek. The periphyton community was comprised entirely of diatoms at both sites and growth was limited by the low availability of nitrogen. Rates of accumulation were near the lowest values reported for extreme nutrient deficient streams in B.C.
- Benthic invertebrates were sampled for two consecutive years. Numbers of invertebrates were more that 30% lower in 1984 than in 1983. As well their development rate was slower throughout the study areas compared to 1983. The benthic community was typically dominated by mayflies and stoneflies.
- As part of the study a Biological Condition Index was calculated for the benthic invertebrate sample sites. It was suggested that this index could be used in the future to monitor the tolerance to changes in water quality of the various taxa of aquatic invertebrates found.
- A detailed evaluation of fish habitat within the study area (including Hubert Creek) was undertaken and the results of the program confirmed the importance of the study streams as rearing areas for steelhead trout.

The study concluded that potential impacts to the aquatic resources in the study area could result from acid mine drainage and stream sedimentation but that based on information from other study components, these potential problems could be managed.

Mitigation and enhancement options for the various study streams were said to be feasible and included steelhead trout fry plantings and stream fertilization in the tributary streams and coho salmon and steelhead trout fry plantings and side channel development in the Telkwa River.

8.5.3 Regional District of Bulkley Nechako - Smithers/Telkwa Landfill PR-7687 (new) and PR-2270 (old)

8.5.3.1 Background

The current Smithers/Telkwa landfill (PR-7687) is owned and operated by the Regional District of Bulkley-Nechako and is located about 8 km south of Smithers between Highway 16 and the Bulkley River. The site serves a population of about 8,000 including Smithers, Telkwa and surrounding rural areas. Only wood wastes are allowed to be burned at the site. An old landfill also operated by the RDBN, PR-2270, located across the road, is now closed except for a septic sludge disposal lagoon.

A preliminary leachate assessment was conducted by Gartner Lee (1993). The site is located on gravelly, glacio-fluvial terrace deposits with intermittent clay or till layers occurring in places. There are likely buried permeable gravel channel deposits which influence ground water flow direction and velocities. There is a small water surplus of about 51 mm/yr in this area. This results in production of about 1,530 m^3 of leachate per year assuming 3 hectares have been filled, no runoff, no leachate production from run-on, and that no wastes are placed below the water table.

8.5.3.2 Permitted discharge

Permit PR-7687, issued March 4, 1987, and amended in 1992, 1994 and 1995 authorizes a maximum discharge rate of 4389 tonnes/year of solid waste and an indeterminate rate of discharge for emissions from regulated open burning of non-putrescible refuse. A minimum of 15 cm of cover soil must be applied to compacted refuse at least once every day except where freezing conditions adversely affect normal operation.

8.5.3.3 Receiving environment monitoring

The most important pathway at this site is subsurface ground water flow from the site to the Bulkley River. Ground water flow to the river through gravelly soils is probably rapid however, it is difficult to define the exact leachate pathway. A detailed hydrogeological investigation to determine the stratigraphy, geodetic water level elevations and permeability would be required to fully understand the ground water flow system. Direct surface runoff of leachate to the river appears unlikely.

The most significant environmental receptors are shallow water supply wells near or downgradient from the landfill and the Bulkley River. There are two residential wells: one to the south and one to the west, as well as a well near the landfill gate for use by the site supervisor. There are also two shallow, small diameter plastic monitoring wells, one to the west and one to the south, however no details of the monitor construction (well numbers, stratigraphy, depth, geodetic elevation) were available. Although data have been collected from these wells for a number of years, the Gartner Lee report determined that it was inappropriate to assess leachate impacts from this data for a number of reasons including: lack of water level or flow system data; no knowledge of well site conditions, well development, purging, field chemistry, etc.; no knowledge of well construction; uncertainty about well locations; insufficient data to assess seasonal or natural variations; and no laboratory quality assurance check data.

The Gartner Lee report states that there is no question that leachate from the Smithers Landfill will eventually discharge into the Bulkley River, if it is not already occurring. Potential annual dilution, based on mean annual discharge of 134 - 164 m^3/s, is estimated to be about three million to one. However interstitial water quality in gravel sediment pores could be affected and could affect localized spawning habitat.

Recommendations from the Garner Lee report are as follows:

- Information on the ground water flow system is required in order to assess possible impacts from the leachate. A detailed hydrogeological program as well as a geophysical survey were suggested. The report also proposed four new locations for monitoring wells: a control site to the north of the fill area, and three wells to the south and west.
- Water level elevations should be measured and water quality samples should be collected and tested quarterly until a clear understanding of ground water flow and leachate movement is obtained. Analytical parameters should include conductivity, chloride, hardness, ammonia and iron at a minimum. Organic parameters (BOD, COD, TOC) metals and other water quality parameters could be added if desired.
- The shoreline of the Bulkley River to the south and west of the landfill should be inspected twice annually, for evidence of leachate discharge and staining, during low flow conditions.
- Bulkley River sampling locations should be upstream, adjacent and downstream of the landfill. Samples should be collected four times annually particularly during low flow conditions. Analytical parameters should be the same as those recommended for ground water monitoring, at a minimum.

8.5.3.4 Discussion

In calculating leachate production the Gartner Lee assessment assumed 3 hectares have been filled, however the site map shows a putrescible waste disposal area of 6 hectares, and a metals and wood waste area of 5 hectares. In addition the old Smithers/Telkwa Landfill site (PR-2270) immediately to the east has a filled area of 5 hectares and contains an active septic sludge lagoon with a permitted 300 m^3/yr discharge rate. A recalculation using the above areas (16 ha) and adding the permitted liquid septic sludge volume results in a leachate estimate of about 8,460 m^3/y. The 7 day average 10 year low flow at this site is 15.59 m^3/s (Bulkley River at Quick plus Telkwa River), resulting in an dilution of 3700:1. It is unlikely that negative water quality impacts would occur at this dilution, however if there is entrainment of leachate into subsurface gravel channels, water quality degradation could occur in residential wells and/or in localized river gravel sediments.

8.5.4 Town of Smithers STP PE-0373

8.5.4.1 Background

The Town of Smithers holds permit PE-373 for the discharge of treated domestic sewage to the Bulkley River. In 1983 the treatment plant was changed from an activated sludge system designed for a population of 4500 to an aerated lagoon system with a design capacity for 9200 people. The current population of Smithers is just over 5000. Its projected growth is to 7500 according to a report from the Town of Smithers (1993).

8.5.4.2 Permitted discharge

The sewage treatment plant consists of a headworks and two aerated lagoons operated in series. Permit PE-373 sets the maximum effluent BOD concentration at 45 mg/L and the TSS concentration at 60 mg/L. The permitted maximum daily discharge flow is 10,800 m^3/day and the average daily flow is 4,200 m^3/day. The permit requires monthly sampling of BOD and TSS to be submitted annually along with flow measurements.

The design of the sewage outfall maximizes initial dilution. Although the outfall pipe extends only about 10 m from the shore, it is buried in the bottom of the deep channel, with five equally spaced diffuser heads pointed downstream. Pressure restrictors on the diffusers assure that all are functioning in the dispersal of the effluent. This design promotes good mixing and should minimize water quality impacts in the initial dilution zone (Nijman 1986).

Historical effluent quality measured at the discharge from the second cell is shown in Table 8.8. Effluent quality has remained within permit limits for TSS, but exceedances for BOD are common. There seems to be a regular seasonal increase in BOD and TSS during the summer/fall. This increase has been attributed to excess duckweed and algae growth in lagoon #2. A letter to the Town dated August 9, 1994 from EPP suggested that methods for removal of duckweed from lagoon #2 should be addressed.

EPP assessed toxicity of the Smithers effluent sampled May 20, 1993 using three different bioassay methods: Rainbow trout (RBT) 96 hr LC50, Daphnia 48 hr LC50, and 5 and 15 minute Microtox EC50. The RBT 96 hr LC50 was 74.8 % concentration. The effluent was non-toxic to Daphnia and Microtox. As a result of these finding, the town has agreed to obtain an engineering evaluation to assess available data and determine if additional aeration is required at this STP.

Table 8.8 Effluent quality Town of Smithers Sewage Treatment Plant PE-0373, 1991-1994

Date	TSS mg/L	BOD mg/L	Flow m3/day	Date	TSS mg/L	BOD mg/L	Flow m3/day
2/19/91	17.5	21	2884	5/18/93	43	48	3299
4/23/91	33.5	23	2805	6/15/93	53.5	39	3234
6/25/91	53	93	2153	7/20/93	43	38	2551
8/20/91	48	52	2077	8/19/93	36	35	2318
10/22/91	27	43	3312	9/23/93	22.5	25	1904
12/12/91	10.5	16		10/19/93	42	78	1840
2/19/92	19	25		11/13/93	44	92	2776
4/21/92	59	24		12/15/93	25.5	38	1984
6/17/92	53.5	14		1/18/94	23	45	
7/22/92	57	39		2/22/94	18	32	
8/25/92	78	41		3/23/94	38	21	
9/23/92	57	47		4/27/94	58	10	
10/19/92	52.5	57		5/18/94	33	42	
11/24/92	25.2	27		6/21/94	42	17	
12/15/92	30	22		7/19/94	36	70	
1/20/93	22	29	2921	8/23/94	37	43	
2/9/93	19	25	3213	9/27/94	54	63	
3/16/93	19.5	22	2597	10/17/94	51	78	
4/20/93	30.5	15	3324	11/22/94	39	24	

8.5.4.3 Receiving environment monitoring

There are presently no receiving environment monitoring requirements for this permit. Monitoring of the Bulkley River Water Quality Objectives was carried out by EPP at sites upstream and 100 m downstream of the Smithers STP in 1988-92. Parameters monitored included nutrients and periphyton standing-crop. The water quality objectives have largely been met in all years.

8.5.4.4 Discussion

The 7 day average 10 year low flow at Smithers is estimated to be 15.49 m^3/s. This is the sum of the 7 day average 10 year low flow of the Bulkley River at Quick plus that of the Telkwa River, found in Tables 8.1 and 8.2. The 1991-1994 average discharge rate from the STP (average of flows shown in Table 8.8) is 0.043 m^3/s, which would result in a dilution ratio of 364:1 under 10 year low flow conditions. The permitted average daily and maximum discharge rates would result in dilutions ratios of 230:1 and 90:1 respectively.

An engineering evaluation of this plant is needed due to elevated effluent BOD during the summer/fall months. It is also suggested that much more detailed effluent monitoring data is needed for this discharge. In particular, ammonia-N, nitrite-N and RBT 96 hr LC50 bioassay data would be necessary in order to assess possible receiving environment effects. The monitoring effort should be concentrated in the late summer and late winter low flow periods, when ammonia toxicity would be expected to occur and when dilution is lowest. See further discussion on monitoring of municipal STPs in section 12.5.

8.5.5 West Fraser Mills Ltd. PR-7867

West Fraser Mills Ltd. owns a sawmill operation located on Tatlow Road in Smithers. The wood waste landfill had already been in operation since 1977 when the company applied for a Waste Management Permit in 1987. At the time of application it was recognized that there was a leachate problem. Leachate was pooling up just east of the proposed landfill above Pacific Ave. It was recommended that the leachate pond be isolated by a wide earth berm and eventually covered up with soil and that the landfill should be covered more than the proposed frequency of 2 times per year. Leachate was also found in the ditch water adjacent to Pacific Ave. where it would drain via a culvert to Bigelow Creek during spring run off. The Technical Assessment for the permit stated that because the existing leachate pond and the proposed landfill were separated from Pacific Ave. and Bigelow Creek by an earth berm, present and future leachate would be filtered by the berm and treated by soil organisms. The permit was issued on February 18, 1988.

After continued non-compliances with the permit, a pollution abatement order was issued stating that the leachate which was found to be freely flowing into a marsh on the northern perimeter of the landfill was determined to be toxic to aquatic organisms. As a result of the pollution abatement order dated May 12, 1994, West Fraser Mills submitted a report entitled *Conceptual Design for Leachate Management and Site Remediation* by Terracon Geotechnique Ltd. (1994).

For the short term the company has been spray irrigating the contaminated water over a field adjacent to the landfill site. Long term plans include relocating the landfill site to an area which will facilitate leachate control and closing out the existing and past disposal areas.

8.5.6 Moricetown Sewage

8.5.6.1 Background

Moricetown is located approximately 30 km northwest of Smithers and has a population of approximately 650. This discharge falls under Federal jurisdiction as the site is on Indian Reserve land.

The sewage system consists of septic tanks and collection piping connecting to a conventional gravity sewer leading to one holding cell. The outfall to the Bulkley River was never completed resulting in partially treated sewage flowing overland to a beach above the river where it percolates into the ground. A briefing note from the Gitksan Wet'suwet'en Government dated April 20, 1994 describes the treatment as ranging from adequate in the summer to poor in the winter and suggests the addition of a cell downstream of adequate capacity to store winter effluent with discharge to a constructed wetland. In late 1995 an engineering firm had been contracted to prepare an engineering plan for improved sewage treatment for this discharge.

Monitoring data from 1993 and 1994, presented in Table 8.9, confirm that there is poor treatment during winter, with elevated BOD and ammonia concentrations. No microbiological data have been collected. No receiving environment monitoring data are available from the Bulkley River downstream of the discharge.

8.5.6.2 Discussion

It is obvious that an improved sewage system is needed for Moricetown. Particular care should be taken to ensure adequate treatment and outfall siting for this discharge. This location on the Bulkley River is particularly sensitive because large numbers of fish hold below the Moricetown canyon during migration, and it may be a steelhead overwintering area. This section of the river is also a heavily used recreational area: Idiot Rock is one of the most popular salmon/steelhead angling locations on the Bulkley, and many rafting and kayak expeditions put in at this location.

Table 8.9 Effluent quality Moricetown sewage collection system, 1993-1994

	Aug. 11/93	Nov. 23/93	Jan.10/94	Mar.28/94
TSS mg/L	13	21	15	10
Ammonia-N mg/L	5.43	20.2	21.4	9.4
Nitrate-N mg/L	0.005	0.013	0.017	0.09
Nitrite-N mg/L	0.001	0.001	0.003	0.016
Ortho P mg/L	0.494	2.34	2.05	1.17
BOD	9	32	59	21
TEMP °C	8	1.8	1	5
DO	4.5	4.5	0	2
pH	7.4	7.4	7.1	7.23

8.5.7 Regional District of Kitimat-Stikine Hazelton Landfill PR-4399

8.5.7.1 Background

The RDKS Hazelton Landfill is located east of New Hazelton just south of Highway 16. The landfill serves the communities of New Hazelton, Hazelton, South Hazelton, Two Mile, Moricetown and surrounding areas with an estimated population of 6,475 (1991 estimate).

8.5.7.2 Permitted discharge

PR 4399, issued November 2, 1976 and amended in 1992 and 1994, allows disposal of 840 tonnes/yr of municipal solid wastes to ground. Note that the calculated disposal rate for a population of 6,475 is 5200 tonnes/yr. (E. Rottmiller, EPP, personal communication). Segregation of large metallic wastes and woodwastes are required and open burning of non-putrescible wastes is allowed. The wastes are required to be compacted daily. Cover is required on a schedule of biweekly in summer, monthly in winter, and weekly the remainder of the year. A septage lagoon on site is permitted to receive 216 m^3/yr septic sludge. The permit explicitly disallows the discharge of refuse into water. (Drainage is apparently poor on the site, as standing water has been reported in active waste disposal trenches.)

The landfill has been found out of compliance with the permit for the burning of mixed wastes, lack of cover, waste disposal into water, and litter. RDKS is preparing a Solid Waste Management Plan which is expected to locate a new sub-regional waste disposal site in 1996 and result in the closure of this site.

8.5.7.3 Discussion

Leachate flows have been reported at this site by EPP, however no receiving environment monitoring has taken place. A preliminary leachate assessment should be completed in order to assure that no ground or surface water quality impairment is occurring and in order to assure adequate closure planning.

8.5.8 District of New Hazelton PE-1556

8.5.8.1 Background

Permit PE-1556 was first issued to the District of New Hazelton on October 6, 1972 authorizing the discharge of 230 m^3/day of treated sewage to Waterfall Creek. At this time the effluent was discharged directly into Waterfall Creek, which flows southwest from the discharge site for about three kilometers until it meets Station Creek, from there it flows northwest and enters the Bulkley River after another two kilometers.

An assessment of fish populations in Waterfall and Station Creek near the New Hazelton sewage discharge was conducted in September and October 1986 (Bustard 1986*a*). Bustard states that fish sampling above and below the outfall from the STP suggests that there is very little difference in the densities or biomass of fish populations in the two areas. Production in this section of Waterfall Creek is generally low, and appears to be more related to the habitat limitation imposed by channelization of Waterfall Creek during railroad construction. The main fisheries values in the watershed are located below the highway in Station Creek, where populations of juvenile steelhead were typical of levels found in other Bulkley River tributaries. A poorly installed culvert at Highway 16 had made upstream coho salmon rearing habitat inaccessible. In addition, extensive diversion and channelization by CN Rail along Station Creek and much of Waterfall Creek has probably significantly reduced the rearing capability of these streams.

In order to accommodate increased flows, the permit was amended in February 1989 to allow a discharge rate of 1302 m^3/day. Overland treatment was included as a requirement in the amended permit due to the fact that Waterfall Creek flows were too small to accommodate the increase in discharge rate.

In late July 1989, the District of New Hazelton began discharging secondarily treated sewage effluent into a 32.5 ha wetland adjacent to its existing treatment facilities. The wetland is meant to act as an overland tertiary treatment, or polishing, system essentially stripping nutrients from the effluent before it enters Waterfall Creek (Tamblyn 1989).

8.5.8.2 Permitted discharge

Permit PE-1556 allows a maximum discharge rate of 1302 m^3/day. The characteristics of the effluent must be equivalent to or better than 80 mg/L BOD and 80 mg/L TSS. The works authorized are: a lagoon comprising an aeration zone and a settling zone; flow measuring and sampling facilities; a disposal piping system; and an overland treatment area and 1400 m long retaining berm.

The permit requires a quarterly grab sample of the effluent from the aerated lagoon prior to disposal in the overland area. The sample is to be analyzed for BOD, TSS, fecal coliforms, ammonia-N, total nitrogen, and total phosphorus. The effluent volume discharged over a 24 hour period must be measured once per week.

The 1994 effluent quality data are found in Table 8.10. The 1994 data indicates that BOD and TSS are consistently in compliance with permit limits.

Table 8.10 Effluent quality District of New Hazelton Sewage Lagoon PE-1556, 1994

Date	T.S.S. mg/L	B.O.D. mg/L	FECAL COL #/100 ml	NH3 mg/L	TKN as N mg/L	PHOS. mg/L
01/04/94	24	21	120000	17.3	20.8	2.74
04/18/94	15	13	<1	15.9	16.1	2.16
07/11/94	56	18	13200	20.6	22.7	4.1
10/05/94	32	12	1000	14	20.8	4.4

8.5.8.3 Receiving environment monitoring

The permit also requires three grab samples to be taken quarterly from Waterfall Creek; one upstream, one parallel to and one downstream of the discharge. Parameters to be sampled are the same as for the effluent sample. Stream gauging must be carried out once per week on Waterfall Creek to determine flows in the creek. The 1994 data for Waterfall Creek are presented in Table 8.11.

Table 8.11 Water quality Waterfall Creek New Hazelton Sewage Treatment Plant PE-1556, 1991-1994

Waterfall Creek U/S New Hazelton Sewage discharge						
	TSS	BOD	Fecal Col.	NH3	Total N	Phos
Date	mg/L	mg/L	#/100 ml	mg/L	mg/L	mg/L
04/24/91	12	3	8	0.16	0.757	0.084
09/11/91	4	2	8	<0.01	0.64	<0.003
01/07/92	2	5	<1	0.28	0.43	<0.003
04/06/92	5	6	10	0.07	0.69	<0.003
07/07/92	3	<2	60	0.01	0.14	<0.003
10/13/92	1	7	18	0.05	0.11	0.003
01/04/93	1	<1	1	<0.01	2.05	<0.003
04/05/93	6	<5	<1	0.04	0.37	0.018
07/12/93	6	2	40	0.06	0.25	0.003
10/18/93	17	<1	8	0.003	0.09	0.003
01/04/94	11	8	4	0.14	14	0.003
04/18/94	4	<5	34	0.31	0.37	0.036
Waterfall Creek near New Hazelton Sewage discharge						
	TSS	BOD	Fecal Col.	NH3	Total N	Phos
Date	mg/L	mg/L	#/100 ml	mg/L	mg/L	mg/L
04/24/91	30	3	4	0.27	1.471	0.088
09/11/91	6	2	28	<0.01	0.72	<0.003
01/07/92	<1	5	4	0.19	0.47	0.04
04/06/92	7	3	6	0.14	0.88	<0.003
07/06/92	12	<2	42	<0.01	0.12	0.04
10/13/92	6	<1	36	<0.01	0.71	0.06
01/04/93	115	<1	<1	<0.01	2.96	0.094
04/05/93	34	<5	10	0.53	0.95	0.117
07/12/93	10	6	60	0.05	0.37	0.018
10/18/93	14	<1	8	0.24	0.25	0.016
01/04/94	15	10	4	0.23	0.71	0.155
04/18/94	3	<5	60	0.1	0.63	0.05
Waterfall Creek D/S New Hazelton sewage discharge						
	T.S.S.	B.O.D.	FECAL COL	NH3	TOTAL N	PHOS.
	mg/L	mg/L	#/100 ml	mg/L	mg/L	mg/L
04/24/91	13	3	2	0.25	0.976	0.092
09/11/91	13	2	20	0.05	0.67	<0.003
01/07/92	<1	5	2	0.15	0.36	0.04
04/06/92	9	6	4	0.17	0.9	<0.003
07/06/92	6	<2	72	<0.01	0.07	<0.003
10/13/92	7	<1	42	0.17	0.24	0.044
01/04/93	<1	<1	2	<0.01	1.36	<0.003
04/05/93	7	<5	14	0.05	0.39	0.021
07/12/93	4	2	10	0.22	0.31	0.036
10/18/93	18	<1	8	0.1	0.34	0.008
01/04/94	5	10	8	0.22	0.36	0.035
04/18/94	3	<5	24	0.08	0.54	0.036

8.5.8.4 Discussion

This STP appears to be capable of achieving the Pollution Control Objectives of 45 mg/L BOD and 60 mg/L TSS. It is suggested that the permit be amended to reflect the level of biological treatment which should be expected to continue at this plant. It does appear that the overland wetland treatment markedly improves the quality of this discharge before it enters Waterfall Creek, which has populations of resident cutthroat trout and Dolly Varden char. While ammonia levels in the effluent are high enough to be acutely toxic, levels in Waterfall Creek in the vicinity of the discharge, after wetland treatment, are less than the criterion for the protection of aquatic life. Nonetheless, it is likely that some nutrient loading from this discharge is occurring.

It is suggested that orthophosphate be added as a monitoring parameter, as it is a better indicator of bioavailable phosphorus. It is also suggested that periphyton biomass monitoring be conducted during late summer low flows in order to assess possible effects of nutrient loading to this system.

8.5.9 REPAP Carnaby PR-7861

8.5.9.1 Background

Skeena Cellulose owns and operates the REPAP Carnaby whole log chipping plant located in New Hazelton. Permit PR-7861 was first issued on November 18, 1987 and the whole log chipper plant started operating in June 1988. Despite the fact that operations did not start until 1988, the company at the time (Westar) had been disposing of wood debris at the site for ten years.

8.5.9.2 Permitted discharge

Permit PR-7861 authorizes a discharge rate of 5 m^3/day and 1250 m^3/year of woodwaste to the ground. Prior to the permit amendment in January 1994, the permittee was required to apply intermediate cover to the site once every 20 days. As part of the recent amendment, the permittee is no longer required to apply intermediate cover. This was a result of the 40 to 50% of inert material which was incorporated into the woodwaste.

8.5.9.3 Receiving environment monitoring

The receiving environment which could be most affected by this operation is Waterfall Creek. At the time the permit was amended in January 1994, leachate generated by the landfill was being conveyed away from the creek by a collection ditch where it traveled to another ditch bordering the north side of the CN rail line. Eventually the leachate would percolate into the ground.

On November 1, 1994 a sampling program of the REPAP site was carried out by EPP staff. Leachate was found to be freely flowing into a tributary of Waterfall Creek. Bioassay test results from this tributary found the water to be toxic to aquatic organisms. A five minute EC50 of 29.8% was determined on the Microtox bioassay, representing a toxic effect.

As a result of this finding, a Pollution Abatement Order dated February 13, 1995 was issued to the Skeena Cellulose. As a requirement of the order, Skeena Cellulose was required to immediately, and progressively, as frost conditions allow, remove wood chips and wood residue from the area between the CN rail track and the edge of the tributary to Waterfall Creek to the maximum extent possible, and to prevent future deposition of these material in this area.

In addition the company was required to carry out a sampling program on the plant site drainage following the first significant flushing event upon completion of the clean up. Parameters to be sampled are Microtox bioassay, phenols, resin acids, total organic carbon, BOD, COD, pH and temperature.

8.5.10 Hagwilget Indian Band PE-7460

8.5.10.1 Background

The community of Hagwilget is located within the Hagwilget IR No. 1 at the northwest edge of the District Municipality of New Hazelton. At the time of permit application in 1986, the Village of Hagwilget had a population of 130 and was using individual household septic tanks and tile fields. Most of the systems at this time were failing due to impermeable soils in the area. A community sewage collection and treatment system was constructed and in operation by the fall of 1986. It was expected at this time that the lagoons would not fill up and discharge for another 3 years. Treatment at this site is via two facultative lagoons and outfall which terminates 5 m into the Bulkley River. It was anticipated at the time of application that the population would increase to 350 by the year 2005 (Technical Report PE-746 1986).

8.5.10.2 Permitted discharge

Permit PE-7460 allows a maximum discharge rate of 96 m^3 per day of treated effluent. The characteristics must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The permit requires quarterly grab samples of the effluent for BOD and TSS. Results must be submitted quarterly as well as a monthly record of 24 hour effluent volume discharge.

A permit inspection form dated October 1, 1992 indicated a positive discharge from the lagoons and monitoring and flow data were requested. Effluent quality data shown in Table 8.12 were submitted shortly thereafter.

Table 8.12 Effluent quality Hagwilget sewage discharge PE-7460, 1989-1992 (permittee monitoring)

		31-May-89	5-Sep-89	3-Jul-90	17-Sep-90	27-May-92	13-Jul-92
pH					7.5		7.2
BOD5	mg/L	38	14	5	31	40	49
TSS	mg/L	140	12	43	50	18	12

Analysis of effluent samples taken by EPP in May and November, 1993 are shown in Table 8.13.

Table 8.13 Effluent quality Hagwilget sewage discharge PE-7460, 1993 (EPP monitoring)

		30-May-93	23-Nov-93
pH	pH units	7.3	7.4
Specific Conductance	uS/cm	533	
TSS	mg/L	18	16
BOD	mg/L	76	21
Nitrogen - Ammonia (N)	mg/L	22.7	9.42
Nitrogen NO3+NO2	mg/L	0.03	<0.02
NO3 (N)	mg/L		<0.02
NO2 (N)	mg/L		0.007
Phosphorus Total	mg/L	3.41	2.17
Phosphorus Ortho-P	mg/L	2.1	1.41
Fecal Coliform	CFU	65 000	1050

EPP assessed toxicity of the Hagwilget effluent sampled May 20, 1993 using three different bioassay methods: Rainbow trout (RBT) 96 hr LC50, Daphnia 48 hr LC50, and 5 and 15 minute Microtox EC50. Results were as follows:

- RBT 96 hr LC50 = 30%
- Daphnia 48 hr bioassay = non-toxic
- 15 min. Microtox bioassay = 13.0% with 95% confidence range of 10.7 to 15.8%
- 5 min. Microtox bioassay = 14.0% with 95% confidence range of 11.3 to 17.4%.

The effluent discharge at Hagwilget was again sampled by EPP on July 24, 1994 for toxicity using a 15-minute Microtox bioassay. The effluent was found to be toxic with an EC50 of 5.0% (95% confidence range of 3.9 to 6.5%). In other words, an effluent concentration of 5% caused a 50% decrease in luminescence (that is, it presumably caused 50% of the bacteria to die). It was noted that the effluent had a very strong odor at the time of sampling indicative of anaerobic conditions, which was attributed to excessive duckweed found on the first lagoon.

There is no receiving environment monitoring requirement or data on file for this site.

8.5.10.3 Discussion

The permit has been consistently out of compliance with regard to effluent quality and flow measurement and reporting. The limited data submitted by the permittee indicates occasional non-compliance with permit limits.

Effluent sampling conducted by EPP in May 1993 reveals high BOD and ammonia concentrations. An ammonia-N concentration of 22.7 mg/L is within a range likely be toxic to aquatic life. Elevated ammonia and BOD concentrations are often noted in sewage effluents, particularly from non-aerated lagoons, in northern climates due to ice cover and low temperatures. Toxicity testing on two occasions in 1993-1994 indicated acutely toxic effluent.

Although flow data for the discharge is not available, an estimated dilution ratio was calculated using the 7 day average 10 year low flows at the three gauged sites upstream (Bulkley River at Quick + Telkwa River + Canyon Creek) and the maximum permitted effluent discharge rate. The dilution ratio from this calculation is estimated to be about 10,000:1.

There is a concern that over-wintering steelhead trout and other resident fish may be attracted into the mixing zone of effluents such as this one by warmer water temperatures. It is assumed that the size of mixing zone of this discharge is small however, because available dilution is quite high.

More detailed monitoring of effluent quality is suggested for this discharge, and, in particular, the addition of ammonia-N, nitrite-N and RBT 96 hr LC50 bioassay to the monitoring program is emphasized. The monitoring effort should be directed to low flow periods, particularly during winter. Nutrient loading is unlikely a problem at this location. See section 12.5 for further discussion on monitoring of municipal sewage effluents.

8.5.11 Minor Discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PE-4688	Mountain View Mobile Home Park	Smithers	Septic tanks to exfiltration lagoon	Maximum 114 m^3/day
PE-4921	Forests and Lands, Air Operation	Smithers Airport	Diluted fire retardant to ground	Maximum 45.46 m^3/d Average 0.68 m^3/d
PE-6586	Midway Service Ltd.	Telkwa	Car & truck wash effluent to ground	Maximum 2 m^3/day
PR-7535	REPAP Smithers	Smithers	Woodwaste landfill	Average 5 m^3/day

8.5 SUMMARY AND REVIEW OF MONITORING NEEDS

The Bulkley valley is wide and rolling in this reach, with a long history of agricultural settlement. An estimate 150 ranches are located between Houston and Moricetown, with an approximate total of 4000 breeding cows.

Forestry was historically conducted in conjunction with land clearing for agriculture. Since the early 1970's forestry operations have moved into higher elevations in the tributary streams, such as the Telkwa River, Canyon Creek, and the Suskwa River, and has shifted to primarily clearcut logging.

There has been a long history of coal production in the Telkwa area. Presently the proponents of a thermal coal mine, with proposed open pits north and south of the Telkwa River, are awaiting an assessment of ARD potential and mitigation.

Five urban settlements are found in this reach: Telkwa, Smithers, Moricetown, New Hazelton and Hagwilget, all of which discharge wastewaters into the Bulkley River. In addition, a sizable portion of the population lives in semi-rural settlement areas or on hobby farms. There are housing concentrations, served by septic tanks, around several lakes in the area. Two municipal solid waste landfills and two woodwaste landfills are found in this reach.

8.5.1 Water quality assessment

8.5.1.1 Bulkley River at Quick

The Bulkley River at Quick has soft water, with near neutral pH and moderate colouration due to organic substances contributed by swamps and wetlands in the drainage. Moderately low conductance and low dissolved solids in the water are a reflection of the rapid rate of runoff in the region and are an indication of good water quality. While TSS is fairly low for most of the year, values can be high during freshet. Alkalinity is low but high enough to provide protection from acidic inputs. Nutrient concentrations are generally low. Mean total metals concentrations are generally very close the MOELP criteria for protection of aquatic life at the hardness levels present, while dissolved metals levels are often less than detection limits.

8.5.1.2 Telkwa River

Compared to the Bulkley River, the Telkwa has slightly harder water, although still within the range considered to be soft, with similar colouration. The Telkwa has slightly higher pH (mean=7.5) and higher alkalinity, providing greater protection from acidic inputs. Conductance and dissolved solids are both higher in the Telkwa than in the Bulkley, perhaps reflecting higher mineralization in the Telkwa basin. One of the most noticeable characteristics of the Telkwa River is higher mean TSS than other Bulkley River tributaries or the Bulkley River at their confluence. This is due to glacial silt from the high elevation headwaters, as well as natural sediment sources in a canyon section of Pine Creek. Nutrient levels are low. Like other Skeena tributaries, average total metals concentrations are generally very close the MOELP criteria levels, while dissolved metals levels are often less than or equal to detection limits.

8.5.1.3 Smithers/Telkwa area lakes

Water quality assessment and objectives have been prepared for four small lakes in the Smithers/Telkwa area: Kathlyn, Seymour, Round and Tyhee Lakes. These lakes are important for recreation, domestic water supply and irrigation. The concern was that the spread of agricultural and residential development around the lakes was contributing to lake eutrophication. A second concern was that fecal coliform objectives may not be met for drinking water and recreation.

Based on nutrient concentrations, all four lakes were considered eutrophic, Kathlyn Lake being the least eutrophic, Round Lake the most. Planktonic algal communities were typical of eutrophic lakes, with high biomass and noxious species contributing to taste and odor, slime formation or unattractive appearance. Reduction in spring overturn phosphorus concentrations would be required in order to improve conditions.

Recommendations were to freeze watershed development in all four watersheds until the eutrophic conditions are controlled by a restoration technique. When additional development is permitted, stringent emphasis should be placed on the control of phosphorus movement to the lake. Control would be necessary on the correct setback of septic tank tile field and the number of residences and hobby farms. In addition, installation of aeration systems in Round and Tyhee Lakes was suggested. Methods of hypolimnetic water withdrawal or hypolimnetic aeration were suggested for Seymour Lake.

8.5.2 Hydrometric data needs

Environment Canada is undertaking a review and reduction of the hydrometric network, and a number of stations in this reach may be affected. Station 08EE020 Telkwa River is on a list of stations which require funding support from other agencies or it may be discontinued. Station 08EE014 Canyon Creek will be decommissioned in 1996 or 1997 if funding support is not found. It will be extremely difficult to assess current and future water withdrawals and waste loadings to these streams if these stations are discontinued.

Manalta Coal Ltd. has been evaluating coal reserves on the Telkwa River for several years, with plans for open pit mining in three areas: two pits north of Telkwa River and one south of the river. The outstanding issue, at this time, is the assessment of potential ARD production and mitigation. Hydrometric data will be essential to assessment of waste discharges from this and other mining projects in the watershed.

Canyon Creek is the only small interior stream draining the mainly agricultural region of the valley which is gauged and has been for over 20 years. Hydrometric data from this system is important for several reasons:

- Canyon Creek is a community watershed, that is, it has numerous domestic water users as well as a community waterworks. There is logging in the headwaters, in the McKendrick Pass area, therefore a watershed assessment may be called for under FPC.
- It is also heavily utilized for irrigation, and perhaps may be over-utilized. The estimated water withdrawal for irrigation nearly equals the summertime 7-day average 10-year low flow estimate. This raises concerns as to whether flows are adequate for other water users, for assimilating the wastes from agriculture and for protection of the fisheries.

- Lastly, it has been suggested by several researchers (Coulson 1989, McBean and others 1992) that a potential effect of climate change (warming) may be reduced summer and early autumn flows in streams of the interior regions. Canyon Creek is one of the few relatively long-term stations in this area.

8.5.3 Interaction of agriculture and water quality

When the railway was completed through the valley in 1914, dairy and cattle farming were already well established. Cattle and dairy ranching are still major economic sectors in this reach of the Skeena watershed. While there are essentially no recent data, it has been estimated that 150 ranches are located between Houston and Moricetown, with an approximate total of 4000 breeding cows. MOF grazing permits were issued for 2245 cattle, 36 horses, and 1647 sheep in the Bulkley Forest District in 1992.

Unless careful stream protection practices are followed, runoff from winter feedlots and uncovered manure piles can affect water quality by direct toxic effects (ammonia and nitrite), by the addition of nutrients and bacteria, and by creating oxygen demand. Improper livestock grazing can also result in a decline in streambank vegetation and stability. All animal wastes contain microorganisms, and more than 100 diseases are transmissible between animals and humans. A second concern is water withdrawal for irrigation. At present, there are no data on the actual volumes of water utilized for irrigation, or to what extent in-stream flows in smaller tributaries may be affected.

EPP files indicate there have been public complaints concerning runoff from agricultural areas, particularly with regard to eutrophication of area lakes. The manager of the Toboggan Creek Hatchery has been concerned that agricultural runoff from farms upstream in the watershed may affect the health of hatchery stocks (M. O'Neil, personal communication). Another area of public concern is the Deep Creek watershed.

8.5.3.1 Monitoring needs

An assessment of agricultural interaction with water quality is an important research need for this reach of the Skeena watershed. Agriculture is the most widespread land-use activity, as well as the activity most likely to lead to nutrient enrichment of streams. Runoff of nutrients and bacteria from winter feeding and calving areas near small fish-producing tributaries is a particular concern. In addition, an assessment of range use practices in the watershed is needed.

There over 80 licenses for water withdrawals for irrigation from tributary streams to this reach of the Bulkley River. Total estimated irrigation water consumption from tributary streams, during the summer months, is over 70,000 m^3/day. Canyon Creek is the only stream draining an area heavily utilized for agriculture which is gauged. The estimated total licensed water withdrawal, largely for irrigation, essentially equals the summertime 7 day average 10 year low flow for this creek. Low streamflows can cause problems for fish because of higher temperatures and lack of dilution for nutrients and waste discharges. Further monitoring is required to determine actual utilization of irrigation water by licensees, to identify potentially over-utilized streams, and to assess the in-stream flow needs for fish. See section 12.4 for further discussion.

8.5.4 Interaction of forestry and water quality

An assessment of stream protection practices in the Bulkley TSA, conducted in the mid-1980's, noted that extensive logging operations around tributaries of the Bulkley encompass valuable salmon and steelhead streams. There had been a shift away from leaving riparian reserves towards the use of machine reserves along streams due to windthrow problems. However, it was generally believed that these provided adequate streamside protection. Sediment from roads, due to both construction and inadequate maintenance, was cited as the main impact from logging activities on streams in the Bulkley TSA. As well, blockage of fish movements due to poor culvert installation and maintenance was cited as a problem.

An analysis of possible changes to flow regimes in the Telkwa River as a result of forest harvesting activities, conducted by MOF, found that only a small percentage of the middle and lower sections of the watershed had been clear-cut over the past 20 years, which would have produced no detectable effect on peak flows. Hydrologic modeling of logging proposed for the following five years indicated a theoretical increase of 2% in peak streamflow.

A suspended sediment monitoring program in the Telkwa River watershed found that natural sediment sources from landslides, gully erosion, and streambank erosion dominated the sediment input in all the major tributaries of the Telkwa River during the 1990 freshet. Pine Creek was found to be the most important chronic sediment source to the lower Telkwa, due to unstable terrain. An active program to prevent and mitigate erosion and sediment transport in the watershed will become particularly important with the movement of harvesting activities into steeper and wetter areas.

The Bulkley Valley Community Resources Board is preparing a LRMP for the Bulkley TSA. The board, formed in 1993, has reached a Consensus Management Direction, but is conducting an additional socio-economic study prior to release of the plan. In addition to recommending areas for protected status under PAS, the LRMP is expected to prescribe management practices for stream protection for the many Community Watersheds found in this reach.

8.5.4.1 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is a major land-use activity in this reach. One review of stream protection practices in the mid 1980's identified instances of stream degradation in the Bulkley TSA and identified road building and lack of road maintenance as the main source of sediment to streams. The FPC is expected to improve compliance with stream protection guidelines and the Watershed Restoration Program is intended to address problems such as lack of road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring is also necessary to ensure that LRMP management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.2.

8.5.5 Interaction of mining and water quality

Telkwa Coal Project.— Coal production commenced in the Telkwa area about 1918 and continued sporadically and at different locations both north and south of the Telkwa River and near Goathorn Creek until 1986. Manalta Coal Ltd. now holds the coal reserves at Telkwa and is researching the construction of an open pit mine to produce export thermal coal. The project area under Mine Development Certificate Application consists of one pit south of the Telkwa River, and two pits north of the Telkwa River. A report has been commissioned to assess potential ARD production and how it will be mitigated. Once this report has been completed the company may continue with the Environmental Assessment Board process.

8.5.6 Interaction of urban developments and water quality

8.5.6.1 Municipal sewage treatment plants

Telkwa STP.— A sewage treatment plant has recently been constructed opposite the Village of Telkwa on the Bulkley River, consisting of a 3-cell anaerobic-aerated lagoon system, discharging to an exfiltration lagoon with 45 day holding capacity. The treated effluent filters through gravel to a natural wetland for final polishing before entering the Bulkley River.

The 2.1 ha wetlands to which this discharge exfiltrates have developed in an old channel of the Bulkley River that was cut off by the railroad in the early 1900's. Fish sampling in 1993 concluded that salmonid species such as coho salmon and cutthroat trout were not present in the Telkwa wetlands; however, peamouth chub, redside shiners and longnose suckers were abundant. It was concluded that increased flows into the wetland associated with the sewage project, in conjunction with the removal of the beaver dam at the CN rail culvert, might encourage salmonid use of the wetlands. This would be dependent upon the quality of the effluent.

The permit requires the characteristics of the effluent to be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. Monthly monitoring of the discharge is required for BOD, TSS, total nitrogen, ammonia-N, nitrate-N, nitrite-N, total phosphorus, orthophosphate, temperature, dissolved oxygen and pH. Effluent volume entering the exfiltration lagoon must be monitored to provide the average and maximum daily discharge rates.

Receiving environment monitoring is required at a groundwater sampling well between the exfiltration lagoon and the wetland and at the first intersection of a wetland channel and the CN railway. The intent of this site is to be representative of effluent polishing afforded by the wetland. Parameters monitored are the same as shown for the effluent above. Also required is a baseline floristic survey of the wetland prior to any discharges from the sewage treatment system. This survey will be repeated at intervals of several years to reassess the health of the vegetation communities and so that changes in the value of the wetland as wildlife habitat can be assessed.

The dilution ratio for this discharge, calculated using the 7 day average 10 year low flow and the daily permitted discharge rate to the exfiltration cell, is 1059:1. It is believed that both filtration through gravel and wetland polishing will remove nutrients from this discharge, further improving quality. The discharge and receiving environment monitoring programs for this permit are very comprehensive. Bioassay monitoring has not been required for this effluent, but this considered reasonable, given the discharge pathway at this site.

Smithers STP.— The Town of Smithers sewage treatment plant consists of two aerated lagoons operated in series. The permit sets the maximum effluent BOD concentration at 45 mg/L and TSS at 60 mg/L. The sewage outfall is buried in the bottom of the deep channel of the Bulkley River, with five equally spaced diffuser heads pointed downstream in order to maximize initial dilution.

Effluent quality has remained within permit limits for TSS, but exceedances for BOD are common. There appears to be a regular seasonal increase in BOD and TSS during the summer/fall, which has been attributed to excess duckweed and algae growth in lagoon #2. An assessment of toxicity of the Smithers effluent, sampled in May 1993, found a rainbow trout 96 hr LC50 of 74.8%. The town has agreed to obtain an engineering evaluation to assess available data and determine if additional aeration is required at this STP.

There are no receiving environment monitoring requirements for this permit. Monitoring of the Bulkley River Water Quality Objectives was carried out by EPP at sites upstream and 100 m downstream of the STP in 1988-1992. The water quality objectives have largely been met in all years.

The dilution ratio for this discharge, based on 7 day average 10 year low flow and the 1991-1994 average discharge rate from the STP is 364:1. The average daily and maximum discharge rates allowed by the permit would result in dilution ratios of about 230:1 and 90:1 respectively.

An engineering evaluation of this plant is needed due to elevated effluent BOD during the summer/fall months. It is also suggested that more detailed effluent monitoring data is needed for this discharge. In particular, ammonia-N, nitrate-N, nitrite-N, orthophosphate, bacterial and RBT 96 hr LC50 bioassay data would be necessary in order to assess possible receiving environment effects. The monitoring effort should be concentrated in the late summer and late winter/early spring low flow periods.

Moricetown sewage.— The Moricetown sewage system consists of septic tanks and collection piping connecting to a conventional gravity sewer leading to one facultative holding cell. The outfall to the Bulkley River was never completed, resulting in partially treated sewage flowing overland to a beach above the river where it percolates into the ground. In 1995 an engineering plan for improved sewage treatment for this discharge was in preparation.

Monitoring data collected during 1993-1994 show that there is poor effluent treatment during winter, with elevated BOD and ammonia concentrations. No monitoring data are available from the Bulkley River downstream of the discharge.

It is apparent that an improved sewage system is needed for Moricetown. If any alternative can be found, such as discharge of treated effluent to wetlands, direct discharge to the Bulkley River at Moricetown should be avoided. If direct discharge is unavoidable, particular care should be taken to ensure adequate treatment and outfall siting and configuration for this discharge. This location on the Bulkley River is particularly sensitive because large numbers of salmon and steelhead hold downstream of the Moricetown canyon during migration, and this may be a steelhead overwintering area. This section of the river is also heavily used recreationally.

New Hazelton STP.— The District of New Hazelton holds a permit to discharge treated sewage to Waterfall Creek via overland flow through a wetland. The permit requires the characteristics of the effluent to be equivalent to or better than 80 mg/L BOD and 80 mg/L TSS. Overland treatment was included as a requirement of a permit amendment in 1989 due to fears that Waterfall Creek flows were too small to accommodate an increase in discharge rate. Treated sewage effluent is discharged from a single lagoon, having an aeration zone and a settling zone, into a 32.5 ha wetland, which is meant to act as an overland tertiary treatment system, removing nutrients from the effluent before it enters Waterfall Creek.

Quarterly sampling of effluent and the creek near the wetland is required for the following parameters: BOD, TSS, ammonia, total nitrogen, total phosphorus and fecal coliforms. These data indicate that overland wetland treatment markedly improves the quality of this discharge before it enters Waterfall Creek, which has populations of resident cutthroat trout and Dolly Varden char. Although low, it appears that some nutrient loading from this discharge is occurring.

Monitoring data indicate that this STP is capable of achieving the Pollution Control Objectives of 45/60 mg/L BOD/TSS, rather than 80/80 mg/L BOD/TSS which is required by the current permit. It is suggested that the permit be amended to reflect the level of biological treatment which should be expected to continue at this plant. Orthophosphate could be added as a monitoring parameter, as it is a better indicator of bioavailable phosphorus. It is also suggested that periphyton biomass monitoring be conducted during late summer low flows in order to assess possible effects of nutrient loading to Waterfall Creek.

Hagwilget STP.— The community of Hagwilget is at the northwest edge of the District Municipality of New Hazelton. Prior to 1986, Hagwilget was using individual household septic tanks and tile fields, which were failing due to impermeable soils. A community sewage collection and treatment system was constructed in 1986, consisting of two facultative lagoons and an outfall 5 m into the Bulkley River. The permit requires effluent with characteristics equivalent to or better than 45 mg/L BOD and 60 mg/L TSS, in addition to quarterly effluent sampling and data submission for BOD, TSS and discharge flow.

The limited data which have been submitted by the permittee indicates occasional non-compliance with permit limits. Effluent sampling conducted by EPP in May 1993 found high BOD and ammonia concentrations. These conditions are often noted in sewage effluents, particularly from non-aerated lagoons in northern climates, due to ice cover and low temperatures. Bioassays conducted by EPP on two occasions in 1993-1994 indicated acutely toxic effluent.

The dilution ratio was calculated using a 7 day average 10 year low flow estimate and the maximum permitted effluent discharge rate (actual flow data was not available). The dilution ratio is estimated to be about 10,000:1. This discharge occurs a short distance upstream of the confluence of the Bulkley and Skeena rivers, where dilution will be even greater.

There is a concern that over-wintering steelhead trout and other resident fish may be attracted into the mixing zone of perhaps toxic effluents such as this one by warmer water temperatures. It is likely that the size of mixing zone of this discharge is small, however, because available dilution is quite high. More detailed monitoring of effluent quality is suggested for this discharge. In particular, the addition of ammonia-N, nitrate-N, nitrite-N and RBT 96 hr LC50 bioassay to the monitoring program is emphasized. Nutrient loading is unlikely a problem at this location.

Monitoring needs.— More comprehensive monitoring data is needed in order to assess both short- and long-term cumulative effects of these discharges. While BOD and TSS give a good indication of the degree of biological treatment achieved by a sewage treatment facility, additional data are required to assess possible direct effects within the receiving environment.

Effluent and receiving environment monitoring ideally would take place quarterly (monthly during low flow periods) and include the following parameters: BOD, TSS, total nitrogen, ammonia-N, nitrate-N, nitrite-N, total phosphorus, orthophosphate, temperature (field), dissolved oxygen (field), pH (field) and microbial indicators, such as fecal coliforms and enterococci. Rainbow trout 96 hr LC50 bioassay should be conducted twice per year during summer and late winter low flow periods. It is recognized that monitoring frequencies may be adjusted downward for smaller facilities, but should, at minimum, occur once per year.

The Smithers STP is probably the plant requiring the most detailed monitoring. The current estimated dilution ratio is 364:1, however, the permitted daily average and maximum discharge rates would result in dilution ratios of 230:1 and 90:1 respectively. In addition to engineering changes at this plant to bring BOD levels down, consideration should be given to regulating the discharge rate subject to dilution ratios based on in-stream flow measurement.

There is a concern with all of these discharges that acute and/or chronic toxicity to fish may exist within the initial dilution zones. The Bulkley River is one of few river systems in which steelhead trout are known to overwinter. The concern is that steelhead, in addition to resident trout, may be attracted into the mixing zone by warmer water temperatures. Further discussion of effluent and mixing zone toxicity is found in section 12.5.

8.5.6.2 Municipal landfill leachate

Regional District of Bulkley-Nechako Smithers/Telkwa landfill.— The current Smithers/Telkwa landfill, operated by the RDBN, is located about 8 km south of Smithers between Highway 16 and the Bulkley River. An old landfill, also operated by the RDBN, and located across the road, is now closed except for a septic sludge disposal lagoon. The permit for the current site authorizes a maximum discharge rate of 4389 tonnes/year of solid waste. A minimum of 15 cm of cover soil must be applied to compacted refuse at least once every day except where freezing conditions adversely affect normal operation.

A preliminary leachate assessment, conducted in 1993, stated that the landfill is located on gravelly, glacio-fluvial terrace deposits with intermittent clay or till layers conducive to subsurface ground water flow from the site to the Bulkley River. Ground water flow to the river through gravelly soils is probably rapid; however, it is difficult to define the exact leachate pathway. The second possible receptors are shallow water supply wells near or downgradient from the landfill and the Bulkley River.

The estimated leachate production from the new and old landfill sites combined together with the permitted liquid septic sludge volume, results in a leachate estimate of about 8,460 m^3/yr. The estimated dilution ratio in this section of the Bulkley River, based on the 7 day average 10 year low flow, is 3700:1. It is unlikely that negative water quality impacts would occur at this dilution; however, if there is entrainment of leachate into subsurface gravel channels, water quality degradation could occur in residential wells and/or in localized river gravel sediments.

Information on the ground water flow system is required in order to assess possible impacts from the leachate. A detailed hydrogeological program as well as a geophysical survey have been suggested. Water level elevations in groundwater monitoring wells should be measured and water quality samples collected and tested quarterly until a clear understanding of ground water flow and leachate movement is obtained. Analytical parameters should include conductivity, chloride, hardness, ammonia, BOD, COD and iron at a minimum.

In addition, the shoreline of the Bulkley River to the south and west of the landfill should be inspected twice annually, for evidence of leachate discharge and staining, during low flow conditions. Samples upstream, adjacent to, and downstream of the landfill should be collected four times annually particularly during low flow conditions. Analytical parameters should be the same as those recommended for ground water monitoring, at a minimum.

Regional District of Kitimat-Stikine Hazelton landfill.— The RDKS Hazelton landfill is located east of New Hazelton just south of Highway 16. The landfill serves the communities of New Hazelton, Hazelton, South Hazelton, Two Mile, Moricetown and surrounding areas. RDKS is preparing a Solid Waste Management Plan which is expected to locate a new sub-regional waste disposal site in 1996 and result in the closure of this site.

The permit allows disposal of 840 tonnes/yr of municipal solid wastes to ground. The wastes are required to be compacted daily. Cover is required biweekly in summer, monthly in winter, and weekly the remainder of the year. A septage lagoon on site is permitted to receive 216 m^3/yr septic sludge. The permit explicitly disallows the discharge of refuse into water, since drainage is poor on the site and standing water has been reported in active waste disposal trenches.

Leachate flows during the early spring have been reported at this site by EPP; however, no receiving environment monitoring has taken place. A preliminary leachate assessment should be completed in order to assure that no ground or surface water quality impairment is occurring at this site and to ensure adequate closure planning.

8.5.6.3 *Woodwaste leachate*

West Fraser Mills - Smithers.— The wood waste landfill at the West Fraser Mills sawmill operation on Tatlow Road in Smithers has been in operation since 1977. At the time of permit application in 1987, it was recognized that leachate was pooling up just east of the landfill above

Pacific Avenue, where it would drain via a culvert to Bigelow Creek during spring run off. It was recommended that the leachate pond be isolated by a wide earth berm so that it would be filtered by the berm and that the landfill should be covered frequently.

A pollution abatement order was issued in 1994 stating that the leachate, which was found to be flowing into a marsh on the northern perimeter of the landfill, was determined to be toxic to aquatic organisms. As a result, West Fraser has submitted a plan for leachate management and site remediation. For the short term the company has been spray irrigating the contaminated water over a field adjacent to the landfill site. Long term plans include relocating the landfill site to an area which will facilitate leachate control and closing out the existing and past disposal areas.

Skeena Cellulose - New Hazelton.— A woodwaste disposal site permit was first issued in 1987 to Skeena Cellulose, which owns and operates the REPAP Carnaby whole log chipping plant located in New Hazelton. Despite the fact that operation of the whole log chipper plant did not start until 1988, the company at the time (Westar) had been disposing of wood debris at the site for ten years. In November 1994, an EPP sampling program at the woodwaste site found leachate was flowing into a tributary of Waterfall Creek. Bioassay test results from this tributary found the water to be toxic to aquatic organisms. A pollution abatement order was issued in February 1995, which required Skeena Cellulose remove wood chips and wood residue from the area between the CN rail track and the edge of the tributary to Waterfall Creek and to prevent future deposition of these material in this area. This was to begin immediately and continue, as frost conditions allowed, to the maximum extent possible. A monitoring program following site clean-up was required.

9. SKEENA RIVER TO KITSUMKALUM RIVER CONFLUENCE

After its confluence with the Bulkley River at Hazelton, the Skeena flows southwesterly through the Hazelton Ranges to Terrace (Figures 9.1 and 9.2). Major tributaries in this reach are the Kitseguecla, Kitwanga, Zymoetz and Kitsumkalum rivers. South of Hazelton, the Skeena meets two river valleys: first the Kitseguecla from the south, and second the Kitwanga from the north. The low-lying Kitwanga River valley is nearly continuous with that of the Cranberry River (draining to the Nass), and thus has long been a trade and transportation route. A through-flowing river may have occupied the Kitwanga-Cranberry valley at some time during or prior to the Pleistocene, thus connecting the drainage basins of Nass and Skeena rivers (Clague 1984). Downstream of the Kitwanga, the Skeena cuts through the rugged Hazelton Mountains and most tributaries in this section are fairly short and steep until the confluence of the Zymoetz River near Terrace.

The Zymoetz River (locally called the Copper River) drains the western slopes of the Bulkley Ranges, and is the largest tributary in this reach. Two mountain passes connect the headwaters of the Zymoetz with Bulkley River tributaries, and both have long been access routes for mineral exploration and logging: 1) the McDonnell Lake-Pine Creek route with road connection to Smithers, and 2) the Limonite Creek-Telkwa River route, known as the Telkwa Pass. The natural gas pipeline from the interior crosses the Telkwa Pass to Terrace, then branches to Kitimat and Prince Rupert.

The Kitsumkalum watershed is part of the broad low-lying Kitsumkalum-Kitimat trough, which cuts perpendicularly across the Skeena valley at Terrace. The southern portion of the trough is drained by the Kitimat River (to Douglas Channel) and the northern portion by the Kitsumkalum and Cedar rivers and the Tseax River (to the Nass).

Kitsumkalum-Kitimat trough.— At the end of the last Pleistocene glaciation, ice accumulated to at least 2,000 m over the Coast Mountains, burying them completely (Gottesfeld 1985). The weight of this thickness gradually depressed the crust beneath the mountain ranges, so that the ice-filled valleys were below sea level. As the mountains came out from under their ice cover, the rapid melting of the ice allowed the sea to advance far up the depressed valleys. At its maximum about 10,600 years ago, salt water reached up the Skeena Valley as far as Terrace and up the Kitimat-Kitsumkalum valley almost to Kitsumkalum Lake. Maximum submergence was about 200 m, which rapidly decreased to modern sea level by 8,900 years ago. A huge coalescent valley glacier then retreated up Douglas Channel and continued back up the Kitimat, Kitsumkalum and Skeena valleys. Short standstills and/or minor readvances of this glacier formed huge sand and gravel deltaic deposits in the Kitimat and Kitsumkalum valleys. As the glacier retreated, it left these deposits at the valley constriction south of Lakelse Lake, again north of Lakelse Lake near Thornhill, and again south of Kalum Lake. Lakelse Lake and Kitsumkalum Lake were impounded by these glacial deposits. Lakelse Lake assumed its present drainage northwest into the Skeena as the sea level dropped.

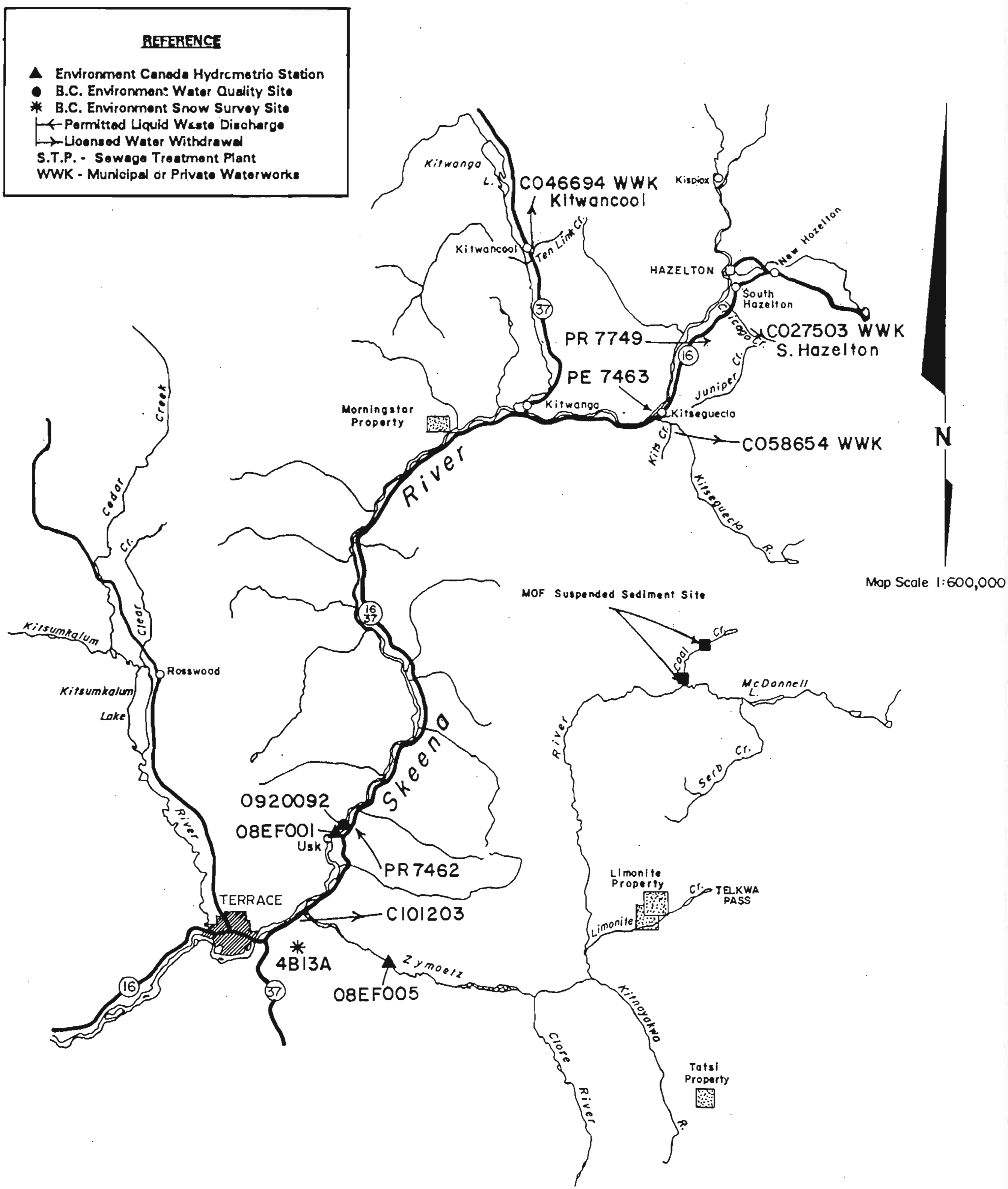


Figure 9.1 Skeena River to Kitsumkalum River confluence

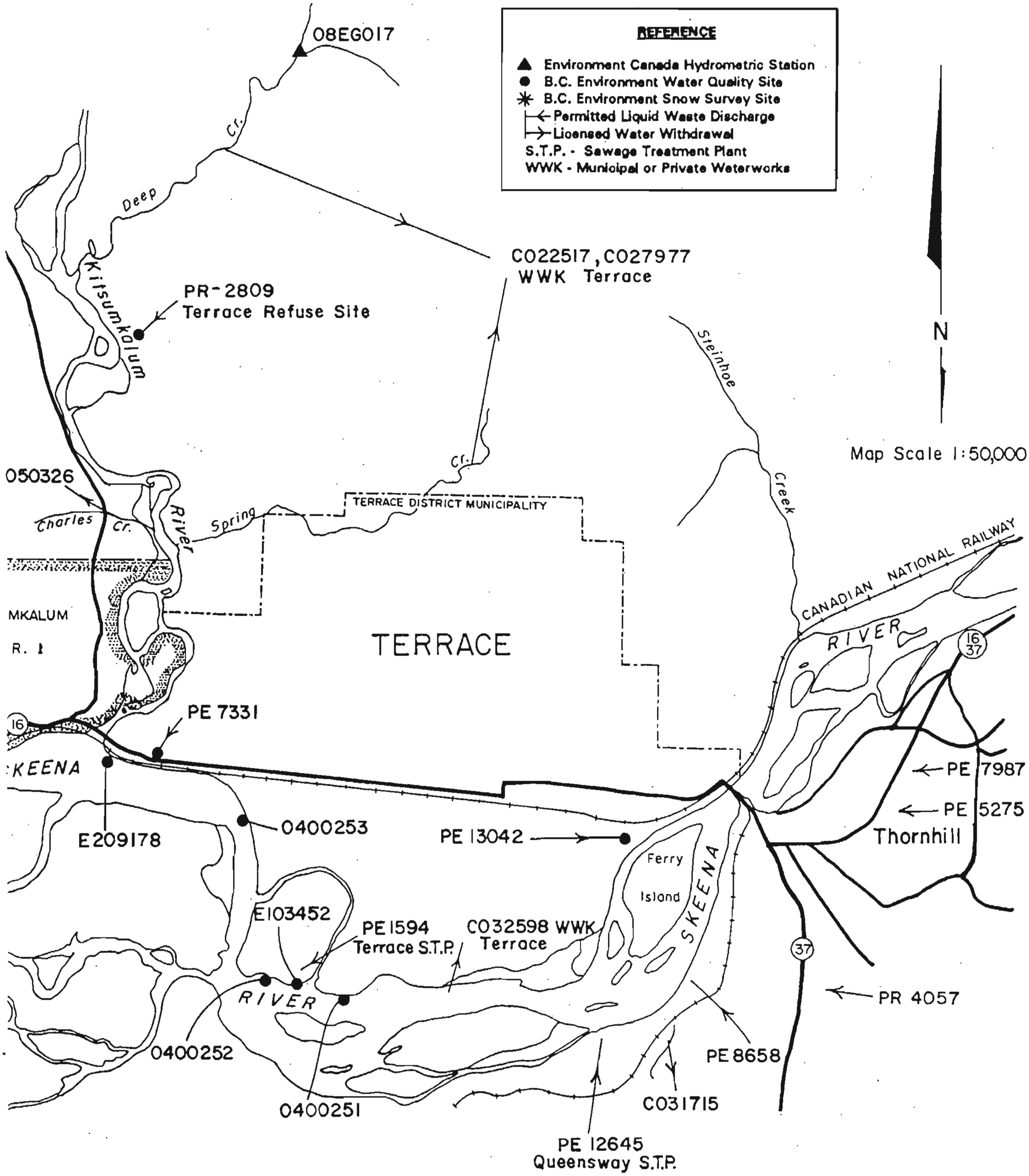


Figure 9.2 Skeena River at Terrace

While these tremendous outwash deposits were being formed in the Kitimat Valley, a deep water fiord was present in the lower Skeena valley. Since the Kitimat valley was plugged with glacial deposits to above sea level, the Skeena River naturally began to drain down the lower Skeena valley into the fiord, essentially filling the fiord with fluvial deposits in the last 10,000 years.

Sport fishing values are high in the rivers of this reach: the Zymoetz is a Class I angling stream above Limonite Creek, and Class II below Limonite. The Kitseguecla, Kitwanga, Kitsumkalum and portions of the Skeena mainstem are Class II angling streams. See section 2.2.4 for explanation of classified waters.

9.1 HYDROLOGY

The Skeena River at Usk, about 18 km north of Terrace, has a drainage area of 42,200 km^2. Monthly mean, maximum and minimum discharge for Station 08EF001, Skeena River at Usk, are presented in Table 9.1 and Figure 9.3. This station has a long period of record and is also a Federal/Provincial water quality and sediment trend monitoring site. The monthly mean, maximum and minimum discharge for Station 08EF005, the Zymoetz River above O.K. Creek, is presented in Table 9.2 and Figure 9.3. Both rivers show a late May/early June discharge peak due to high elevation snowmelt, with a second minor peak in October most years due to fall rains.

A third station 08EG017 is located on Deep Creek, a tributary to the Kitsumkalum north of Terrace. Deep Creek and nearby Spring Creek supply the water utility for the District of Terrace. Environment Canada is undertaking a review of the hydrometric network. The Zymoetz and Deep Creek stations have been placed on a list of stations for which funding is uncertain and which may be subject to discontinuation.

9.2 LAND USE HISTORY

9.2.1 Settlements

In earliest recordings, two Gitksan villages were located on this reach of the Skeena: Gitsegukla at the mouth of the Kitseguecla River, and Gitwangak, at the mouth of the Kitwanga River. Kitwancool (about 20 km upstream at the outlet of Kitwanga Lake) was located on an eulachon oil trade route to the Nass. The Coast Tsimshian had two villages: Kitselas, located on either side of Kitselas Canyon on the Skeena (south of Usk), and Kisumkalum, located at the mouth of the Kitsumkalum River (Sturtevant 1990). The land claims areas of the Gitanyow of Kitwancool extend from the Kitwanga-Cranberry valley north to near Stewart. The estimated 1992 populations of these bands are as follows: Gitsegukla 634, Gitwangak 793, Kitwancool 449, Kitselas 243, and Kisumkalum 407 (Aboriginal Affairs 1992).

Hazelton, located near Gitanmaax at the junction of the Bulkley and Skeena Rivers, was one of the earliest trading centers on the Skeena River. When the Grand Trunk Pacific Railway was constructed, the lower Skeena section of the line was laid on the north side of the river, while the Bulkley portion was located on the south side, with the crossing near Gitsegukla. At this time Hazelton was the only populated center, but since it was located on the opposite side of the river, two new rival townsites were surveyed on the south side, New Hazelton and Sealy (later called

Table 9.1 Monthly discharge summary Skeena River at Usk, Station 08EF001

Latitude: 54 37 50 N
Longitude: 128 25 55 W
Drainage Area Gross: 42 200 km2
Period of Record 1928-1931, 1936-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	399	448	553	1120	3590	4780	3420	1730	1190	2010	1150	792
Monthly Min.	73.9	56.4	60.6	104	860	2020	1010	564	383	342	200	115
Monthly Mean	194	172	160	401	1900	2830	1750	961	745	844	545	292

Average 7-day, 10-year low flow is 78.7 m3/s with 95% confidence limits of 70.3 and 87.8.

Figure 9.3 Discharge envelope Skeena River at Usk, Station 08EF001

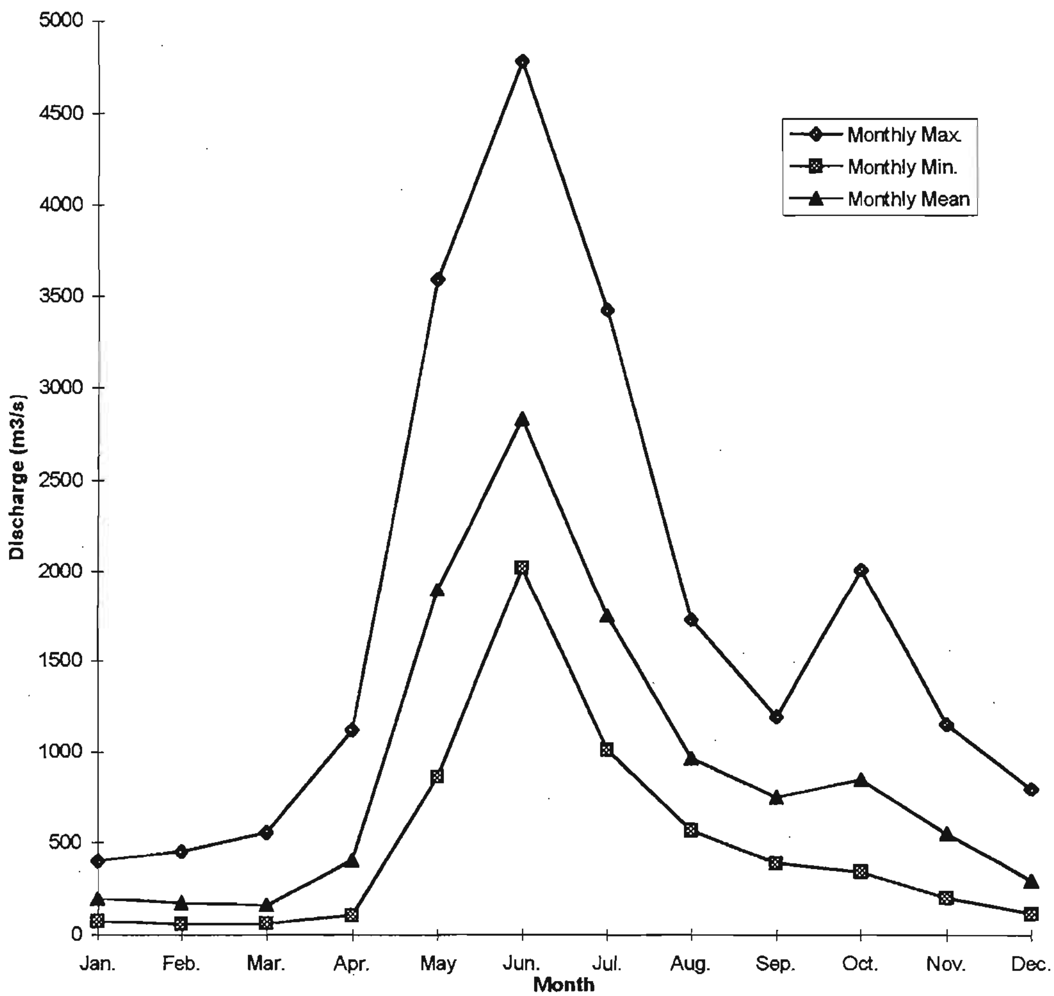


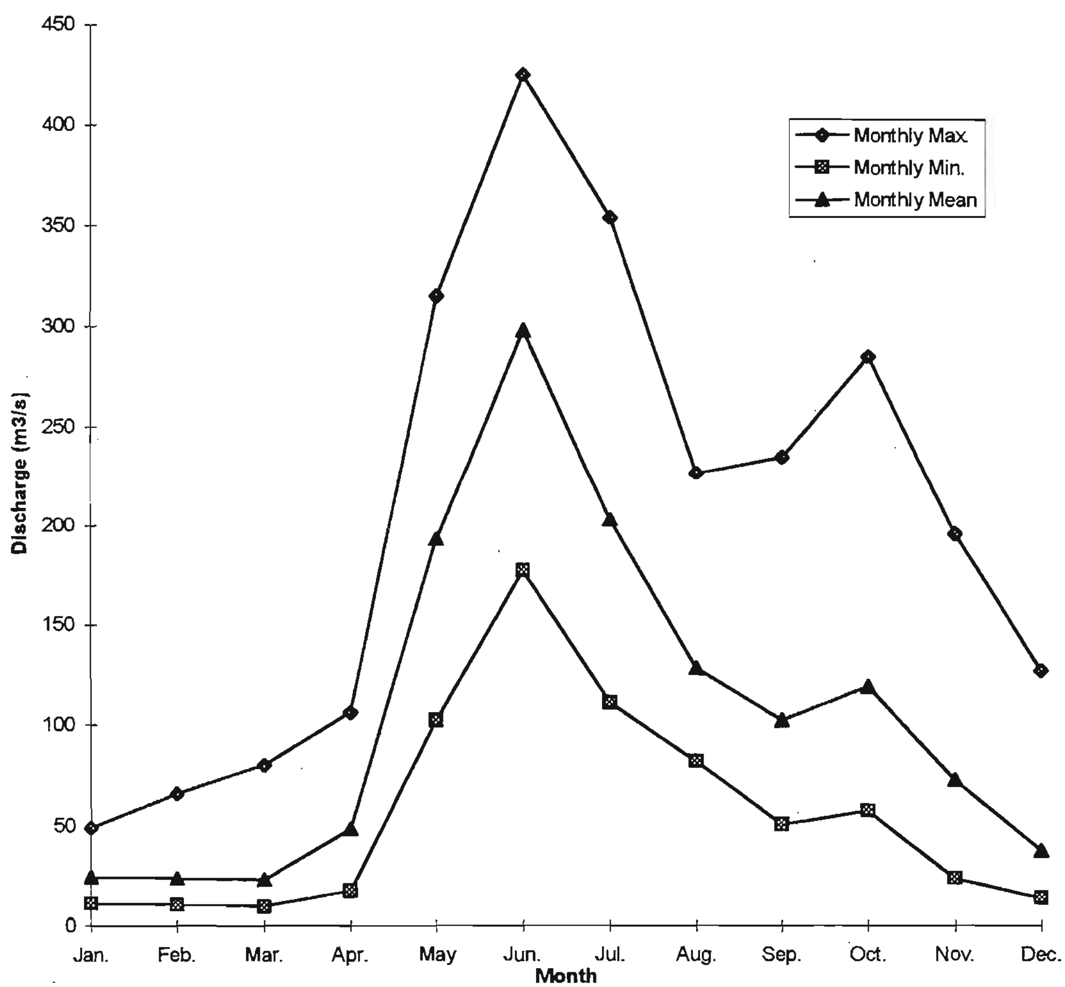
Table 9.2 Monthly discharge summary Zymoetz River above O.K. Creek, Station 08EF005

Latitude: 54 29 00 N
Longitude: 128 19 50 W
Drainage Area Gross: 4980 km2
Period of Record 1963-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	48.7	65.6	79.8	106	315	425	354	227	235	285	196	127
Monthly Min.	11.0	10.4	9.57	17.1	102	177	111	81.6	50.2	56.9	23.3	13.6
Monthly Mean	24.2	23.3	22.8	47.9	193	298	203	128	102	119	72.5	37.2

Average 7-day, 10-year low flow is 9.57 m3/s with 95% confidence limits of 7.98 and 11.2.

Figure 9.4 Discharge envelope Zymoetz River above O.K. Creek, Station 08EF005



South Hazelton). A sawmill located at South Hazelton is the present economic mainstay, although the settlement is the smallest of the three Hazeltons.

The broad, low elevation Kitsumkalum-Kitimat trough was a natural transportation corridor into the Skeena/Nass area and up-river into the interior. A proposed railway from Kitimat never got as far as actual construction, but by 1905 settlers were moving into the Terrace area. The broad valley was suited to agriculture, with alluvial deposits along the river, gravelly glacio-marine deposits on the surrounding terraces and a mild climate. With the coming of the railroad, a townsite was surveyed in 1910 which was eventually named Terrace. Terrace gradually grew with the influx of settlers working in transportation, mineral prospecting and later forestry. During the 1950's, construction of the Alcan Aluminum smelter in Kitimat, construction of the CNR Railine to Kitimat, and a growing lumber industry contributed to the large population increase in the Terrace area. Today the City of Terrace is the largest urban center in the watershed, with an estimated 1994 population of 12,631.

The settlement of Thornhill, located on the south side of the Skeena River opposite Terrace, predated the community of Terrace. However, with the completion of the railway on the north side of the river, growth concentrated around Terrace. The Thornhill area became a concentration of small farms and homesteads which were eventually further subdivided into smaller and smaller holdings as the Terrace/Kitimat populations expanded. In the 1960's the population of Thornhill more than doubled as large subdivisions were established throughout the Thornhill area. These subdivisions had varying levels of services varying from those with community water systems and street lighting, to those which had no services.

9.2.2 Agriculture

Although the climate and river terrace soils are suited to small fruit and vegetable growing, agriculture is no longer a major activity in this reach, although there are hobby farms and some small-scale potato and market garden operations.

9.2.3 Forestry

Most of the ties which went into the initial building of the Grand Trunk Pacific Railway were produced from hemlock stands in the Terrace-Usk area. This was followed by a proliferation of small portable mills, often using water transportation of logs. By the mid-1960's, changing rules of timber utilization, favoring mills that could process waste wood and slabs into chips for the new pulp mills at Kitimat and Prince Rupert, slowly replaced the small operators. While earlier operations concentrated on high-value timber in easily accessible sites, more recent operations have expanded roads and logging activities into much of the forested landbase. Small scale selective and strip logging operations common prior to the mid-1960's have been replaced by primarily clearcut logging.

9.2.3.1 River training of Kitsumkalum River

The Kitsumkalum River was "channelized" to facilitate log driving down the river to Terrace (Canada Department of Fisheries 1964, cited in Sedell and others 1991). Apparently channeling did not stabilized the river bed because as the flow was directed from one place, it scoured others.

During log driving on the river, the logging company continually made requests for further river improvements and, in some instances, had to repair or rebuild previous work. Despite construction to facilitate log driving, stranding of logs remained a major problem. It has been suggested (Miles 1991) that the documentation of the long-term changes in channel morphometry and sediment transport which have occurred as a result of historic river training of the Kitsumkalum River should be a research priority.

9.2.3.2 Zymoetz River suspended sediment research project

Miles (1991) stated that dramatic changes in channel morphometry had occurred in the Zymoetz River due to unknown causes, and recommended the documentation of these long-term changes as a research priority. Presently the MOF Regional Forestry Section, in cooperation with Environment Canada, are conducting a multi-year research study of suspended sediment sources in the Zymoetz River watershed. An automatic sediment sampler has been installed at the Environment Canada hydrometric gauge site on the lower river, and the watershed is being mapped for suspended sediment sources. This study is pertinent to fisheries/forestry interactions, as well as interactions with the existing and proposed natural gas pipeline routes through the watershed.

9.2.3.3 Forestry planning

This reach of the Skeena watershed is divided into a number of forestry tenures:

- The northern half of this reach is in the Kispiox TSA, with timber transported to mills in the Hazeltons.
- The upper Zymoetz watershed is in the Bulkley TSA with timber transported to mills at Smithers via the McDonnell Lake road.
- Most of the southern half of this reach is in the Kalum TSA, with timber transported to mills at Terrace.
- The majority of the Zymoetz River watershed and the western half of the Kitsumkalum watershed are in Tree Farm License (TFL) 1, held by Skeena Cellulose Inc., with a mill in Terrace.

Kispiox TSA.— The main forestry operators in this area are REPAP Carnaby (Skeena Cellulose Inc.), with a large sawmill located at Carnaby south of Hazelton, Isolite Stege Forest Products, located at South Hazelton, and Kitwanga Lumber Co. & Hobenshield Bros. in Kitwanga. A 1986 review of stream protection practices in the Kispiox TSA (Bustard 1986*b*), as well as a review of the recently completed Kispiox TSA Land and Resource Management Plan is found in section 5.2.3. The Kispiox LRMP recognized the Kitseguecla River as containing very productive fish spawning and rearing habitats. Therefore harvesting will be deferred within 150 m either side of the Kitseguecla River until a more detailed management plan delineating appropriate riparian zones is complete.

Bulkley TSA.— A review of stream protection practices in the Bulkley TSA is found in section 4.2.3. The upper Zymoetz was recognized as one of the more valuable steelhead trout and coho salmon areas in the region and observations specific to the upper Zymoetz were detailed (Bustard 1986*b*). A stream clean-up had been required on a tributary of McDonnell Lake. In this situation, stream and lakeside treatments that had been agreed upon in the field were not undertaken by the contractor. Timber was felled into McDonnell Lake and several small fish creeks were logged across and diverted. Problems arose in this situation due to a lack of communication between MOF and the logging contractor. The result was that there had probably been a loss of fish production capabilities due to stream blockage and diversion, bank damage and channel instability due to the presence of small debris.

Road building and lack of road maintenance was identified as the main source of sediment to streams. Measures to minimize erosion from roads in the upper Zymoetz were generally taken after there was a problem, and consisted of measures such as sediment traps. During interviews, foresters identified the requirement of a temporary bridge crossing on the upper Zymoetz River as an example of an unreasonable requirement by the fisheries agencies. Fisheries agencies stated that this was a site specific recommendation made at a sensitive area with erodable banks and deep, fine-textured soils and felt that it was a valid request.

The Bulkley Valley Community Resources Board, formed in 1993, has reached a Consensus Management Direction for a LRMP for the Bulkley TSA, but is conducting additional socio-economic studies prior to release of the plan.

Kalum TSA.— The major forestry operators in this reach are West Fraser's Skeena Sawmills Ltd. and Skeena Cellulose Inc., both with mills in Terrace. A LRMP planning process is underway for the Kalum TSA, which will also encompass TFL 1.

Application and effectiveness of the Coastal Fisheries Forestry Guidelines in the Kalum Forest District.— Tripp and others (1993) conducted an assessment of the effectiveness of the Coastal Fisheries Forestry Guidelines (see section 2.2.7) in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts, as part of a coastwide audit. Results of a survey of 50 cut blocks, in the fall of 1992, showed there was considerable variation between forest districts and logging companies in compliance with either site specific stream prescriptions, or the more general Coastal Fisheries Forestry Guidelines. Hill slope accounted for a large part of the variation - the steeper the slopes, the poorer the compliance and the more frequent the impacts. The steep blocks in the Kalum District (average block slope 35.1%) had 2.20 impacts per 100 ha.

In the Kalum district, 53% (n=17) of the stream reaches inspected had impacts due to logging. The Kalum and North Coast Districts had two and three times the number of impacts recorded per unit area in the QCI District. Both were also considerably high than the average recorded on Vancouver Island. In Class IV streams, the number of major/moderate alterations to the channel was approximately 2.2 times higher in both the Kalum and North Coast Districts than on Vancouver Island.

The amount of fish habitat lost in Class I - III streams ranged from 3.9% (QCI) to 15.7% (North Coast) of the total habitat inspected, most of it in small streams. By comparison, stream areas affected in Class IV streams with moderate to high transport potentials were much larger (88.9% in the Kalum) of the total stream area inspected. Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts (20.2% of the reaches), followed by bank scouring (14.9%) and channel scouring (7.8%).

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO ranged from a low of 57.1% in Kalum to a high of 90.3% in QCI. Compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was generally poor (29.9%). When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams in 214 out of the 217 cases (98.6%).

Fiddler Creek Total Resource Plan.— While the Kalum LRMP is being completed, a Total Resource Plan (MOF 1995) has been developed for the Fiddler Creek and several small watersheds located north of the Skeena River and about half way between Kitwanga and Terrace. This is a lower-level plan which will eventually be incorporated into the Kalum LRMP. A bridge crossing of the Skeena north of Usk was constructed by Skeena Cellulose Inc. a few years ago allowing road access to this side of the river for the first time.

Terrain analysis indicates that areas of high instability and sediment transfer are present in the Fiddler Creek area due to soil structure and properties and evidence of past landslides or erosion. Therefore, the plan calls for riparian zones to be from the stream to the natural break in the land and to include any adjacent unstable terrain. Fiddler and other creeks support steelhead and several salmon species, and the most abundant fish habitat was found to be coho salmon habitat. Fiddler Creek provides water for the community of Dorreen, therefore a watershed assessment program will be implemented.

9.2.4 Mining

Many old mines and exploration sites are found in the Hazelton Mountains. The abandoned Duthie Mine, located in the headwaters of the Zymoetz River is discussed in section 9.5.2.

Major exploration properties, at which diamond drilling is occurring, are at the following locations:

- Tatsi Property (Golden Hemlock) is a gold-copper showing on Tatsi Creek, tributary to the Zymoetz River, located at about 2000 m elevation in the Howson Ranges.
- Limonite Creek Property (Limonite Creek Limited Partnership) is a copper-gold-silver prospect also at high elevation in the Telkwa Pass area of the Zymoetz watershed.
- Morningstar Property is a gold-molybdenum property located near the Skeena River at Woodcock.

9.3 WATER WITHDRAWALS

A summary of licensed water withdrawals from streams and rivers in this reach is found in Table 9.3. The major water consumption is concentrated in and around Terrace, for municipal and industrial purposes. The District of Terrace holds licenses on Deep and Spring Creeks for a total of 0.289 m^3/s. Woodlands Utilities distributes water from Caruso, Cary and Carver Springs to subdivisions in Thornhill. Other community waterworks systems are located on Chicago Creek (South Hazelton), Kits Creek (Gitsegukla), Ten Link Creek, tributary to the Kitwanga River (Kitwancool), Eneeksagilaguaw Creek (Kitsumkalum).

Table 9.3 Licensed water withdrawals Skeena River to Kitsumkalum River confluence

Input streams - Kitsumkalum River							
Domestic/stock watering			Waterworks				
GD	m3/d	m3/s	License	Licensee	GY	m3/d	m3/s
(25 licences)				District of Terrace			
16000	72.7	8.42E-04	C022517	(Deep Cr./Spring Cr.)	182500000		
			C027977	(Deep Cr./Spring Cr.)	1825000000		
Irrigation*				total	2007500000	25003.0	2.89E-01
AF	m3/d	m3/s	Industry		GD	m3/d	m3/s
(10 licences)				Skeena Cellulose			
169.5	3484.6	4.03E-02	C050326	(Charles Cr.)	2500	11.4	1.32E-04
Input streams - other							
Domestic/stock watering			Waterworks				
GD	m3/d	m3/s	License	Licensee	GY	m3/d	m3/s
(125 licences)				S. Hazelton Wwks. Dist.			
80500	366.0	4.24E-03	C027503	(Chicago Cr.)	14600000	181.8	2.10E-03
			C050320	(Chicago Cr.)	365000000	4546.0	5.26E-02
Irrigation*				Woodlands Utilities			
AF	m3/d	m3/s	C062377	(Caruso Spring)	1825000	22.7	2.63E-04
(15 licences)			C050733	(Cary Spring)	19710000	245.5	2.84E-03
280.4	5763.4	6.67E-02	C062378	(Carver Spring)	9307500	115.9	1.34E-03
					GD	m3/d	m3/s
			C046694	Kitwankool Indian Band (Ten Link Cr.)	50000	227.3	2.63E-03
			C031715	Timberland Trailer Park (Virginia Brook)	15000	68.2	7.89E-04
			C041644	Kitsumkalum Indian Band (Eneeksagilaguaw Cr.)	25000	113.7	1.32E-03
			Industrial proc. (sand & gravel)		GD	m3/d	m3/s
			C101203	Terrace Wade Contracting Co. (Greeley Cr./Turnbull Cr.)	540000	2454.8	2.84E-02
			C072701	Eichhorst, G. (Hurley Spring)	10000	45.5	5.26E-04
Skeena River			Waterworks				
			License	Licensee	GY	m3/d	m3/s
			C032598	District of Terrace	547500000	6819.0	7.89E-02
			Industrial proc. (sand & gravel)		GD	m3/d	m3/s
			C032765	Min. of Trans. and Highways	8250	37.5	4.34E-04

* Irrigation licences have been converted from acre-feet to m3/s by assuming 2 months of operation, 12 hours/day in the summer.

9.4 WATER QUALITY AND AQUATIC RESEARCH

9.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Summary water quality data, collected at the Skeena River at Usk during 1966-1990, are presented in Table 9.4.

Table 9.4 Water quality summary Skeena River at Usk, Site 0920092, 1966-1990

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	176	169	5	90	19.6	19.7	10
pH	229	229	6.4	8.1	7.44	0.43	7.6
Conductance (umhos/cm)	248	248	58	174	95.0	23.5	90
Total Residue (mg/L)	17	17	58	377	100.3	73.0	81
Filterable Residue (mg/L)	24	21	36	86	64.6	15.0	63
Non-filterable Residue (mg/L)	149	137	1	1840	72.7	221.3	13
Turbidity (NTU)	193	193	0.3	210.0	16.21	28.83	5.6
Alkalinity (mg/L)	86	86	24.1	86.1	39.30	11.02	37.3
Hardness Total (mg/L)	8	8	33.8	51.5	41.50	6.82	40.2
Hardness Dissolved (mg/L)	176	176	27.9	94.8	44.89	11.79	43.1
Total N (mg/L)	19	19	0.08	0.44	0.191	0.097	0.16
T.K.N. (mg/L)	16	16	0.05	0.40	0.122	0.085	0.10
Ammonia (mg N/L)	81	29	0.002	0.100	0.0190	0.0290	<0.005
NO2 + NO3 (mg N/L)	78	69	0.01	0.02	0.070	0.047	0.06
Total Carbon (mg/L)	34	34	2	9	5.8	1.8	6
Organic Carbon (mg/L)	27	25	1	12	3.1	2.4	2
Inorganic Carbon (mg/L)	27	27	5	20	9.8	3.3	10
Chloride (mg/L)	188	179	0.1	1.8	0.54	0.35	0.5
Ortho P (mg/L)	25	4	0.003	0.020	0.0108	0.0074	<0.003
Silica (mg/L)	179	179	2.4	6.8	4.48	0.85	4.5
Sulfate (mg/L)	186	186	2.4	16.9	7.23	1.88	7.3
Fluoride (mg/L)	108	35	0.02	0.05	0.046	0.010	0.05

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	88	85	0.01	18.80	1.437	2.764	0.55
As	82	54	0.0001	0.0130	0.0011	0.0020	
Ca	60	60	9.70	40.30	14.687	4.885	13.60
Cd	187	37	0.0001	0.020	0.0007	0.0033	
Co	65	4	0.11	0.18	0.150	0.036	<0.1
Cr	96	42	0.0002	0.060	0.0075	0.0104	
Cu	194	132	0.001	0.012	0.0107	0.0176	
Fe	176	176	0.02	72.20	2.102	6.888	0.60
Mg	63	63	1.30	16.80	2.710	1.886	2.33
Mn	193	150	0.01	2.10	0.080	0.237	0.02
Mo	65	15	0.0003	0.07	0.014	0.017	<0.01
Ni	89	27	0.0005	0.13	0.012	0.032	
P	145	141	0.005	0.878	0.0550	0.1004	0.020
Pb	196	81	0.001	0.300	0.0060	0.0333	
V	60	8	0.01	0.12	0.039	0.045	<0.01
Zn	192	140	0.001	0.230	0.0174	0.0298	

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 9.4 (continued) Water quality summary Skeena River at Usk, Site 0920092, 1966-1990

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	16	10	0.01	0.16	0.058	0.042	0.03
As	24	1	0.001	0.001	0.0010		<0.001
B	10	0					<0.01
Ba	10	9	0.01	0.02	0.018	0.004	0.02
Ca	185	185	1.60	29.60	14.323	3.910	13.60
Cd	21	0					<0.0005
Co	10	1	0.13	0.13	0.130		<0.1
Cr	11	0					<0.01
Cu	29	4	0.002	0.004	0.0028	0.0010	
Fe	35	27	0.01	0.12	0.049	0.028	0.03
K	121	121	0.10	1.00	0.358	0.163	0.30
Mg	118	118	1.27	3.90	2.211	0.605	2.13
Mn	13	0					<0.01
Mo	10	0					<0.01
Na	187	187	1.00	3.40	1.879	0.642	1.70
Ni	11	1	0.002	0.002	0.002		<0.002
P	68	44	0.003	0.012	0.0055	0.0019	0.004
Pb	28	0					<0.001
V	10	0					<0.01
Zn	30	6	0.002	0.020	0.0075	0.0067	

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

The most noticeable change in water quality at this station is the much higher TSS concentrations than seen at upstream sites (mean TSS=73 mg/L with a range of 1 to 1840 mg/L). The Skeena cuts through the rugged Hazelton Ranges downstream of Kitwanga, and many steep drainages which receive fairly high precipitation feed into this reach, resulting in higher suspended sediment loading. Colouration is similar to many of the upstream sites (mean=20 TCU). The waters are soft, with mean hardness of 41.5 mg/L (range 33.8 - 51.5 mg/L). The mean pH of 7.4 is neutral to slightly alkaline. Alkalinity, a measure of pH buffering capacity of a waterbody is low to moderate (mean=39.3 mg $CaCO_3$/L). Conductivity and dissolved solids (filterable residue) are low, due to the high precipitation and rapid runoff, and are a reflection of good water quality.

Nutrient concentrations are generally low. The mean total phosphorus concentration (0.055 mg/L) may look elevated relative to other tributaries, but is likely a reflection of the high TSS concentrations experienced at this site. Orthophosphate concentrations, which are a measure of dissolved biologically available phosphorus, are almost always less than the detection limit. The total range of metals concentrations appear relatively high, and total metals concentrations often exceed MOELP criteria for the protection of aquatic life at hardness levels present. See the next section for discussion on the relationship of total phosphorus and total metals to suspended sediments and discharge. Dissolved metals concentrations are generally less than or equal to their respective detection limits.

9.4.2 Seasonal and long-term variations in water quality of British Columbia Rivers: Skeena River at Usk, B.C. 1984-1992

The Skeena River at Usk is a water quality monitoring station operated cooperatively by the governments of Canada and British Columbia. The station is also a part of the G.E.M.S. (Global Environment Monitoring System) and is operated cooperatively to share data around the world on ocean loadings. Bhangu and Whitfield (1994) analyzed the biweekly data collected at Usk from 1984 to 1992 to examine seasonal and long-term variation in water quality. The minimum and maximum concentrations of the 21 parameters which were analyzed regularly over this period are presented in Table 9.5. Concentration in most water quality variables measured were flow driven, either increasing in concentration with increasing discharge, or decreasing in concentration with increasing discharge. Hysteresis diagrams were used to display the relationship between concentration and discharge.

Peaks in the major ion concentrations (calcium, sodium, potassium, dissolved chloride, magnesium) had a negative relationship between concentration and discharge. Total alkalinity, specific conductance, and hardness, which are related to ion concentration, also exhibited a negative relationship to discharge, as did pH. Snowmelt and surface runoff dilute ground water during freshet and as a result ion concentration decreases.

The nutrients, nitrate/nitrite and total dissolved nitrogen, exhibited seasonal variability with no relationship to discharge. Presumably biological processes are affecting these concentrations.

Total phosphorus along with total iron, total zinc, total lead, turbidity, and apparent color exhibited a positive relationship to discharge. A complex relationship to discharge was sometimes demonstrated related to a primary discharge peak occurring in early summer with freshet and a secondary peak occurring in October due to fall rains. These variables exhibit a positive relationship to discharge due to increased sediment transportation resulting from increased surface runoff.

Plots of the water quality variables against time indicated that no significant trends in water quality occurred during the 1984 to 1992 study period.

Table 9.5 Minimum and maximum values of selected water quality variables, Skeena River at Usk Station 08EF0001, 1984-1992

Variables	Minimum	Maximum	Units	Variables	Minimum	Maximum	Units
PHYSICAL				*NUTRIENTS*			
Discharge	71	5310	m^3/s	Nitrate+Nitrite	0.002	0.4	mg/L
Turbidity	0.1	210	FTU	Total Diss. Nitrogen	0.03	1.7	mg/L
Spec. Conductance	53	231	uS/cm	Total Phosphorus	0.001	0.9	mg/L
pH	6.4	8.1	pH units	*TRACE ELEMENTS*			
Apparent Colour	5.0	90.0	relative	Total Iron	0.06	51.1	mg/L
Air Temperature	-18.0	30.0	°C	Total Lead	0.0002	0.01	mg/L
Water temperature	0.0	26.0	°C	Total Zinc	0.0002	0.2	mg/L
MAJOR IONS							
Total Alkalinity	21.5	59.2	mg/L				
Calcium	7.5	25.3	mg/L				
Potassium	0.1	1.0	mg/L				
Sodium	1.0	13.6	mg/L				
Dissolved Chloride	0.2	27.5	mg/L				
Hardness	23.6	79.0	mg/L				
Dissolved Sulphate	1.2	11.4	mg/L				
Magnesium	1.2	3.9	mg/L				

Source: Bhangu and Whitfield 1994

9.4.3 Productivity of Skeena watershed sockeye nursery lakes - 1994

Monthly limnological surveys were carried out by DFO on Kitsumkalum Lake during May-October 1994 as part of a survey of selected Skeena sockeye nursery lakes. Further description of the project and productivity comparison with four other lakes is found in section 1.3.5.2. Preliminary water quality data from this project are found in Table 9.6.

Kitsumkalum Lake is a cool lake (maximum August temperature 13 C) which is very turbid (average Secchi depth less than 1 m). It has low dissolved solids and very low alkalinity. It has very low primary productivity (photosynthetic rate is about 25 percent that of Babine Lake). The total phosphorus concentrations for Kitsumkalum Lake are noticeably high. This is because of the lake's high turbidity and should not be interpreted as an indication of eutrophication. Primarily because of its high turbidity and its fast flushing rate, Kitsumkalum Lake is considered highly oligotrophic (K. Shortreed, personal communication).

Table 9.6 Kitsumkalum Lake productivity May-October 1994 (mean epilimnetic concentrations)

Date	Temp °C	pH	Secchi depth m	Euphotic zone depth m	TDS mg/L	Total alkalinity mg CaCO3/L	Total P ug P/L	Nitrate ug N/L	Total Chlorophyll ug/L	Photosyn-thetic rate mg C/m2/d
19-May-94	7.7	7.21	0.9	3.1	31	18.64	16.1	78.7	0.16	7.2
15-Jun-94	9.4	7.23	1.1	4.7	41	17.92	9.3	56.1	0.44	21.2
13-Jul-94	12.1	7.20	1.4	5.2	24	15.48	7.6	28.0	0.69	44.9
17-Aug-94	13.0	7.31	0.5	2.8	27	12.43	16.3	11.0	1.10	34.8
8-Sep-94	11.5	6.82	0.8	3.4	21	12.66	15.8	21.7	0.61	113.2
1-Oct-94	9.2	7.01	0.3	1.8	24	13.98	29.1	37.5	0.43	10.6

9.5 LIQUID WASTE DISCHARGES

9.5.1 Gitsegukla Indian Band PE-7463

9.5.1.1 Background

Gitsegukla Indian Reserve is located approximately 25 km west of New Hazelton on Highway 16. Prior to 1986 the village utilized individual septic tanks and disposal fields, most of which had a history of failing. In 1986 a community sewerage system was built and a rotating biological contactor (RBC) was installed to treat the waste. The outfall terminates 0.7 m below the surface of the Skeena River and is at least 6 m from the beach.

9.5.1.2 Permitted discharge

Permit PE-7463 authorizes a maximum rate of discharge of 300 m^3/day and requires the characteristics of the effluent to be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The works authorized are a 2-chambered septic tank, an equalization tank, a rotating biological contactor, a final clarifier, outfall and related appurtenances.

Sampling of the effluent is required quarterly for BOD and TSS. Flow measurements are required as well. Permittee monitoring data submitted in 1992 (Table 9.7) indicate excellent compliance with permitted BOD and TSS limits. An EPP site inspection in November 1993 stated that no monitoring data had been submitted since 1992 and that flow monitoring devices were being adjusted.

Table 9.7 Effluent quality Gitsegukla RBC treatment plant discharge PE-7463, 1988-1992 (permittee monitoring)

	23-Jun-88	11-Aug-88	27-Sep-88	14-Feb-89	31-May-89	2-Aug-89	5-Sep-89	21-Sep-89
pH	7.0	7.3	7.1	6.8				
BOD5 mg/L	10	42	10	20	10	9	15	18
TSS mg/L	3	5	1	5	7	4	3	9
	13-Mar-90	**17-Sep-90**	**9-Jul-91**	**26-Sep-91**	**12-Nov-91**	**1-Apr-92**	**13-Jul-92**	**20-Oct-92**
pH mg/L	6.8	7.1					7.1	7.1
BOD5 mg/L	10	16	10	11	15	18	10	11
TSS	16	7	8	16	26	18	7	6

Data collected by EPP in November, 1993, May 1994 and August 1994 are presented in Table 9.8. EPP assessed toxicity of the Gitsegukla effluent sampled May 20, 1993 using three different bioassay methods: Rainbow trout (RBT) 96 hr LC50, Daphnia 48 hr LC50, and 5 and 15 minute Microtox EC50. The effluent was non-toxic to all three organisms. There is no receiving environment monitoring required for this permit.

Table 9.8 Effluent quality Gitsegukla RBC treatment plant discharge PE-7463, Nov 23, 1993, May 30 and Aug 24, 1994 (EPP monitoring)

		23-Nov-93	31-May-94	24-Aug-94
pH	pH units	6.7	6.79	7.4
TSS	mg/L	8	6	8
BOD	mg/L	12	26	12
Nitrogen - Ammonia (N)	mg/L	0.811	0.086	0.063
Nitrogen NO3+NO2	mg/L	20.8	17.9	12.3
NO3 (N)	mg/L	20.4	17.6	12.2
NO2 (N)	mg/L	0.437	0.339	0.123
Phosphorus Total	mg/L	4.28		3.37
Phosphorus Ortho-P	mg/L	3.91	3.63	2.79
Fecal Coliform	CFU	13 300		

9.5.1.3 Discussion

Analysis of effluent samples taken by the permittee and EPP indicates not only compliance with permitted BOD and TSS limits, but very low ammonia and nitrite concentrations. The low ammonia and nitrite concentrations (indicating the RBC system is performing complete biological digestion of the wastes) probably explains the non-toxic nature of the effluent. Comparison of the maximum permitted discharge rate of 300 m^3/day with the 7 day average 10 year low flow for the Skeena River at Usk (78.7 m^3/s) gives an dilution ratio of >16,000:1. Given the high degree of treatment and high dilution ratio, this discharge is considered a low risk to aquatic resources. A suggested addition to the monitoring program is RBT 96 hr LC50 bioassay at once per year during the late winter low flow period.

9.5.2 Silver Standard Resources Inc. PR-6681 (Duthie Mine)

9.5.2.1 Background

Silver Standard Resources presently own the mineral rights to the Duthie Mine located on the McDonnell Lake Forestry Road 12 km west of Smithers. The mine is 1 km north of Aldrich Lake which forms part of the headwaters of the Zymoetz River.

The Duthie Mine operated intermittently from 1923 to the mid 1980's. Over much of this time period hand picked direct shipping ore was mined. Of an estimated 72,600 tonnes mined, about 53,915 tonnes were milled: 29,990 tonnes by Duthie Mines Ltd. from 1927 to 1930, 24,200 tonnes by Sil-Van Consolidated Mining and Milling Co. Ltd. from 1953 to 1954 and an estimated maximum of 726 tonnes by P. Kindrat in the early 1980's. Concentrate shipments totaled 6,481 tonnes, indicating 47,434 tonnes were discharged as tailings.

Tailings during the Sil-Van operation flowed by gravity, in a wooden flume, to a swampy area 100 m in elevation below the mill where they were impounded in settling ponds. The tailings are presently contained behind a berm which was constructed in 1987. There are sufficient tailings within the bermed area to indicate that the 1927 to 1930 tails were deposited at the same site.

In 1981 a request to place dry tailings on top of the old tailings was made by Mr. Kindrat. As part of the permitting process a site visit was made by the Waste Management Branch and

Environment Canada and it was noted that seepage from the tailing containment area was acidic and showed elevated metal concentrations

Field investigations were carried out at the minesite and receiving environment sites in the Aldrich Lake watershed in 1982-1983 (Maclean 1983). The dyking around the old tailings was failing causing contaminated runoff to Henderson Creek, subsequently to Glacial Creek and then into Aldrich Lake. Aldrich Lake drains into Dennis Lake which drains into McDonnell Lake via the upper Zymoetz River. It had been speculated but unconfirmed that sockeye and coho salmon runs to Aldrich Lake had been eliminated by habitat degradation of previous mining operations. (A fisheries inspector in the early 1950's reported siltation from the mine occurring in Henderson Creek and Aldrich Lake coupled with reports of fish kills.)

As the majority of the estimated 80,000 tonnes of ore processed since 1950 came from an arsenopyrite ore deposit, tailings were found to have a high concentration of arsenic, iron, aluminum and lead. Analysis of tailings leachate showed metal concentrations in excess of the regulatory criteria at point of discharge for As, Zn (up to 29 times the regulation) and pH.

Elevated metals levels were found in Glacial Creek in exceedance of water quality criteria for Cd, Cu, Pb and Zn. In Aldrich Lake water quality objectives were exceeded for As, Cd, Cu, Pb and Zn, with the highest total metals levels at the Glacial Creek inlet. Arsenic concentrations in the lake were found to exceed maximum allowable drinking water standards of 0.05 mg/L on one occasion. All bottom sediments in the lake appeared to have elevated metals, with decreasing concentrations with distance from the Glacial Creek inlet. There was no corresponding evidence of metal contamination in fishes collected from Aldrich Lake on 14 July 1983. This finding was contrary to expectations since chronic sublethal effects would be predicted to occur given existing concentrations of Cu and Zn.

Subsequent covering of the tailings and diversion of leachate were carried out. Sampling was carried out in 1993 by Silver Standard Resources (Bruce Geotechnical 1994). The results are summarized as follows:

- The results of the tailings analysis suggest that the area within the tailings disposal area, combined with the acidic environment, are, or have the potential to be, acid generating. Concentrations of arsenic, copper, lead and zinc in the tailings are high and represent a potential for significant contamination of groundwater.
- All groundwater samples contained concentrations of arsenic, copper, lead and zinc in excess of the Canadian Water Quality Guidelines. Groundwater from the area of the fresh tailings appeared to contain the highest concentrations of metals.
- Seepage from the site was generally highly acidic with metals at concentrations that are in excess of the regulatory criteria at the point of discharge.

A plan was submitted for remediation of the site and mitigation of the ARD (Silver Standard Resources 1994). After some adjustments to the monitoring program the plan was accepted by the NWMDRC in November of 1994.

The detailed monitoring program was outlined with the final modifications detailed in a letter dated September 2, 1994 found in Permit file PR-6681. The monitoring program is meant to address the deficiencies in knowledge about the tailings and their environs so that a final remediation plan may be recommended. Areas to be studied are ground water, surface water, surface gravels, glacial till and tailings.

9.5.3 City of Terrace PE-1594

9.5.3.1 Background

The City of Terrace sewage treatment plant discharges treated sewage to the Skeena River. Up until 1988 the City of Terrace was treating their sewage only to the primary level using macerators, screens and a pump station. The permit had a long history of non-compliance with monitoring results often exceeding the permitted levels of 130/130 mg/L BOD/TSS. Samples of the effluent taken in 1984 by the Waste Management Branch showed not only high fecal coliforms but toxicity to fish as well. The City of Terrace was given until July 31, 1988 to upgrade their works to secondary treatment. In addition to the existing headworks two aerated lagoons were constructed and in operation by 1988. At the time of these improvements the population of Terrace was about 12,000 and was expected to grow to about 21,000 over the 20 year design life of the treatment plant.

9.5.3.2 Permitted discharge

Permit PE-1594 allows a maximum discharge rate of 12,210 m^3/day. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The permittee is required to obtain a grab sample of the effluent once each month and have it analyzed for TSS, BOD and fecal coliforms. The effluent volume discharged over a 24 hour period must also be recorded once per month. Since the upgrade, results have been consistently in compliance with the permit.

9.5.3.3 Receiving environment monitoring

Receiving environment monitoring is also required by permit PE-1594. The following sites are specified in the permit (Figure 9.2):

- Site 1: 300 m upstream from outfall, right bank of the Skeena River, in 0.5 m of water, SEAM site 0400251;
- Site 2: Effluent being discharged, SEAM site E103452;
- Site 3: 300 m downstream from the outfall, right bank of the Skeena River in 0.5 m of water, SEAM site 0400252;
- Site 4: Approximately 2 km downstream from the outfall, right bank of the Skeena River, in 0.5 m of water, SEAM site 0400253;
- Site 5: Just upstream from Fisherman's Park in the Skeena River, SEAM site E209178.

Data from the 1994 monitoring program are summarized in Table 9.9.

Table 9.9 City of Terrace Receiving Environment Monitoring, 1994

Site #1 (0400251) Skeena R. U/S

Date	Temp (oC)	pH	Total P (mg/l)	NH3 (mg/l)	TSS (mg/l)		Fecal Coliforms (mpn/100ml)
9/1/94	14.0	6.90	0.040	0.090	10	<	27
9/8/94	12.0	6.55	0.060	0.070	10	<	68
9/15/94	11.0	6.70	0.070	0.100	30		30
9/22/94	11.0	6.60	0.110	0.120	10	<	10
9/27/94	9.5	6.25	0.100	0.140	10	<	6
mean	11.5	6.60	0.076	0.104	14.		28.
STD	1.7	0.24	0.029	0.027	9.		25.

Site 2 (E103452) Effluent

Date	Temp (oC)	pH	Total P (mg/l)	NH3 (mg/l)	TSS (mg/l)	Fecal Coliforms (mpn/100ml)	Max Conc'n NH3 (WQC)
9/1/94	20.5	7.05	3.850	21.000	29	24000	18.55
9/8/94	17.0	7.05	3.980	19.000	30	89000	18.85
9/15/94	16.5	7.00	3.850	20.000	20	5900	20.75
9/22/94	17.0	6.90	4.050	19.300	30	7800	20.7
9/27/94	16.5	6.75	3.950	18.600	40	20000	22.35
mean	17.5	6.95	3.936	19.580	30.	29340.	20.
STD	1.7	0.13	0.086	0.944	7.	34236.	2.

Using the Temp and pH for each sample day, the ammonia concentration is just below the maximum for protection of freshwater aquatic life (max approx. 20.0 mg/l)

Site #3 (0400252) Skeena R. 300 M D/S

Date	Temp (oC)	pH	Total P (mg/l)	NH3 (mg/l)	TSS (mg/l)		Fecal Coliforms (mpn/100ml)
9/1/94	14.0	6.95	0.070	0.070	10	<	19
9/8/94	12.0	6.70	0.050	0.100	10	<	85
9/15/94	11.0	6.80	0.110	0.200	30		40
9/22/94	11.0	6.80	0.120	0.140	10	<	71
9/27/94	9.5	6.45	0.120	0.200	10	<	15
mean	11.5	6.74	0.094	0.142	14.		46.
STD	1.7	0.19	0.032	0.058	9.		31.

The average 30 day concentration for total ammonia nitrogen (mg/l N) for protection of freshwater aquatic organisms is approx. 1.82 mg/l

Table 9.9 (continued) City of Terrace Receiving Environment Monitoring, 1994

Site #4 (0400253) Skeena R. 2.5 Km D/S

Date	Temp (oC)	pH	Total P (mg/l)	NH3 (mg/l)	TSS (mg/l)		Fecal Coliforms (mpn/100ml)
9/1/94	14.0	6.85	0.050	0.080	10	<	17
9/8/94	12.0	6.70	0.060	0.070	10	<	79
9/15/94	11.0	6.80	0.060	0.100	40		50
9/22/94	11.0	6.75	0.090	0.160	10	<	15
9/27/94	9.5	6.70	0.120	0.090	10	<	8
mean	11.5	6.76	0.076	0.100	16.		34.
STD	1.7	0.07	0.029	0.035	13.		30.

Site #5 (E209178) Skeena R. U/S Fisherman's Park

Date	Temp (oC)	pH	Total P (mg/l)	NH3 (mg/l)	TSS (mg/l)		Fecal Coliforms (mpn/100ml)
9/1/94	14.0	6.85	0.050	0.080	10	<	18
9/8/94	12.0	6.80	0.060	0.080	10	<	76
9/15/94	11.0	6.70	0.070	0.090	30		30
9/22/94	11.0	6.85	0.090	0.120	10	<	6
9/27/94	9.5	6.70	0.110	0.110	10	<	148
mean	11.5	6.78	0.076	0.096	14.		56.
STD	1.7	0.08	0.024	0.018	9.		58.

9.5.3.4 Discussion

There is no evidence from this limited dataset that the STP effluent would significantly impact aquatic life in the Skeena River, except for within the initial dilution zone. The undiluted effluent has ammonia concentrations almost equal to the water quality criterion for the protection of freshwater aquatic life at the ambient temperature and pH (maximum allowable concentration approximately 20.0 mg/L). Effluents with ammonia concentrations greater than 10 or 12 mg/L have been shown to often produce toxic results in the rainbow trout 96 hr LC50 bioassay. Data from Site #3 indicate good mixing by 300 m downstream of the discharge, with ammonia concentrations an order of magnitude below the 30 day average criterion intended to protect aquatic organisms from chronic toxicity. The data for sites 2.5 km downstream and just upstream of the Kitsumkalum River confluence indicate a return to near background water quality.

A comparison of maximum permitted discharge rate of 12,210 m^3/d with the 7 day average 10 year low flow for the Skeena at Usk of 78.7 m^3/s (Table 9.1) indicates a dilution ratio of 400:1. At this site the annual low flow period occurs during late winter, which is also the timeperiod that increased ammonia concentrations in effluent might be expected, due to poor nitrification at low wastewater temperatures. In addition to ammonia, other nitrogen species may contribute to toxicity, as well as metals and other unregulated discharges to the municipal collection system.

More comprehensive monitoring data is needed in order to assess the possibility of toxicity within the mixing zone for the Terrace STP. Suggested additional parameters to the receiving environment monitoring program are: total nitrogen, nitrate-N, nitrite-N, total phosphorus, orthophosphate, fecal streptococci and RBT 96 hr LC50 bioassay. In addition to better characterization of the effluent at all times of the year, data which would help in the assessment of this discharge is the areal extent and fisheries values associated with the mixing zone. See section 12.5 for further discussion on monitoring of municipal sewage discharges.

9.5.4 City of Terrace PR-2809

9.5.4.1 Background

The City of Terrace landfill, located 5 km northwest of Terrace, serves a population of about 12,000. The landfill is located on gravel terrace deposits along the east side of the Kitsumkalum River valley. The landfill area itself is relatively flat but there is a very steep bank along the west side of the landfill which slopes down to the floodplain. A drainage channel or intermittent creek runs through the landfill site, draining to the Kitsumkalum River.

9.5.4.2 Permitted discharge

Permit PR-2809 allows for a maximum discharge rate of 16 tonnes per day. This is a trench fill operation and requires daily cover with local sandy soils.

9.5.4.3 Receiving environment monitoring

An initial leachate investigation was conducted at this site in 1992 (Gartner Lee 1993). The two most likely pathways for leachate movement to the Kitsumkalum are via the intermittent drainage channel which dissects the landfill and ground water flow in the sand and gravel aquifer. The landfilled area comprises about 14.7 ha. Water budget information indicates there is a surplus of about 628 mm/yr. An annual leachate production rate of 64,700 m^3/yr was calculated by assuming that 70% of the water surplus infiltrates into the waste and the remaining 30% runs off the surface cover.

Water samples collected in August, 1992 from a stagnant pond in the intermittent drainage channel between the two landfill areas and from a shallow hand dug pit downgradient of the landfill area indicated elevated concentrations for leachate parameters such as specific conductance, chloride and ammonia.

The estimated average annual leachate flow is 0.002 m^3/s compared to average flows in the Kitsumkalum River of 123 m^3/s, which results in an estimated dilution ratio of 61,500:1. The potential receptors of leachate from the Terrace landfill are the Kitsumkalum River water quality, and wildlife using the intermittent drainage channel which dissects the landfill. If the residences along Kalum Lake Road have water supply wells which are pumped very heavily and develop large drawdown cones then there is a possibility that leachate could be drawn eastward; however, this was thought unlikely.

Recommendations from the Lee Gartner report are as follows:

- If the landfill is closed soon, a properly graded, clay, final cover and diversion ditches should be installed to reduce infiltration into the wastes and resultant leachate production. Bottom lands and river shoreline should be inspected for leachate springs.
- If the landfill is to remain in operation by area filling above grade, then ground water and surface water monitoring is recommended. Four groundwater monitoring well sites were recommended; one upslope (east of the landfill), one downslope (west) of the active fill area, one downslope of the woodwaste and compost area, and one downslope of the old landfill area. Samples should be collected four times per year and analyzed for conductivity, chloride, hardness, ammonia and iron, at a minimum.

9.5.4.4 Discussion

It is unlikely that negative water quality impacts would occur at this dilution, however if there is entrainment of leachate into subsurface gravel channels, water quality degradation could occur in localized Kitsumkalum River gravel sediments.

Recommended additions to the hydrogeological monitoring suggested in the Lee Gartner report are as follows:

- Should any of the groundwater monitoring or residential wells prove to have elevated concentrations of leachate parameters, a toxicity test should be performed. A toxicity test (rainbow trout or benthic invertebrate bioassay) is recommended as an indicator of the potential for the specific leachate mixture to have actual effects.
- The shoreline of the Kitsumkalum River to west of the landfill should be inspected twice annually, for evidence of leachate discharge and staining, during low flow conditions. Should there be evidence for leachate discharge to the river, a detailed water quality and benthos monitoring program should be initiated.

9.5.5 Regional District of Kitimat Stikine Thornhill Landfill PR-4057

9.5.5.1 Background

The landfill is located about 4 km southeast of Thornhill and about 6 km southeast of the City of Terrace. It is operated by the Regional District of Kitimat-Stikine (RDKS) and services a population of about 6,000. Expansion of the service area is being considered. The wastes are covered daily with granular soils from the south end of the landfill property.

The site is located in moderate to steep rolling terrain. The south end of the site is a ridge of sand and gravel fluvial sediments which overlay extensive marine silt and clay deposits which outcrop at the north end of the site. The gravel ridge has been excavated for gravel and cover material. The site drains northward via intermittent drainage channels to wetland areas which constitute the head waters of Thornhill Creek. There are many leachate seepages above the clay which occur at the northern toe of the landfill. Thornhill Creek flows northwest through rural residential areas and Thornhill and eventually discharges to the Skeena River.

9.5.5.2 Permitted discharge

Permit PR-4057 authorizes a maximum daily discharge rate of 3.4 tonnes per day of municipal refuse and requires daily cover. The landfill receives up to 60% of commercial/industrial wastes from Terrace, and 40% residential wastes from the surrounding area. 4400 m^3/y of sewage sludge is permitted.

9.5.5.3 Receiving environment monitoring

A preliminary leachate assessment at this site was conducted in 1992 by Gartner Lee Ltd. (1993). The landfill area is estimated to be about 2.5 ha. The calculated water surplus is 784 mm/yr for this area. Assuming that 60% of the water surplus infiltrates the refuse and 40% runs off the surface cover, leachate production was estimated to be 470 mm/yr. Leachate movement through the groundwater flow system in the extensive marine clays and silts which appear to present across the entire site at depth was estimated to be very slow.

However leachate movement from springs at the north toe of the landfill overland to Thornhill Creek was indicated. Leachate seepage at the north end of the landfill and intermittent drainages to Thornhill Creek were sampled in August 1992 by the consultant and EPP. Specific conductance measurements of the leachate (field and laboratory) show values of 1800 to 2500 µs/cm. Laboratory results show typical leachate water quality degradation with elevated hardness (678-929 mg/L), chloride (234-303 mg/L), and ammonia (8-19 mg/L). An October, 1995 sample of Thornhill landfill leachate taken by EPP also shows an elevated COD (156 mg/L).

Field specific conductance measurements in drainage channels off the property showed elevated specific conductance near the landfill of 1421 µs/cm, which decreased downstream of the landfill to 462 µs/cm prior to entering wetlands in the headwaters of Thornhill Creek. Thornhill Creek is fairly sensitive to leachate impacts due to its low flows. Fisheries values are high in the lower reaches of Thornhill Creek. Human consumption or use of Thornhill Creek water for irrigation or recreation were not documented.

Recommendations in the Lee Gartner assessment include:

- Improvements to the landfill design and operation: construction of a perimeter ditch; construction of a leachate collection ditch and storage/renovation lagoon along the north toe of the landfill inside the perimeter ditch; and progressive closure and final covering of completed portions of the landfill.
- Monitoring of surface water at the landfill property boundary and at several locations along Thornhill Creek at least 6 times per year. Semi-annual ground water monitoring. Samples should be analyzed for conductivity, chloride, hardness, ammonia and iron, at a minimum.
- Additional information on water use and fishery potential in Thornhill Creek. This may involve a door-to-door survey and field biology investigations, and may include better mapping of intermittent drainages courses north of the landfill.

9.5.5.4 Discussion

Improvements to the landfill design and operation appear to be necessary. If this site is under consideration for a regional landfill site, a detailed leachate collection and remediation plan will be necessary. Recommended additions to the monitoring suggested in the Lee Gartner report are as follows:

- Ground water monitoring: water level elevations should be measured and water quality samples be collected and tested quarterly until a clear understanding of ground water flow and leachate movement is obtained.

- Should any of the ground or surface water monitoring prove to have elevated concentrations of the above parameters, toxicity testing (rainbow trout or benthic invertebrate bioassay) should be added. Toxicity testing is recommended as an indication of the potential for the specific leachate mixture to have actual effects.
- If water quality monitoring indicates, receiving environment monitoring on the headwaters of Thornhill Creek may be necessary.

9.5.6 Regional District of Kitimat Stikine Queensway PE-12645

9.5.6.1 Background

Over the last 12 years, there have been problems of raw sewage surfacing in ditches or backing up in basements, as septic systems failed due to poor soil conditions and high groundwater table in the Bobscien Crescent-Queensway area of Thornhill. The problems were examined in various engineering reports, but remained unsolved due to the financial constraints of local tax payers.

A referendum was passed by the residents in 1993 for construction of an oversized gravity sewer system serving most of Thornhill. The site is located on the west half of a small, 100-ha island, southwest of Ferry Island in the Skeena River, approximately 1 km south of Terrace. The location of the outfall pipe to the Skeena River is about 1.1 km downstream of the City of Terrace river water intake.

The sources of sewage are a residential core (population 1600) and a commercial area of Thornhill. The average design discharge rate will be 800 m^3/day. Sewage from individual septic tanks will be discharged to a low-pressure sewer system called STEPS (Septic Tank Effluent Pumping System), thence to the treatment system.

The treatment system will consist of 4 lagoons, the first two aerated and the final two used as rapid infiltration basins. During flood stages in the Skeena River, treated effluent will overflow from one of the infiltration basins to a side channel of the river via a 400 m long outfall pipe.

9.5.6.2 Permitted discharge

There are two authorized discharges associated with permit PE-12645: one to the ground and one to the Skeena River during flood stages.

The maximum rate of effluent which may be discharged to the ground is 1500 m^3/day. The average rate permitted is 800 m^3/day. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS.

The maximum and average rates of effluent which may be discharged to the river during flood conditions only are 1500 m^3/day and 800 m^3/day, respectively. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS.

The proposed effluent discharge monitoring program is as follows:

Parameter (units)	Sample Type	Sampling Frequency	Reporting Frequency
Effluent Flow Rate (m^3/day)	Field measurement	Continuously	Monthly
Temperature (C)	Field measurement	Monthly	Monthly
Dissolved O_2 (mg/L)	Field measurement	Monthly	Monthly
pH	Field measurement	Monthly	Monthly
Total Ammonia (mg/L)	Field measurement	Monthly	Monthly
BOD_5 (mg/L)	Grab	Monthly	Monthly
TSS (mg/L)	Grab	Monthly	Monthly
Total Phosphorus (mg/L)	Grab	Monthly	Monthly
Total Nitrogen (mg/L)	Grab	Monthly	Monthly

9.5.6.3 Receiving environment monitoring

Prior to commencing discharge to the side channel, the permittee is also required to measure the conditions in the side channel. Samples should be collected during typical low flow conditions. A minimum of 2 sets of samples are to be collected with approximately 1 week between sets. Sampling locations shall be the same points as those to be used for the receiving environment monitoring program described below. Field measurements shall be taken for flow rate, temperature, pH, ammonia, and dissolved oxygen. Water samples from the side channel shall be analyzed for nitrate/nitrite, total nitrogen, fecal coliform and fecal streptococci.

The proposed receiving environment monitoring program RDKS Queensway Sewage Treatment Plant PE-12645 is presented in Table 9.10. The location of the upstream site is approximately at the B.C. Hydro Right-of Way, upstream of the outfall. The location of the downstream site is be 50 - 100 meters downstream of the outfall.

9.5.6.4 Discussion

The innovative method of discharge at the RDKS Thornhill STP, discharge to an infiltration basin and discharge to the river only during flood periods, should provide an additional degree of protection for aquatic life. There is some risk in the location of this plant on an island in the Skeena, in that erosion of the island caused by extreme flooding or ice jams, causing flooding, may occur. The monitoring program in place for the RDKS Thornhill facility is thorough, and the omission of receiving environment monitoring for phosphorus and toxicity can be justified by the fact that direct discharge will only occur during flood conditions.

Table 9.10 Receiving environment monitoring program RDKS Queensway Sewage Treatment Plant PE-12645

Parameter (units)	Upstream site	Downstream site	Sample Frequency
Side channel flow rate			Weekly during discharge and for 1 month after discharge
Outfall effluent flow rate			Weekly during discharge
Temperature (C)	Field measurement	Field measurement	Weekly for 1 month after discharge.
pH	Field measurement	Field measurement	Weekly for 1 month after discharge.
Ammonia (mg/L)	Field measurement	Field measurement	Weekly for 1 month after discharge.
Dissolved Oxygen (mg/L)	Field measurement	Field measurement	Weekly for 1 month after discharge.
Nitrate/Nitrite (mg/L)	Grab	Grab	Sample if D.O. <2.0 mg/L or NH_3 >2.0 mg/L
Total Nitrogen (mg/L)	Grab	Grab	Sample if D.O. <2.0 mg/L or NH_3 >2.0 mg/L
Fecal Coliform (MPN/100 mL)	Grab	Grab	Sample if D.O. <2.0 mg/L or NH_3 >2.0 mg/L
Fecal Streptococci (MPN/100 mL)	Grab	Grab	Sample if D.O. <2.0 mg/L or NH_3 >2.0 mg/L

9.5.7 Minor discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PE-3650	Robert Lavoie Holdings	Thornhill near Terrace	Store and Laundromat septic tank and tile field	
PE-5275	Northern Motor Inn	Thornhill near Terrace	sewage treatment plant with tile fields	Maximum 68 m^3/day
PE-7331	Bytown Diesel	Terrace	Oil/water separator to ground	Maximum 16 m^3/day
PE-7987	Lomak Transport	Terrace	Oil/water separator to ground; fuel dispensing area and truck wash	Maximum 78 m^3/day
PE-8658	Rauter Holdings	Thornhill	Trailer Court septic tank and tile fields	Maximum 55 m^3/day
PE-13042	Petro Can	Terrace	Oil/water separator to ground	
PR-7462	RDKS Usk landfill	Usk	This landfill is now closed	Problems with illegal dumping north of Usk persist
PR-7749	REPAP Carnaby	Carnaby	Woodwaste landfill	

9.6 SUMMARY AND REVIEW OF MONITORING NEEDS

Forestry is the main land-use activity in this reach. Since the early 1970's forestry operations have moved into higher elevations, particularly in the Zymoetz River watershed, the main tributary stream in this reach, and have shifted to primarily clearcut logging.

The District Municipality of Terrace, on the north bank of the Skeena River, and the nearby settlement of Thornhill, on the south bank, are the largest urban settlements in the watershed. Both communities have municipal wastewater treatment plants discharging to the river. Municipal solid waste landfills are located on the Kitsumkalum River north of Terrace and in Thornhill. Several smaller settlements in this reach, South Hazelton, Gitwangak, Kitwancool, Kitselas and Kisumkalum, are served by septic tanks.

The major water consumption is concentrated in and around Terrace, for municipal and industrial purposes. The District of Terrace holds water distribution licenses on Deep and Spring Creeks, north of Terrace. Woodlands Utilities distributes water from several springs to subdivisions in the Thornhill area. Other community waterworks systems are located on Chicago Creek (South Hazelton), Kits Creek (Gitsegukla), Ten Link Creek, tributary to the Kitwanga River (Kitwancool) and Eneeksagilaguaw Creek (Kitsumkalum).

9.6.1 Water quality assessment

9.6.1.1 Skeena River at Usk

The Skeena River at Usk is a water quality monitoring station operated cooperatively by the governments of Canada and British Columbia. The most noticeable change in water quality at this station, as compared to upstream sites, is the much higher TSS concentration (mean TSS=73 mg/L, maximum=1840 mg/L). TSS exhibits a positive relationship to discharge due to increased sediment transportation resulting from increased surface runoff. The Skeena cuts through the rugged Hazelton Ranges in this reach, which have many steep drainages receiving high precipitation.

The waters are soft, moderately coloured, with neutral to slightly alkaline pH (mean=7.4). Alkalinity is moderately low. Conductivity and dissolved solids are low due to the rapid runoff and high dilution rates characteristic of the watershed, and reflecting good water quality. Nutrient concentrations are generally low. The mean total phosphorus concentration of 0.055 mg/L appears elevated relative to other tributaries, but this has been shown to be a reflection of high seasonal runoff and TSS concentrations at this site. Orthophosphate levels, which are representative of dissolved biologically available phosphorus, are generally less than the detection limit.

Total metals concentrations are generally very close to the MOELP criteria for protection of aquatic life at the hardness levels present. Metals levels appear relatively high compared to upstream sites, but this has also been shown to be related to seasonally high discharge and TSS levels. Dissolved metals concentrations are often less than their respective detection limits. Plots of the water quality variables against time indicate that no significant trends in water quality occurred at this station during the period of 1984 to 1992.

9.6.2 Interaction of forestry and water quality

While earlier small-scale forestry operations concentrated on high-value timber in easily accessible sites, more recent operations have expanded roads and logging activities into much of the forest landbase, with a shift to primarily clearcut logging.

9.6.2.1 Kitsumkalum River training

The Kitsumkalum River was channelized to facilitate log driving down the river to Terrace in the early 1960's. Such operations can cause major changes in channel morphometry, breaking down river banks and gouging the stream bed. The documentation of the long-term changes in channel morphometry and sediment transport which have occurred as a result of historic river training of the Kitsumkalum River should be a research priority.

9.6.2.2 Zymoetz River suspended sediment research project

Changes in channel morphometry have occurred, due to unknown causes, in the Zymoetz River. The MOF Regional Forestry Section, in cooperation with Environment Canada, are conducting a multi-year research study of suspended sediment sources in the Zymoetz watershed. This study is pertinent to fisheries/forestry interactions, as well as interactions with the existing and proposed natural gas pipeline routes through the watershed.

9.6.2.3 Stream protection practices

A review of stream protection practices in the Kispiox and Bulkley TSAs, conducted in the mid-1980's, noted that the upper Zymoetz was recognized as one of the more valuable steelhead trout and coho salmon areas in the region. There had been a shift away from leaving riparian reserves towards the use of machine reserves along streams due to windthrow problems. It was generally believed that machine reserves provided adequate streamside protection. Road building and lack of road maintenance was identified as the main source of sediment to streams. Blockage of fish movements due to poor culvert installation and maintenance was also cited as a problem.

An audit of the effectiveness of the Coastal Fisheries Forestry Guidelines was conducted in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts in 1992. Results of the survey showed there was considerable variation between forest districts and logging companies in compliance with either site specific stream prescriptions, or the more general Coastal Fisheries Forestry Guidelines. Hill slope accounted for a large part of the variation - the steeper the slopes, the poorer the compliance and the more frequent the impacts. The steep blocks (average block slope 35.1%), which were particularly prevalent in the Kalum District, had more forestry related impacts.

In the Kalum district, 53% of the stream reaches inspected had impacts due to logging, which was considerably high than the average recorded in the QCI District or on Vancouver Island. The amount of fish habitat lost in Class I-III streams ranged from 3.9% (QCI) to 15.7% (North Coast) of the total habitat inspected, most of it in small streams. Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts, followed by bank scouring and channel scouring.

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO was lowest in the Kalum District (57.1%). Compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was generally poor (29.9%). When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams.

An LRMP has been prepared for the Kispiox TSA, and similar planning processes are underway in the Bulkley and Kalum districts. In addition to recommending areas for protected status under PAS, the LRMPs are expected to prescribe management practices for stream protection and for protection of the Community Watersheds found in this reach.

9.6.2.4 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is the major land-use activity in this reach. One review of stream protection practices in the mid 1980's identified instances of stream degradation in the upper Zymoetz and identified road building and lack of road maintenance as the main source of sediment to streams. A 1992 audit of stream protection practices in the Kalum TSA found poor compliance with stream protection guidelines resulting in loss of fish habitat. The FPC is expected to improve compliance with stream protection guidelines and the Watershed Restoration Program is intended to address problems such as lack of road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring, such as the audit discussed above, is also necessary to ensure that LRMP management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.3.

9.6.3 Interaction of mining and water quality

9.6.3.1 Duthie Mine

Silver Standard Resources own the mineral rights to the Duthie Mine, located 12 km west of Smithers on the McDonnell Lake Forestry Road. The old mine is located 1 km north of Aldrich Lake, which forms part of the headwaters of the Zymoetz River. The Duthie Mine operated intermittently from 1923 to the mid 1980's, during which time over 47,000 tonnes of tailings were discharged. Tailings flowed in a wooden flume to a swampy area below the mill where they were impounded in settling ponds.

Field investigations carried out at the minesite in 1982-1983 found that the dyking around the old tailings was failing, causing contaminated runoff to Henderson Creek, subsequently to Glacial Creek and Aldrich Lake. Aldrich Lake drains into Dennis Lake which drains into McDonnell Lake via the upper Zymoetz River. The tailings were found to have a high concentration of arsenic, iron, aluminum and lead. Analysis of tailings leachate showed metal concentrations in excess of the regulatory criteria at point of discharge for arsenic, zinc and pH.

Metals levels were found in Glacial Creek and Aldrich Lake in exceedance of water quality criteria for cadmium, copper, lead and zinc. Arsenic concentrations in the lake were found to exceed maximum allowable drinking water standards of 0.05 mg/L on one occasion. Bottom sediments in the lake had elevated metals; however, there was no corresponding evidence of metal contamination in fish. Subsequent covering of the tailings and diversion of leachate were carried out. The tailings are presently contained behind a berm which was constructed in 1987.

Sampling in 1993 found that the tailings were still generating ARD with high concentrations of arsenic, copper, lead and zinc, and represented a potential for significant contamination of groundwater. All groundwater samples contained concentrations of arsenic, copper, lead and zinc in excess of the Canadian Water Quality Guidelines.

A plan for remediation of the site and mitigation of the ARD was submitted to the NWMDRC in 1994. A monitoring program was agreed upon to address deficiencies in knowledge about the tailings and their environs so that a final remediation plan may be recommended. Areas to be studied are ground water, surface water, surface gravels, glacial till and tailings.

9.6.4 Interaction of urban developments and water quality

9.6.4.1 Municipal sewage treatment plants

Gitsegukla STP.— In 1986 a community sewerage system was built in Gitsegukla, about 25 km west of New Hazelton, and a rotating biological contactor (RBC) was installed to treat the waste. The outfall terminates 0.7 m below the surface of the Skeena River and is at least 6 m from the shore. The permit authorizes a maximum rate of discharge of 300 m^3/day with characteristics of the effluent equivalent to or better than 45 mg/L BOD and 60 mg/L TSS.

Sampling of the effluent is required quarterly for BOD, TSS and discharge flow. Analysis of effluent samples taken by the permittee and EPP indicates not only excellent compliance with permitted BOD and TSS limits, but low ammonia and nitrite concentrations. EPP assessed toxicity of the Gitsegukla effluent sampled May 1993 using three different bioassay methods: Rainbow trout (RBT) 96 hr LC50, Daphnia 48 hr LC50, and 5 and 15 minute Microtox EC50. The effluent was non-toxic to all three organisms. The low ammonia and nitrite concentrations (indicating the RBC system is performing complete biological digestion and nitrification of the wastes) probably explains the non-toxic nature of the effluent. Comparison of the maximum permitted discharge rate of 300 m^3/day with the 7 day average 10 year low flow for the Skeena River at Usk (78.7 m^3/s) gives an estimated dilution ratio of >16,000:1.

Regional District of Kitimat Stikine Queensway STP.— In the past, there have been problems of raw sewage surfacing in ditches or backing up in basements, as septic systems failed due to poor soil conditions and high groundwater table in the Bobscien Crescent-Queensway area of Thornhill. In 1993, a referendum was passed by the residents for construction of an oversized gravity sewer system serving most of Thornhill.

The site is located on the west half of a small island, southwest of Ferry Island in the Skeena River, approximately 1 km south of Terrace. Sewage from individual septic tanks will be discharged to a low-pressure sewer system called STEPS (Septic Tank Effluent Pumping

System), thence to a treatment system consisting of 4 lagoons, the first two aerated and the final two used as rapid infiltration basins. During flood stages in the Skeena River, treated effluent will overflow from one of the infiltration basins to a side channel of the river via a 400 m long outfall pipe.

The maximum and average rates of effluent which may be discharged to the infiltration basin or to the river, during flood conditions only, are 1500 m^3/day and 800 m^3/day, respectively. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The effluent discharge monitoring program requires continuous effluent flow measurement, and monthly monitoring and reporting of temperature, dissolved oxygen, pH, BOD, TSS, ammonia-N, total phosphorus and total nitrogen.

A receiving environment monitoring program is required for sites upstream and 50-100 meters downstream of the outfall, with monitoring for side channel flow rate, effluent flow rate, temperature, pH, ammonia-N, dissolved oxygen, nitrate/nitrite-N, total nitrogen, fecal coliforms and fecal streptococci. Sampling frequency is generally weekly during discharge and for one month after discharge.

The innovative method of discharge at the RDKS Thornhill STP, discharge to an infiltration basin and discharge to the river only during flood periods, should provide an additional degree of protection for aquatic life. There is some risk in the location of this plant on an island in the Skeena, in that erosion of the island caused by extreme flooding or ice jams, causing flooding, may occur. The monitoring program in place for the RDKS Thornhill facility is thorough, and the omission of receiving environment monitoring for phosphorus and toxicity can be justified by the fact that direct discharge will only occur during flood conditions.

Terrace STP.— The City of Terrace operates a sewage treatment plant discharging to the Skeena River consisting of two aerated lagoons and a maximum permitted discharge rate of 12,210 m^3/day. The characteristics of the effluent must be equivalent to or better than 45 mg/L BOD and 60 mg/L TSS. The permittee is required to obtain a grab sample of the effluent once each month and have it analyzed for TSS, BOD and fecal coliforms. The effluent volume discharged over a 24 hour period must also be recorded once per month. Results have been consistently in compliance with the permit.

Receiving environment monitoring is required at 5 sites: 300 m upstream from the outfall, the effluent at discharge, 300 m downstream from the outfall, 2 km downstream from the outfall, and just upstream from Fisherman's Park in the Skeena River. Parameters analyzed are temperature, pH, total phosphorus, ammonia-N, TSS and fecal coliforms.

There is no evidence from the available data that the STP effluent would significantly impact aquatic life in the Skeena River, except for within the initial mixing zone. The undiluted effluent has ammonia concentrations almost equal to the maximum water quality criterion for the protection of aquatic life at the ambient temperature and pH (approximately 20.0 mg/L). Data from 300 m downstream of the discharge indicate good mixing, with ammonia concentrations an order of magnitude below the 30-day average, or chronic effect, criterion. The data for sites 2.5 km downstream and at Fisherman's Park, upstream of the Kitsumkalum River confluence, indicate a return to near background water quality.

A calculation using the maximum permitted discharge and the 7-day average 10 year low flow for the Skeena at Usk indicates a dilution ratio of 400:1. Usually the annual low flow period would occur during late winter, which is also the timeperiod that increased ammonia concentrations in effluent might be expected due to poor nitrification at low wastewater temperatures. In addition to ammonia, other nitrogen species may contribute to toxicity, as well as metals and other unregulated discharges to the municipal collection system

More comprehensive monitoring data are needed in order to assess the possibility of toxicity within the mixing zone for the Terrace STP. Suggested additional parameters to the receiving environment monitoring program are: total nitrogen, nitrate-N, nitrite-N, total phosphorus, orthophosphate, fecal streptococci and rainbow trout 96 hr LC50 bioassay. In addition to better characterization of the effluent at all times of the year, data which would help in the assessment of this discharge include the areal extent and fisheries values associated with the mixing zone. The concern is that overwintering steelhead, as well as resident trout, will be attracted into the effluent mixing zone by warmer water and be exposed to undiluted effluent. Further discussion on monitoring of municipal sewage effluents is found in section 12.5.

9.6.4.2 Municipal solid waste landfills

Terrace landfill.— The Terrace landfill is located 5 km northwest of Terrace on gravel terrace deposits along the east side of the Kitsumkalum River. The landfill area itself is relatively flat but there is a very steep bank along the west side of the landfill which slopes down to the floodplain and an intermittent creek runs through the landfill site, draining to the Kitsumkalum River. Maximum permitted discharge rate is 16 tonnes per day. This is a trench fill operation about 14.7 ha in area, and requires daily cover with local sandy soils.

An initial leachate investigation conducted in 1992 found that the two most likely pathways for leachate movement to the Kitsumkalum are via the intermittent drainage channel, and ground water flow in the sand and gravel aquifer. The annual leachate production at the site was estimated to be 64,700 m^3/yr.

Water samples collected in August 1992 from a stagnant pond in the intermittent drainage channel and from a shallow hand dug pit downgradient of the landfill area indicated elevated concentrations for leachate parameters such as specific conductance, chloride, and ammonia.

The estimated dilution ratio in average flows in the Kitsumkalum River was 61,500:1. The potential receptors of leachate from the Terrace landfill are the Kitsumkalum River water quality, and wildlife using the intermittent drainage channel which dissects the landfill. It is unlikely that negative water quality impacts would occur at this dilution, however if there is entrainment of leachate into subsurface gravel channels, water quality degradation could occur in localized Kitsumkalum River gravel sediments.

The RDKS is preparing a solid waste management plan which is expected to result in the closure of this site. If the landfill is closed soon, a properly graded clay final cover and diversion ditches should be installed to reduce infiltration into the wastes and resultant leachate production.

The shoreline of the Kitsumkalum River to west of the landfill should be inspected twice annually, for evidence of leachate discharge and staining, during low flow conditions. Should there be evidence for leachate discharge to the river, a detailed water quality and benthos monitoring program should be initiated.

If the landfill is to remain in operation by area filling above grade, then ground water and surface water monitoring is recommended. Four groundwater monitoring well sites were recommended: one upslope (east of the landfill); one downslope (west) of the active fill area; one downslope of the woodwaste and compost area; and one downslope of the old landfill area. Samples should be collected four times per year and analyzed for conductivity, chloride, hardness and ammonia.

RDKS Thornhill Landfill.— This landfill is located about 4 km southeast of Thornhill and about 6 km southeast of the City of Terrace. The site is located in moderate to steep rolling terrain and comprises about 2.5 ha. The south end of the site is a ridge of sand and gravel fluvial sediments which overlay extensive marine silt and clay deposits which outcrop at the north end of the site. The site drains northward via intermittent drainage channels to wetland areas which constitute the headwaters of Thornhill Creek. Thornhill Creek flows northwest through rural residential areas and Thornhill and eventually discharges to the Skeena River.

The permit authorizes a maximum daily discharge rate of 3.4 tonnes/day of municipal refuse. A septage lagoon is permitted to receive 4400 m^3/y of sewage sludge. The landfill receives up to 60% of commercial/industrial wastes and 40% residential wastes. The wastes are covered daily with granular soils from the south end of the property.

A preliminary leachate assessment estimated leachate production to be 470 mm/yr. Leachate springs at the north end of the landfill and intermittent drainages to Thornhill Creek were sampled in August 1992. Specific conductance measurements of the leachate show values of 1800 to 2500 μs/cm. Analysis of leachate samples show typical leachate water quality degradation with elevated hardness, chloride, ammonia, and COD.

Field specific conductance measurements in drainage channels off the property showed elevated specific conductance near the landfill of 1421 μs/cm, which decreased downstream of the landfill to 462 μs/cm prior to entering wetlands in the headwaters of Thornhill Creek.. Thornhill Creek is fairly sensitive to leachate impacts due to its low flows and high fisheries values. Human consumption or use of Thornhill Creek water for irrigation or recreation were not documented.

Improvements to the landfill design and operation were recommended, including: construction of a perimeter ditch; construction of a leachate collection ditch and storage/renovation lagoon along the north toe of the landfill inside the perimeter ditch; and progressive closure and final covering of completed portions of the landfill.

Other recommendations include the monitoring of surface water at the landfill property boundary and at several locations along Thornhill Creek at least 6 times per year, and semi-annual ground water monitoring. Toxicity testing is recommended as an indication of the potential for the specific leachate mixture to have actual effects. Additional information on water use and fishery potential in Thornhill Creek is needed. This may involve a door-to-door survey and field biology investigations, and should include better mapping of intermittent drainages north of the landfill.

10. LAKELSE RIVER AND LAKE

Lakelse Lake is oriented in a north-south direction in the Kitsumkalum-Kitimat trough and empties into the Skeena to the west via the Lakelse River (Figure 10.1). Lakelse Lake was impounded at the close of the last glaciation by retreating glaciers (see introduction section 9). Williams Creek is the largest tributary stream to the lake, as well as twelve smaller streams.

Lakelse Lake is about 8.7 km long and has an area of 1416 ha. The lake has a maximum depth of 32 m (at the north end opposite Furlong Bay), but a large portion of the lake (42 percent) is considered littoral (Cleugh and others 1978). This extensive littoral zone affects temperature, dissolved oxygen, aquatic plants, and overall productivity of the lake. Temperature profiles indicate the absence of a stable thermocline, probably as a consequence of relative shallowness combined with strong prevailing southwesterly winds (Abelson 1976).

Lakelse Lake is a popular sport fishing and recreational area, with provincial park sites located on the bay which forms the northeast corner of the lake, and on the eastern shore in Furlong Bay. Populations of winter and summer-run steelhead and coastal cutthroat trout sustain a significant sport fishery, and Lakelse is a sockeye nursery lake. The Lakelse River is designated a Class II angling stream. See section 2.2.4 for explanation of classified waters.

10.1 HYDROLOGY

The annual flushing rate of Lakelse Lake was estimated to be five to six times per year. The high flushing rate is caused by the lake's large watershed, and the high annual precipitation for the area (1131 mm average at Terrace Airport).

A large percentage of the precipitation occurs during the winter as snow. Although long-term hydrometric data is not available, Cleugh and others (1978) estimate the greatest discharge occurs in the summer months, with maximum discharge in June. MOELP Water Management Branch has recently installed a manual gauge on the Lakelse River; however, there is insufficient data for analysis at this time.

10.2 LAND USE HISTORY

10.2.1 Settlements

Lakelse Lake is within the traditional territory and land claim area of the Coast Tsimshian, who traditionally maintained summer villages near the lake outlet, and on Lakelse River.

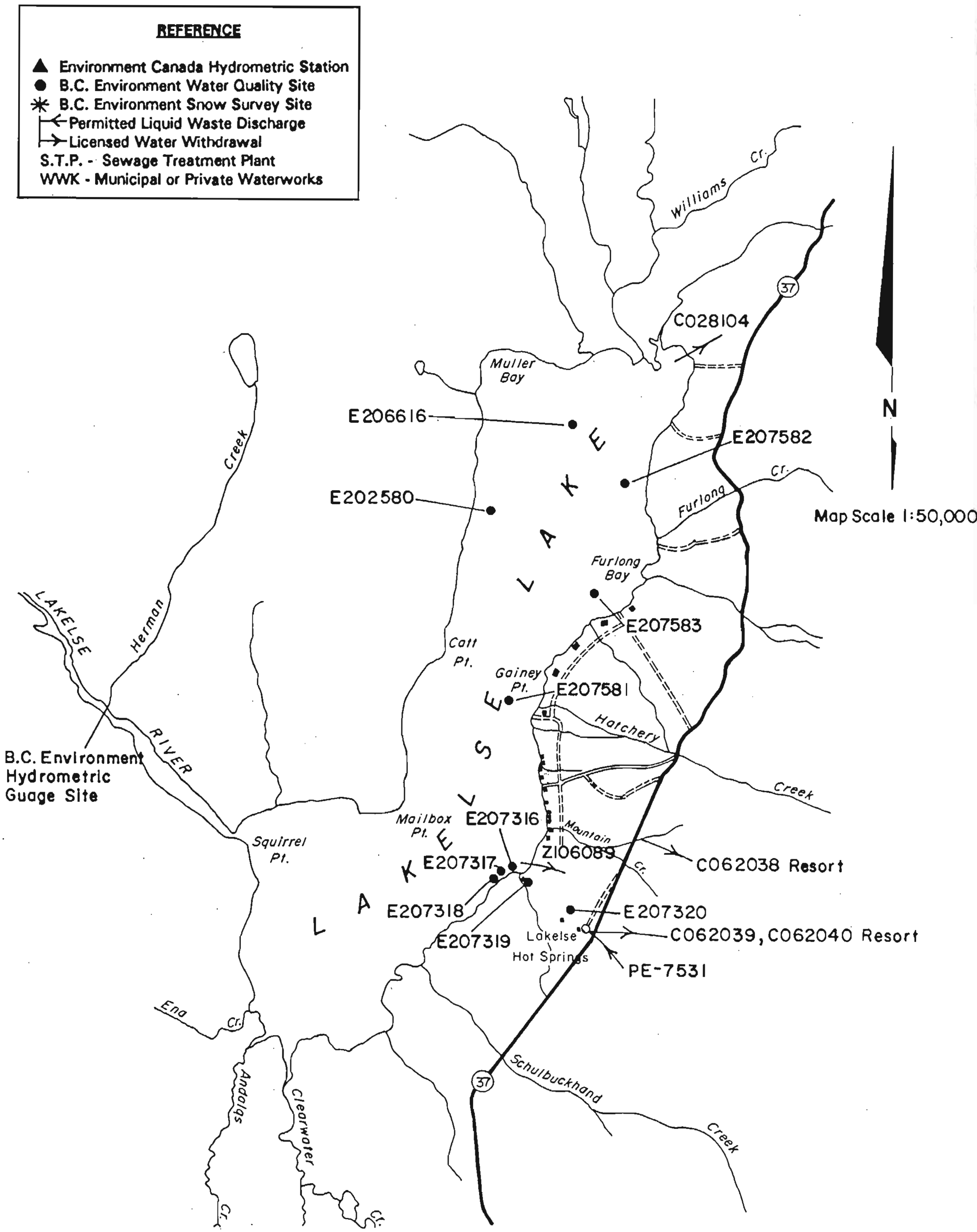


Figure 10.1 Lakelse River and Lake

There are no incorporated settlements in this reach, however a density of waterfront permanent and recreational residences occur along the eastern shore of Lakelse Lake, commonly called Lakelse Lake or the lake community. These residences are served by septic systems only. McKean (1986) found that 235 houses were located within 120 m of the lake shoreline, out of a total of 257 houses in the watershed (based on 1983 air photos). The largest proportion of present and probably future housing development (because of its proximity to the lakeshore) is located in soils which have good physical characteristics but poor phosphorus adsorption capacity. According to a Water Management Branch soils specialist, approximately 56 percent of the watershed development lies within landforms considered moderately suitable for septic tank tile fields. About 30 percent of the development, or 72 houses, of which 60 houses are adjacent to the lakeshore, are located on poor landforms.

A number of hot springs with a temperature of about 85 °C occur on the eastern shore of Lakelse Lake. The first hotel was built at Lakelse Hotsprings in 1910 and operated until 1936. Between 1936 and 1958, the resort was dormant. In 1959, a motel and pool were constructed and the hotsprings were operated until 1979, when the facilities again fell dormant. In 1985 the site was purchased by Mt. Layton Hotsprings Resort which has constructed hot and cold pools, waterslides, hotel and restaurant at the site (see section 10.5.1).

10.2.2 Forestry

The Lakelse watershed is in the Kalum Forest District. The major forestry operators in the Kalum are West Fraser's Skeena Sawmills Ltd. and Skeena Cellulose Inc., both with mills in Terrace. A LRMP process is currently underway for the Kalum.

10.2.2.1 Water quality objectives and monitoring for forestry interactions

McKean (1986) prepared Water Quality Objectives were Lakelse Lake (section 10.4.2), stating that the impact of forestry on water quality has been a concern in the Lakelse watershed. The main concern of logging within the watershed is the siltation of spawning and rearing streams. There had, however, been no data collected within the watershed to quantify the degree of siltation attributable to logging. In 1986, the majority of past and proposed logging activities were in the Williams Creek watershed, Clearwater Creek and the west side of the lake.

A specific Water Quality Objective for turbidity was established for tributary streams to the lake to protect spawning areas possibly affected by logging (Table 10.3). For streams without domestic water licenses, the induced turbidity shall not exceed 5 NTU when background turbidity is ≤50 NTU nor shall the induced turbidity be more than 10% of background when background is >50 NTU. Monitoring recommendations include intensive turbidity sampling one year prior to logging, with two sites per stream required. Samples should be collected at an upstream and downstream site monthly throughout the year prior to, during, and following a logging operation.

10.2.2.2 Application and effectiveness of the Coastal Fisheries Forestry Guidelines in the Kalum Forest District

Tripp and others (1993) conducted an assessment of the effectiveness of the Coastal Fisheries Forestry Guidelines (see section 2.2.7) in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts, as part of a coastwide audit. Results of a survey of 50 cut blocks, in the fall of 1992, showed there was considerable variation between forest districts and logging companies in compliance with either site specific stream prescriptions, or the more general Coastal Fisheries Forestry Guidelines. Hill slope accounted for a large part of the variation - the steeper the slopes, the poorer the compliance and the more frequent the impacts. The steep blocks in the Kalum District (average block slope 35.1%) had 2.2 impacts per 100 ha.

In the Kalum district, 53% (n=17) of the stream reaches inspected had impacts due to logging. The Kalum and North Coast Districts had two and three times the number of impacts recorded per unit area in the QCI District. Both were also considerably high than the average recorded on Vancouver Island. In Class IV streams, the number of major/moderate alterations to the channel was approximately 2.2 times higher in both the Kalum and North Coast Districts than on Vancouver Island.

The amount of fish habitat lost in Class I - III streams ranged from 3.9% (QCI) to 15.7% (North Coast) of the total habitat inspected, most of it in small streams. By comparison, stream areas affect in Class IV streams with moderate to high transport potentials were much larger (88.9% in the Kalum) of the total stream area inspected. Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts (20.2% of the reaches), followed by bank scouring (14.9%) and channel scouring (7.8%).

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO ranged from a low of 57.1% in Kalum to a high of 90.3% in QCI. Compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was generally poor (29.9%). When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams in 214 out of the 217 cases (98.6%).

10.2.2.3 Thunderbird Integrated Resource Management Plan

Recognizing that future harvesting activities would be constrained due to past practices and the high fisheries, wildlife and recreation values within the Lakelse area, an interagency integrated resource management plan was developed for the Thunderbird forest area (MOF 1992). The Thunderbird forest area, which is named for a CNR station, encompasses Lakelse Lake and River north to the Skeena River, including the Alwyn Creek watershed (which drains the area north of the lake to the Skeena). It does not include the major tributary streams entering the Lakelse Lake from the east such as the largest tributary, Williams Creek, or Hatchery and Schulbuckhand Creeks. Skeena Sawmills Ltd. (West Fraser) has timber licenses in the area, but the majority of the area (65%) occurs as vacant crown land available for harvest to small business. Blowdown is a significant forest management consideration in the Thunderbird area, thus specific blowdown management prescriptions are given for each management zone.

The plan establishes a Lakelse River Management Zone approximately 1 km on either side of the Lakelse River with the priority of protecting the fish habitat and Class II angling waters. A subzone is established approximately 200 m on either side of the Lakelse River in which no timber harvesting or salvage of blowdown will occur. Riparian corridors approximately 200 m in width, in which no harvesting will occur, are recommended along Coldwater, White, and Herman Creeks, in addition to unnamed creeks connecting the Hai Lake to the Lakelse River.

South-North Lakelse Lake Management Zone is established over wetlands to the north and south of Lakelse Lake. Numerous streams at the south end of Lakelse Lake are spring fed. These streams are unique and have specific hydrological characteristics of value to the maintenance of the Lakelse fisheries. This zone includes an area originally studied for the South Lakelse Lake Wildlife Plan as well as the wetland areas to the north of the lake. The committee endorsed the intent of the Kitimat-Stikine Regional District's recommendations for protective measures for a sensitive environmental designation around South-Lakelse Lake Fish and Wildlife area. Crown lands in this area have been proposed for Section 13 Environmental Management designation by MOELP Fish and Wildlife Branch (W. Bergen, MOELP, personal communication).

Management priorities for the Lakelse Lake Residential Area, which includes private and leased recreational properties around the lake, are to maintain visual quality objectives, water quality and recreational opportunities. The advisory committee noted that many residences around the lake have septic systems which have never been inspected and recommended improved septic system inspection and requirements for compliance with modern standards in order to maintain water quality. The recommendation was also made that no further vacant crown land on the foreshores of the lake should be alienated.

All areas outside other management zones are to be managed as working forest. Future plans included a hydrological study of the Alwyn Creek watershed, and evaluation and rehabilitation of Mink Creek to determine sediment transfer location and remedial measures. The need for a district erosion control specialist to identify erosion problem areas and recommend appropriate rehabilitation plans was identified. The Thunderbird IRMP will eventually be incorporated into a higher level plan and included in the Kalum LRMP (K. Stuart, Kalum Forest District, personal communication).

10.3 WATER WITHDRAWALS

A summary of licensed water withdrawals from Lakelse Lake and its tributary streams is found in Table 10.1. There are 38 domestic and one irrigation licenses on input streams to Lakelse Lake, and five domestic licenses on Lakelse Lake itself. Mount Layton Hotsprings Resort holds licenses on Lakelse Hot Springs and Mountain Creek for mineral baths, swimming pool and resort.

Table 10.1 Licensed water withdrawals Lakelse River and Lake

Input streams

Domestic

GD	m3/d	m3/s
(38 licences)		
26000	118.2	1.37E-03

Irrigation*

AF	m3/d	m3/s
(1 licence)		
3	61.7	7.14E-04

Mineral baths, swimming pool & resort

License	Licensee	GD	m3/d	m3/s
	Mount Layton Hotsprings Resort Ltd.			
C062039	(Lakeslse Hot Springs)	54400	247.3	2.86E-03
C062040	(Lakeslse Hot Springs)	15000	68.2	7.89E-04
C062038	(Mountain Cr.)	120000	545.5	6.31E-03

Provincial Park

License	Licensee	GD	m3/d	m3/s
C028104	Min. of Env. Lands, & Parks	40000	181.8	2.10E-03

Lakeslse Lake

Domestic

GD	m3/d	m3/s
(5 licences)		
2500	11.4	1.32E-04

* Irrigation licences have been converted from acre-feet to m3/s by assuming 2 months of operation, 12 hours/day in the summer.

10.4 WATER QUALITY AND AQUATIC RESEARCH

10.4.1 Comparison of water quality in seven rivers in the Skeena watershed, 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly from seven stations located on the upper Bulkley River, Morice River, Bulkley River at Quick, Telkwa River, Kispiox River, Skeena River at Usk, and Lakelse River (Wilkes and Lloyd 1990). Summary water quality data for 1983-1987 for the Lakelse River Site 0400211 (Figure 10.1) are found in Table 10.2. This station, near the confluence of the Lakelse and the Skeena, was generally sampled once per month for five years.

Values below the MDC.— In many cases, the levels of ions present in the river water were observed to be below the minimum detectable concentration (MDC) used in the analyses. When minimum, maximum, mean, and standard deviation values were computed, observations below the detection limit were excluded from the calculations. Thus, where some values were below the MDC, the minimum and mean statistics will be an overestimation the true values.

When the 50th percentile was computed, the low values were included as "<MDC". This means that the values given for the 50th percentile used all the data points, including the observations which were below detection. In cases in which many observations were below the MDC, the 50th percentile, or median, value may be a more accurate estimate of the true "average" concentration than is the mean.

Table 10.2 Water quality summary Lakelse River, Site 0400211, 1983-1987

	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Colour	14	12	5	30	16.7	8.9	18
pH	51	51	6.7	7.6	7.08	0.16	7.1
Conductance (umhos/cm)	52	52	37	72	53.8	7.6	54
Total Residue (mg/L)	51	51	20	128	50.3	19.3	48
Filterable Residue (mg/L)	19	19	26	54	40.3	6.7	38
Non-filterable Residue (mg/L)	43	43	1	79	9.1	16.9	3
Turbidity (NTU)	46	46	1.0	43.0	4.06	7.20	2.0
Alkalinity (mg/L)	51	51	15.8	28.6	21.09	2.81	21.4
Hardness Total (mg/L)	8	8	18.1	23.0	20.53	1.65	20.4
Hardness Dissolved (mg/L)	8	8	15.9	23.0	19.53	2.18	19.6
Total N (mg/L)	21	21	0.05	0.71	0.210	0.150	0.18
T.K.N. (mg/L)	51	51	0.02	0.58	0.140	0.100	0.12
Ammonia (mg N/L)	51	41	0.005	0.381	0.0444	0.0758	0.010
NO2 + NO3 (mg N/L)	51	44	0.02	0.13	0.067	0.026	0.06
Total Carbon (mg/L)	30	30	4	10	7.4	1.6	8
Organic Carbon (mg/L)	21	20	1	5	2.8	1.3	2
Inorganic Carbon (mg/L)	15	15	3	8	5.3	1.1	5
Chloride (mg/L)	15	15	1.5	3.2	2.40	0.51	2.7
Ortho P (mg/L)	45	22	0.003	0.037	0.0076	0.0075	<0.003
Silica (mg/L)	14	14	4.0	6.2	5.17	0.78	5.2
Sulfate (mg/L)	17	17	1.1	3.6	2.48	0.71	2.6
Fluoride (mg/L)	6	0					<0.1

Total Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	51	48	0.06	2.87	0.300	0.485	0.16
As	73	5	0.001	0.002	0.0014	0.0005	<0.001
Ca	52	52	5.03	9.12	6.880	0.930	6.83
Cd	73	0					<0.0005
Co	52	4	0.10	0.13	0.110	0.014	<0.1
Cr	52	3	0.01	0.02	0.013	0.006	<0.01
Cu	52	28	0.001	0.020	0.0031	0.0041	0.001
Fe	52	52	0.19	4.11	0.530	0.620	0.38
Mg	52	52	0.51	1.92	0.830	0.220	0.82
Mn	52	48	0.01	0.10	0.021	0.016	0.02
Mo	52	4	0.01	0.02	0.018	0.005	<0.01
Ni	52	1	0.06	0.06	0.06		<0.05
P	52	52	0.006	0.140	0.0230	0.0240	0.015
Pb	52	25	0.001	0.010	0.0030	0.0024	<0.001
V	52	2	0.01	0.03	0.02		<0.01
Zn	52	12	0.005	0.040	0.0126	0.0103	<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

Table 10.2 (continued) Water quality summary Lakelse River, Site 0400211, 1983-1987

Dissolved Metals (mg/L)	# of Values	# of Values above MDC[a]	Min.	Max.	Mean	Standard Deviation	50th%
Al	44	39	0.02	0.15	0.057	0.034	0.04
As	57	1	0.001	0.001	0.001		<0.001
B	44	0					<0.01
Ba	44	16	0.01	0.02	0.011	0.003	<0.01
Ca	44	44	4.93	8.78	6.540	0.930	6.46
Cd	56	0					<0.0005
Co	44	0					<0.1
Cr	44	0					<0.01
Cu	57	8	0.001	0.001	0.001		<0.001
Fe	47	45	0.07	0.29	0.172	0.058	0.18
K	14	14	0.40	0.60	0.490	0.070	0.50
Mg	44	44	0.44	0.93	0.700	0.130	0.73
Mn	44	27	0.01	0.02	0.013	0.005	0.01
Mo	44	1	0.01	0.01	0.01		<0.01
Na	15	15	2.00	3.40	2.680	0.390	2.70
Ni	44	0					<0.05
P	50	48	0.003	0.041	0.0093	0.0065	0.008
Pb	57	4	0.001	0.001	0.001		<0.001
V	44	0					<0.01
Zn	56	2	0.006	0.006	0.006		<0.005

Source: Wilkes and Lloyd 1990

[a] Minimum detectable concentration

The Lakelse River is exceptional in the group of seven Skeena watershed sites in having very low TSS as a result of being lake headed (mean=9.1 mg/L, range 1-79 mg/L). Turbidity, an indicator of suspended sediments, is also low. The Lakelse River is moderately coloured (mean=16.7 TCU), which is attributable to natural organic substances such as humic substances, tannins and lignins contributed by wetlands around the lake. Although colouration in drinking water may not be aesthetically pleasing, it is not harmful to human health. Lakelse pH was near neutral (mean=7.1) with a range of 6.7 to 7.6. Alkalinity is low (mean=21.1 mg $CaCO_3$/L) and very near the water quality criterion of >20 mg $CaCO_3$/L, indicating that the waterbody would be sensitivity to acidic inputs. All the Skeena watershed stations have soft water, but Lakelse waters are classified as very soft, with a mean hardness of 16.7 mg/L. Nutrients are generally low. Orthophosphate, a water quality variable which is usually limiting to productivity in lakes and streams, is low. Mean orthophosphate concentration is 0.008 mg/L; however, about half of the values recorded were less than the detection limit of <0.003 mg/L, so the 50th percentile (<0.003 mg/L) may better reflect the true "average" concentration. Metals concentrations were low, often less than the detection limits.

10.4.2 Water quality assessment and objectives

Water Quality Objectives for Lakelse Lake and tributaries are found in Table 10.3 (McKean 1986). Lakelse Lake is considered to be oligotrophic because of its low phosphorus concentrations, low oxygen depletion rates of the bottom waters, and low chlorophyll *a* concentrations. These attributes, in association with the lake's good water clarity, collectively determine the recreational and fisheries importance of the lake. Concern was for protection of drinking and recreational waters, particularly from impacts associated with the rural residential developments around the lake. These residences are served by septic systems most of which are located in soils with moderate suitability for septic tank tile fields. About 30% of the housing development, or 72 houses, of which 60 houses are adjacent to the lakeshore, are located on poor landforms.

Table 10.3 Provisional water quality objectives for the Lakelse Lake and tributaries

Water Bodies		Lakelse Lake	Tributaries to Lakelse Lake
Designated Water Uses		Drinking water, aquatic life, and recreational	Drinking water, aquatic life, recreation, and irrigation,
Fecal Coliforms[1]	Near water intakes	≤10/100 mL 90th percentile	
	At bathing beaches	≤200/100 mL geometric mean ≤400/100 mL 90th percentile	
Turbidity[2]		≤1 NTU average 5 NTU maximum	see footnote 4
Total Phosphorus[3]		≤0.010 mg/L average	not applicable
Chlorophyll a[3]		≤0.003 mg/L average	not applicable
Dissolved Oxygen		>6.0 mg/L @ 5m above sediment	not applicable

Source: McKean 1986

1 the geometric mean and 90th percentile are calculated from at least 5 weekly samples taken in a period of 30 days. The drinking water objective (10/100 mL) applies year-round and the recreation objective (200-400/100 mL) applies during the recreation season.

2 the average is calculated from at least 5 weekly samples taken in a period of 30 days and applies to any point of the water body. The objectives do not apply during the freshet season.

3 the average is calculated from a set of samples, taken mostly in the period of May to August at a site over the deepest part of the lake. For total phosphorus discrete samples taken at depths of 0.5, 6 and 30 m should be analyzed. For chlorophyll a, a composite of samples taken at depths of 0, 2, 4 and 6 m should be analyzed.

4 for streams with domestic water supplies: ≤1 NTU average
5 NTU maximum

for streams without water licenses: The induced turbidity shall not exceed 5 NTU when background turbidity is ≤50 NTU nor shall the induced turbidity be more than 10% of background when background is >50 NTU.

A monitoring program was recommended, to check compliance of the water quality objectives, as well as provide a biological and water quality database. The monitoring entailed testing drinking water intakes for fecal coliforms and turbidity. Monthly monitoring (May to August) was recommended for phosphorus and other nutrients, chlorophyll *a* and hypolimnetic oxygen. Monitoring to determine the attainment of the water quality objectives was carried out in 1988 - 1992. This is published in an annual report of Objectives attainment in the province. The Lakelse water quality objectives were attained in 1988-89. In 1990-91 the chlorophyll *a* objective was exceeded at Site E206616, at the north end, deepest point, with average concentrations of 0.004 and 0.0042 mg/L. In 1992 the total phosphorus objective was exceeded at the same site with an average concentration of 0.016 mg/L (n=9).

10.4.3 Productivity of Skeena watershed sockeye nursery lakes, 1994

Monthly limnological surveys were carried out by DFO on Lakelse Lake during May-October 1994 as part of a survey of selected Skeena sockeye nursery lakes. Further description of the project and productivity comparison with four other lakes is found in Section 1.3.5.2. Preliminary water quality data from this project are found in Table 10.4.

Table 10.4 Lakelse Lake water quality and productivity May -October 1994 (mean epilimnetic concentrations)

Date	Temp °C	pH	Secchi depth m	Euphotic zone depth m	TDS mg/L	Total alkalinity mg CaCO3/L	Total P ug P/L	Nitrate ug N/L	Total Chlorophyll ug/L	Photosyn-thetic rate mg C/m2/d
18-May-94	12.0	7.36	3.5	4.9	44	20.81	4.8	31.0	1.45	111.7
14-Jun-94	13.7	7.29	3.5	6.3	79	19.85	5.9	7.4	2.57	109.3
12-Jul-94	16.4	7.28	5.9	8.3	37	19.47	4.6	2.4	0.67	69.3
16-Aug-94	19.9	7.39	5.0	8.5	43	24.10	4.5	1.4	1.31	122.0
7-Sep-94	16.9	7.45	5.2	9.8	36	23.68	5.8	4.6	1.31	99.5
30-Sep-94	13.7	7.15	2.5	6.8	33	23.15	7.8	21.9	0.97	24.6

Lakelse Lake is the lowest elevation and most coastal of the sockeye rearing lakes studied with the warmest temperatures (maximum 19.9 °C in August). Lakelse has relatively low dissolved solids and alkalinity. It is oligotrophic, and its primary productivity (as photosynthetic rate) is 43 percent lower than that of Babine Lake. Physics (light, climate and thermal regime) and chemistry (levels of nitrogen and phosphorus) suggest that increased nutrient loading would quickly increase lake productivity and phytoplankton biomass in Lakelse Lake. Further, already low N:P ratios indicate that increases in phosphorus loading without concomitant increases in nitrogen loading could result in the development of undesirable blue-green algal blooms (K. Shortreed, personal communication).

10.4.3.1 Discussion

There is a noticeable difference in the 1992 total phosphorus concentrations reported by EPP of mean=16 µg/L (n=9), and those reported in 1994 by DFO of mean=5.6 µg/L (n=6). These samples were all taken over the deep basin of the lake. The reason may be that different analytical methods were used by the two agencies. The EPP laboratory uses the ascorbic acid colorimetric method. The DFO laboratory began using the more sensitive stannous chloride colorimetric method of phosphorus determination in the early 1980's, because of the very low phosphorus concentrations encountered in most British Columbia waters (E. MacIsaac, DFO, personal communication). In addition, the orthophosphate analysis is very sensitive to natural coloration in waters, therefore turbidity and color correction are made at the DFO laboratory.

10.5 LIQUID WASTE DISCHARGES

10.5.1 Mount Layton Hotsprings PE-7531

10.5.1.1 Background

Mount Layton Hotsprings is located on the east side of Lakelse Lake on Highway 37 approximately 21 km south of Terrace. In 1959, a motel and pool were constructed, and the hotsprings were operated successfully until 1969. Under the new ownership which followed, the facilities fell into disrepair and eventually ceased operating altogether in 1979, at which time the facilities were taken over by the province.

It was during this latter era that the then Pollution Control Branch became involved. At that time sewage from the resort was treated in an extended aeration package treatment plant and discharged into a 850 meter canal, leading to the lake. A permit was issued on July 31, 1973 and soon developed a history of non-compliance, due mostly to lack of maintenance on the part of the owners.

Between 1979 and 1985 the resort once again fell into dormancy under the auspices of the province, who tried several times unsuccessfully to auction the property. In 1985 Mount Layton Hotsprings Ltd. put forth a development proposal and a successful bid, obtaining the hotsprings in September of that year.

An application requesting authorization to discharge sewage effluent from the proposed resort was submitted to the Waste Management Branch in February 1986. The permit was issued on September 2, 1986 for the discharge of tertiary treated sewage effluent to Lakelse Lake.

The major environmental concern regarding Lakelse Lake is its level of phosphorus. It has been described as a phosphorus limited system that is in danger of becoming mesotrophic, or even eutrophic.

10.5.1.2 Permitted Discharge

Permit PE-7531 allows a maximum discharge rate of 30 m^3/day. The characteristics of the effluent shall be equivalent to or better than 2.0 mg/L total phosphorus from the alum settling chamber and 30 mg/L BOD, 40 mg/L TSS final discharge from the canal. The works authorized are alum addition facilities, a pumphouse, 2 concrete settling chambers, 2 facultative lagoons, disinfection facilities, a cattail lagoon and related appurtenances.

Table 10.5 presents the data from the outfall. Monitoring data from the outfall shows consistent compliance with permit requirements from March 1992 until April 1994. Total phosphorus is exceeded on a number of occasions at the settling chamber during this same time period (Table 10.6). It would appear that even though these exceedances exist, by the time the discharge reaches the outfall, the phosphorus limits have fallen well below the permit requirement of 2.0 mg/L.

Table 10.5 Effluent quality Mt. Layton Hotsprings PE-7531, 1992-1994

	TSS	BOD	Fecal Col.	Total P
Date	mg/L	mg/L	col/100 ml	mg/L
03/26/92	1	<10	<1	0.500
04/01/92	1			0.050
04/21/92		2.1		
04/30/92			3	
05/13/92	1	2.2	8	0.090
05/17/92				
06/21/92	3	<10	<1	0.040
07/31/92	1	<10	6	0.090
08/25/92	2	<10	<1	0.039
09/30/92	1	<10	<1	0.150
10/25/92	1	<10	<1	0.042
11/09/92	2	<10	<1	0.023
03/25/93	1	<10	<1	0.031
04/27/93	1	<10	<1	0.057
05/17/93	3	<10	<1	0.051
06/24/93	13	<10	<1	0.018
07/19/93	6	<10	<1	0.074
08/18/93	5	<10	<1	0.087
09/01/93		<10		
09/02/93	32		32	0.227
10/20/93	6	<10	<1	
10/21/93				0.033
11/03/93				0.234
11/17/93	6	<10	<1	
03/30/94	3	<10	<1	0.050
04/18/94	2	<10	<1	0.021

Table 10.6 Total phosphorus at alum settling chamber, Mt. Layton Hotsprings PE-7531, 1992-1994

	Total-P		Total-P
Date	mg/L	Date	mg/L
1/5/92	0.830	3/25/93	1.507
2/22/92	0.830	4/30/93	2.960
3/6/92	1.440	5/21/93	1.970
4/3/92	2.200	6/28/93	2.860
5/17/92	3.230	7/19/93	3.150
6/21/92	3.460	8/18/93	2.110
7/31/92	5.300	9/2/93	1.933
8/31/92	3.400	10/21/93	2.123
9/30/92	0.100	11/3/93	0.767
10/25/92	3.617	12/31/93	2.380
11/22/92	1.230	1/31/94	2.783
12/15/92	3.070	2/1/94	2.790
1/29/93	1.520	3/30/94	3.457
2/23/93	1.930	4/18/94	3.710

On August 12, 1993, Mt. Layton Hotsprings submitted an application for amendment to the existing permit. The request was to amend the existing permit PE-7531 such that testing take place on the outfall, and the settling chamber if and only if there is discharge from the outfall into Lakelse Lake. It was also requested that testing discontinue on the receiving waters and that the addition of alum take place if and only if there is a positive discharge into the lake.

The file is currently being reviewed to determine if these requests can be amended into the permit without jeopardizing the quality of the receiving environment.

10.5.1.3 Receiving Environment monitoring

The receiving environment program required by Permit PE-7531 is as follows:

Site 1 100 m NE of canal E207316;
Site 2 25 m SW of canal E207317;
Site 3 100 m SW of canal E207318;
Site 4 in canal at lake confluence E207319;
Site 5 in canal, 25 m downstream from point of discharge E207320.

VARIABLE	SAMPLING FREQUENCY	LOCATION	DEPTH
fecal coliform MPN/100 mL	samples taken every six days during the months of April, July, August and October	Sites 1, 2, 3, 4 & 5	surface
total phosphorus mg/L	once per month for May, June, July, August, September and October	Sites 1, 2, 3, 4 & 5	surface
ortho phosphorus mg/L	once per month for May, June, July, August, September and October	Sites 1, 2, 3, 4 & 5	surface

Sampling sites are shown in Figure 10.1. Monitoring data for 1992-1993 are shown in Table 10.7.

Table 10.7 Lakelse Lake water quality, Mt. Layton Hotsprings PE-7531, 1992-1993

Date	Site 1			Site 2			Site 3		
	Total P mg/L	Ortho P mg/L	Fecal Col. /100 ml	Total P mg/L	Ortho P mg/L	Fecal Col. /100 ml	Total P mg/L	Ortho P mg/L	Fecal Col. /100 ml
04/03/92			<1			<1			<1
04/10/92			<1			<1			<1
04/18/92			<1			1			6
04/25/92			<1			1			8
04/30/92			<1			<1			3
05/03/92	0.05	0.03		0.05	0.03		0.11	0.02	
06/22/92	0.03	0.02		0.04	0.02		0.04	0.02	
07/04/92	0	0	<1			<1			<1
07/10/92	0	0	1			<1			<1
07/17/92			<1			<1			<1
07/22/92			1			<1			<1
07/29/92			2.2			5.1			2.2
07/31/92	0.03	0.02		0.03	0.01		0.02	0.01	
08/07/92			<1			<1			1
08/12/92			<1			<1			<1
08/19/92			2			1			<1
08/20/92	0.007	0.022		0.18	0.04		0.016	0.024	
08/24/92			<1			<1			<1
08/28/92			<1			<1			1
09/08/92			1			1			4
09/11/92			3			4			10
09/16/92			5			3			1
09/27/92			20			21			23
10/05/92			30			43			35
10/12/92			31			14			9
10/19/92			3			4			3
10/25/92	0.026	0.014	14	0.024	0.033	15	0.03	0.007	23
10/30/92			4			9			5
04/01/93			<1			<1			<1
04/07/93			<1			<1			<1
04/13/93			2			1			<1
04/19/93	0.023	0.014	20	0.033	0.034	4	0.04	0.024	2
04/25/93						12			6
05/17/93	0.051	0.033		0.023	0.015		0.017	0.012	
06/24/93	0.017	0.01		0.007	0.012		0.01	0.008	
07/01/93			<1			<1			1
07/07/93			3			<1			1
07/13/93			53			11			13
Average	0.023	0.016		0.048	0.024		0.035	0.016	

Table 10.7 (continued) Lakelse Lake water quality, Mt. Layton Hotsprings PE-7531, 1992-1993

Date	Site 4 Total P mg/L	Site 4 Ortho P mg/L	Site 4 Fecal Col. col/100 ml	Site 5 Total P mg/L	Site 5 Ortho P mg/L	Site 5 Fecal Col. col/100 ml
04/03/92			<1			<1
04/10/92			<1			2
04/18/92			<1			3
04/25/92			<1			6
04/30/92			<1			<1
05/03/92	0.04	0.02				
05/17/92				0.12		
05/18/92					0.09	
06/22/92	0.04	0.02		0.05	0.02	
07/04/92			1			2
07/10/92			3			3
07/17/92			2			6
07/22/92			3			2
07/29/92			2.2			2.2
07/31/92	0.03	0.01		0.55	0.86	
08/07/92			26			36
08/12/92			1			7
08/19/92			3			6
08/20/92	0.019	0.017		0.13	0.08	
08/24/92			2			10
08/28/92			8			7
09/08/92			12			13
09/11/92			5			5
09/16/92			15			14
09/27/92			30			2
09/30/92				0.116	0.034	
10/05/92			2			<1
10/12/92			7			<1
10/19/92			3			<1
10/25/92	0.039	0.005	1	0.039	0.011	1
10/30/92			4			<1
04/01/93			<1			<1
04/07/93			<1			<1
04/13/93			<1			<1
04/19/93	0.062	0.022	<1	0.057	0.025	<1
04/25/93			4			4
05/17/93	0.024	0.015		0.005	0.019	
06/24/93	0.012	0.01		0.019	0.021	
07/01/93			<1			2
07/07/93			78			
07/13/93			28			52
07/19/93	0.095	0.074	6	0.087	0.077	9
07/25/93			6			6
07/31/93			76			40
08/06/93			13			5
08/12/93			1			31
08/18/93	0.041	0.028	<1	0.252	0.068	<1
08/24/93			<1			18
08/30/93			2			<1
09/02/93	0.036	0.03	15	0.064	0.019	28
10/02/93			<1			2
10/08/93			3			2
10/14/93			3			4
10/20/93			35			47
10/21/93	0.006	0.004		0.029	0.003	
10/26/93			14			14
11/03/93	0.059	0.047				
Average	0.039	0.023		0.117	0.102	

10.5.1.4 Discussion

The Lakelse Lake Water Quality Assessment and Objectives (1986) sets an objective of ≤10 µg/L (≤0.010 mg/L) average total phosphorus over the spring and summer periods. The objective applies to the average of at least four monthly samples taken from May to August, at a site over the deepest part of the lake.

Samples taken at the five receiving environment monitoring sites near the hotsprings resort discharge during 1992 and 1993 exceeded this objective. High total phosphorus and orthophosphate concentrations are found in the canal at sites 4 and 5. It is not clear from this data what the flow rate is from the canal to the lake. Average total phosphorus concentrations in the vicinity of the entrance of the canal (sites 1, 2 and 3) are 0.023, 0.048 and 0.035 mg/L (n=8), which are two to four times the objective level for the lake.

The available data indicate that no decrease in the level of alum treatment or receiving environment monitoring should occur at this facility. However, it is believed that the permittee may be preparing these analyses in an on-site laboratory (D. Portman, EPP, personal communication). It is suggested that these data should be reviewed in terms of applicability of analytical method, quality control and quality assurance. The analytical method required to determine phosphorus levels in the range required to monitor an alum addition facility (in mg/L), may not be appropriate for monitoring the much lower concentrations in the receiving environment (in µg/L). Discussion of analytical methods for phosphorus determination is found in section 10.4.3, as well as the need to perform a color correction prior to analysis in moderately coloured waters such as Lakelse Lake.

10.6 SUMMARY AND REVIEW OF MONITORING NEEDS

The largest concern in this reach is the maintenance of water quality in Lakelse Lake, a popular sport fishing and recreational lake, with populations of steelhead and coastal cutthroat trout and sockeye salmon. The density of waterfront permanent and recreational residences along the lakeshore is a concern. A number of hot springs occur on the eastern shore of Lakelse Lake and a resort with hot and cold pools, waterslides, hotel and restaurant discharges tertiary treated sewage to the lake. Forestry is the main land-use activity in the remainder of the watershed.

10.6.1 Water quality assessment

Lakelse Lake is considered to be oligotrophic because of its low phosphorus concentrations, low oxygen depletion rates of the bottom waters, and low chlorophyll *a* concentrations. These attributes, in association with the lake's good water clarity, collectively determine the recreational and fisheries importance of the lake. Physics (light, climate and thermal regime) and chemistry (levels of nitrogen and phosphorus) suggest that increased nutrient loading would quickly increase lake productivity and phytoplankton biomass in Lakelse Lake. Further, already low Nitrogen:Phosphorus ratios indicate that increases in phosphorus loading without concomitant increases in nitrogen loading could result in the development of undesirable blue-green algal blooms.

The concern has been for protection of drinking and recreational waters, particularly from impacts associated with the rural residential developments around the lake. These residences are served by septic systems most of which are located in soils with moderate suitability for septic tank tile fields. About 30% of the housing development, or 72 houses, of which 60 houses are adjacent to the lakeshore, are located on poor landforms for septic disposal.

The Lakelse River has exceptionally low TSS and turbidity levels, as a result of being lake headed, and the waters are classified as very soft. The Lakelse River is moderately coloured, which is attributable to natural organic substances such as humic substances, tannins and lignins contributed by wetlands around the lake. Although colouration in drinking water may not be aesthetically pleasing, it is not harmful to human health. The pH is near neutral, and alkalinity is low and very near the water quality criterion of >20 mg $CaCO_3$/L, indicating that the lake would have some sensitivity to acidic inputs. Nutrient concentrations are generally low. Total phosphorus concentration is mean=0.023 mg/L. Orthophosphate concentration is less than the detection limit of <0.003 mg/L (50th percentile). Total metals concentrations occasionally exceed the MOELP criteria for protection of aquatic life. Dissolved metals levels are often less than the detection limits.

10.6.2 Interaction of forestry and water quality

10.6.2.1 Stream protection practices

An audit of the effectiveness of the Coastal Fisheries Forestry Guidelines was conducted in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts in 1992. In the Kalum district, 53% of the stream reaches inspected had impacts due to logging, which was considerably higher than the average recorded in the QCI District or on Vancouver Island. The amount of fish habitat lost in Class I - III streams ranged from 3.9% (QCI) to 15.7% (North Coast) of the total habitat inspected, most of it in small streams. Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts, followed by bank scouring and channel scouring.

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO was lowest in the Kalum District (57.1%). Compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was generally poor (29.9%). When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams.

10.6.2.2 Thunderbird Integrated Resource Management Plan

Recognizing that future harvesting activities would be constrained due to past practices and the high fisheries, wildlife and recreation values within the Lakelse area, an interagency integrated resource management plan was developed for the Thunderbird forest area in 1992. The plan establishes a Lakelse River Management Zone approximately 1 km on either side of the Lakelse River with the priority of protecting the fish habitat and Class II angling waters, as well as riparian corridors on other streams. A special management zone is established over wetlands to the north and south of Lakelse Lake. Numerous streams at the south end of Lakelse Lake are spring fed and have hydrological characteristics of value to the maintenance of the Lakelse fisheries.

10.6.2.3 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is a major land use activity in this watershed. A 1992 audit of stream protection practices in the Kalum TSA found poor compliance with stream protection guidelines, and indicated that impacts were occurring mainly in small Class I-III streams, resulting in loss of fish habitat. The FPC is expected to improve compliance with stream protection guidelines and the Watershed Restoration Program is intended to address problems such as lack of road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and immediate remedial actions. Implementation monitoring, such as the audit mentioned, is also necessary to ensure that LRMP management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.2.

10.6.3 Interaction of urban developments and water quality

10.6.3.1 Mount Layton Hotsprings Resort

Mount Layton Hotsprings Resort, which operates hot and cold pools, water slides, restaurant and motel on the east shore of Lakelse Lake, has a permit for the discharge of tertiary treated sewage effluent to Lakelse Lake. The system consists of alum addition facilities for the removal of phosphorus, two settling chambers, two facultative lagoons, disinfection facilities, a cattail lagoon and discharge into a canal leading to the lake. The permit allows a maximum discharge rate of 30 m^3 per day, and requires the characteristics of the effluent to be equivalent to or better than 2.0 mg/L total phosphorus (from the alum settling chamber), with 30 mg/L BOD and 40 mg/L TSS in final discharge from the canal.

Monitoring data from the outfall submitted by the permittee during 1992-1994 show consistent compliance with permit requirements, although total phosphorus is exceeded on a number of occasions at the alum settling chamber during this same time period. It appears that even though these exceedances exist, by the time the discharge reaches the outfall, the phosphorus limits have fallen below the permit requirement of 2.0 mg/L.

Mt. Layton Hotsprings submitted an application for amendment to the existing permit in 1993 requesting a reduction in monitoring requirements and requesting that the addition of alum take place if and only if there is a positive discharge into the lake.

The Lakelse Lake Water Quality Objectives sets an objective of ≤0.010 mg/L average total phosphorus over the spring and summer periods. The objective applies to the average of at least four monthly samples taken from May to August, at a site over the deepest part of the lake.

Samples taken at the five receiving environment monitoring sites near the hotsprings resort discharge during 1992 and 1993 exceeded this objective. High total phosphorus and orthophosphate concentrations are found in the discharge canal; however, the flow rate from the canal to the lake is not specified. Average total phosphorus concentrations in the vicinity of the confluence of the canal with the lake are 0.023, 0.048 and 0.035 mg/L (n=8), which are two to four times the objective level for the lake.

The available data indicate that a decrease in the level of alum treatment or receiving environment monitoring would not be justified at this facility. It is believed that the permittee may be preparing these phosphorus analyses in an on-site laboratory (D. Portman, EPP, personal communication). It is suggested that these data should be reviewed in terms of applicability of analytical method, quality control and quality assurance. The analytical method required to determine phosphorus levels in the range required to monitor an alum addition facility, may not be appropriate for monitoring the much lower concentrations in the receiving environment. Discussion of analytical methods for phosphorus determination is found in section 10.4.3, as well as the need to perform a colour correction prior to analysis in moderately coloured waters such as Lakelse Lake.

Nitrogen to phosphorus ratios suggest that increased phosphorus loading to Lakelse Lake could result in the development of undesirable blue-green algal blooms or eutrophication. A review of all monitoring data for Lakelse Lake should be undertaken, with particular reference to appropriate analytical methods for phosphorus determination. If necessary, a season or more of detailed monitoring for sources of phosphorus loading to the lake should be completed. Any changes in the permitted discharges from the hotsprings resort should be based on this review.

Management of the unincorporated residential area around the lake has been suggested by water quality experts for many years. The advisory committee for the Thunderbird IRMP has noted that many residences around the lake have septic systems which have never been inspected and recommended improved septic system inspection and requirements for compliance with modern standards in order to maintain water quality. The recommendation was also made that no further vacant crown land on the foreshores of the lake should be alienated. The Lakelse Lake community and regional district should be encouraged to act upon these recommendations.

11. LOWER SKEENA RIVER

The Skeena River flows westward to meet the Pacific just south of the port city of Prince Rupert. The upper reach of tidal influence is encountered at about the Kasiks River (Figure 11.1). The valley below Terrace is a steep-sided former fiord which cuts through the Coast Mountains. The Skeena carries a heavy sediment load, and essentially the whole Skeena fiord has been filled in the last 10,000 years (Gottesfeld 1985). The resulting fill, comprising the Skeena valley below Terrace, is about 140 km long, 10 km wide and at least 100 m deep. The gradient of the Skeena River in this stretch is 40 to 50 cm/km, low enough for commercial river boat travel, and just high enough to transport the sediment still coming down the Skeena out to the estuary. The river in this reach is braided with many abandoned and active side channels.

Major tributaries in this reach are the Zymagotitz, Lakelse, Exstew, Gitnadoix, Exchamsiks, Kasiks and Khyex Rivers. The Ecstall River enters the Skeena at the estuary, and the lower reaches of the Ecstall are tidal. For this reason, the Ecstall is not considered as a tributary in this assessment. The lower parts of these valleys were flooded by the sea at the close of glaciation, at the time the entire Skeena valley below Terrace was a fiord. Like the Skeena, the mouths of these river valleys have been isostatically uplifted and filled with sediment since the end of the Pleistocene. As a result, the lower reaches of many tributaries in this reach, for example the Exstew, Exchamsiks and Gitnadoix, have floodplains with braided river channels and numerous wetlands.

The Gitnadoix River watershed, headed by Alastair Lake, has been made a Provincial Recreation Area because of the excellent sport fishing for a range of salmon and trout species. The Gitnadoix River and tributaries is one of only five Class I streams in the province, which are unique in providing special fishing opportunities in a wilderness setting. The Skeena from the Exchamsiks River to above Terrace is Class II water. See section 2.2.4 for explanation of classified waters.

11.1 HYDROLOGY

Precipitation is heavy on the windward side of the Coast Ranges and the tributary streams are large, particularly the Exstew, Exchamsiks, and Gitnadoix. The monthly discharge summary for the Zymagotitz River near Terrace, Station 08EG011 is shown in Table 11.1 and streamflow envelope in Figure 11.2. The operation of this station was discontinued in 1995. The discharge summary and streamflow envelope for the Exchamsiks River Station 08EG012, which joins about half way to the mouth of the river, are shown in Table 11.2 and Figure 11.3. Because of the strong coastal influence, discharge peaks in the Exchamsiks can often occur during late autumn rains rather than during snowmelt in May/June.

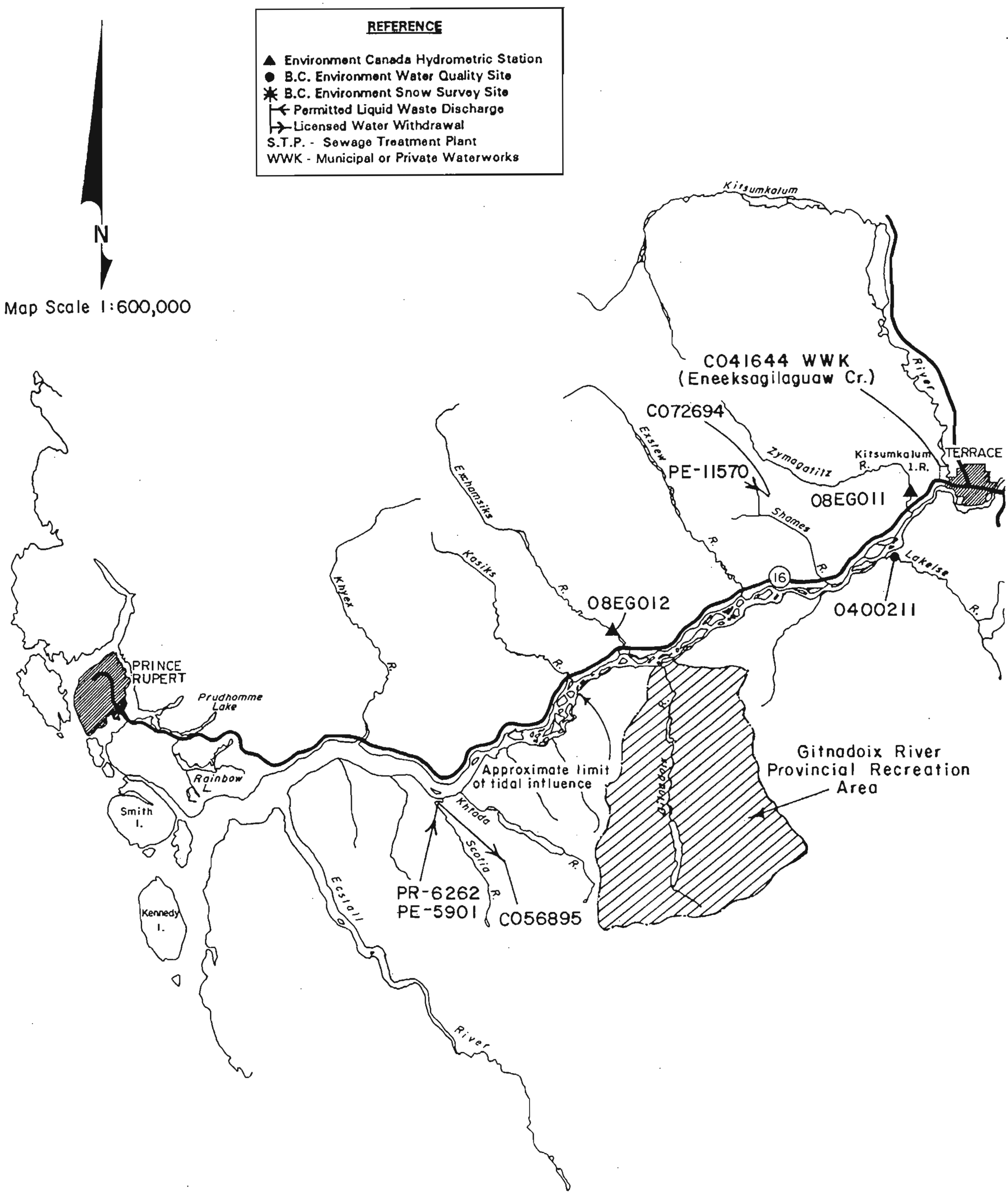


Figure 11.1 Lower Skeena River

Table 11.1 Monthly discharge summary Zymagotitz River near Terrace, Station 08EG011

Latitude: 54 31 07 N
Longitude: 128 43 40 W
Drainage Area Gross: 376 km2
Period of Record 1960-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	21.3	18.3	16.6	23.3	56.9	86.3	70.9	51.2	61.0	69.7	34.0	32.9
Monthly Min.	2.23	1.70	2.00	7.31	25.3	34.0	24.5	18.1	12.0	13.2	5.76	2.81
Monthly Mean	6.28	6.60	6.85	15.4	38.2	55.9	44.3	29.2	24.6	30.2	17.6	8.81

Figure 11.2 Discharge envelope Zymagotitz River near Terrace

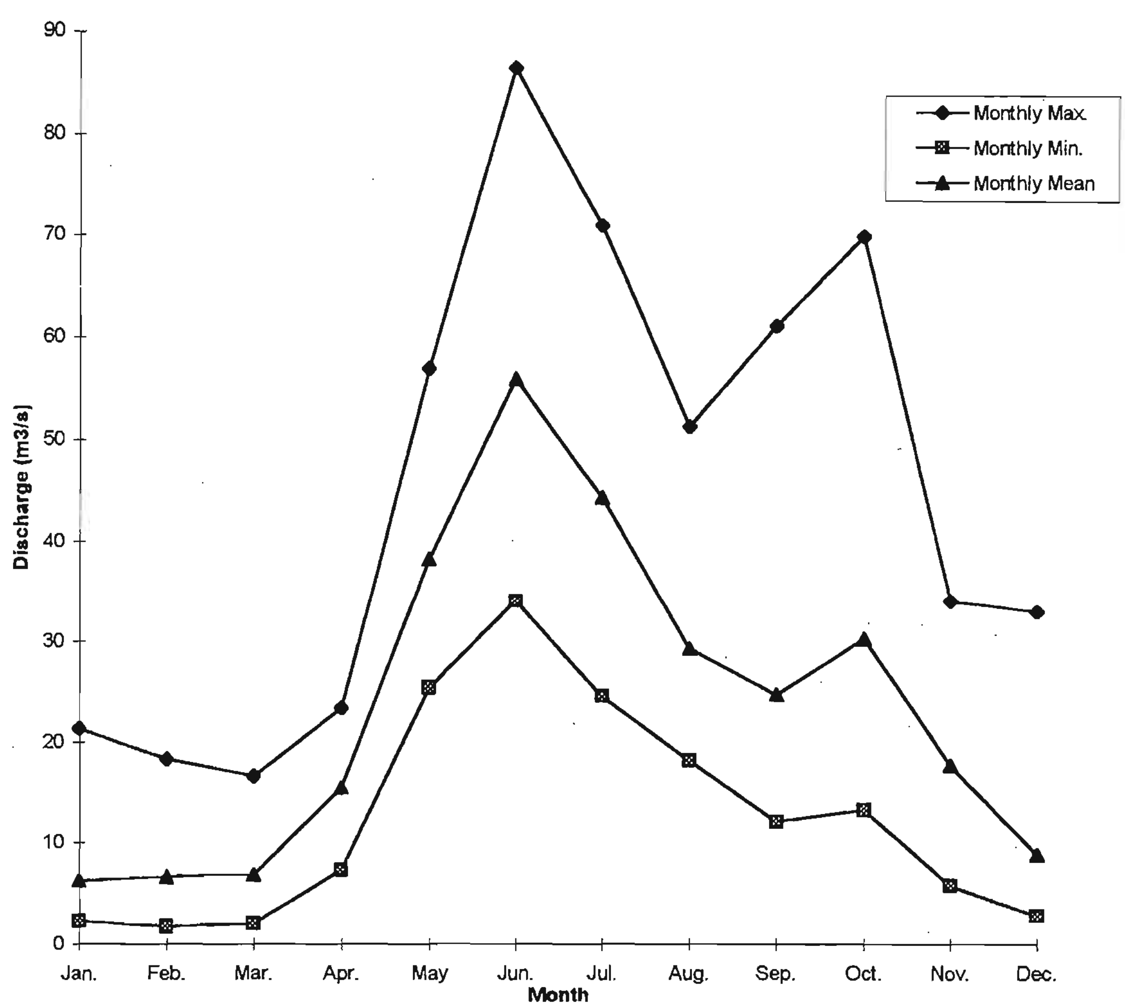
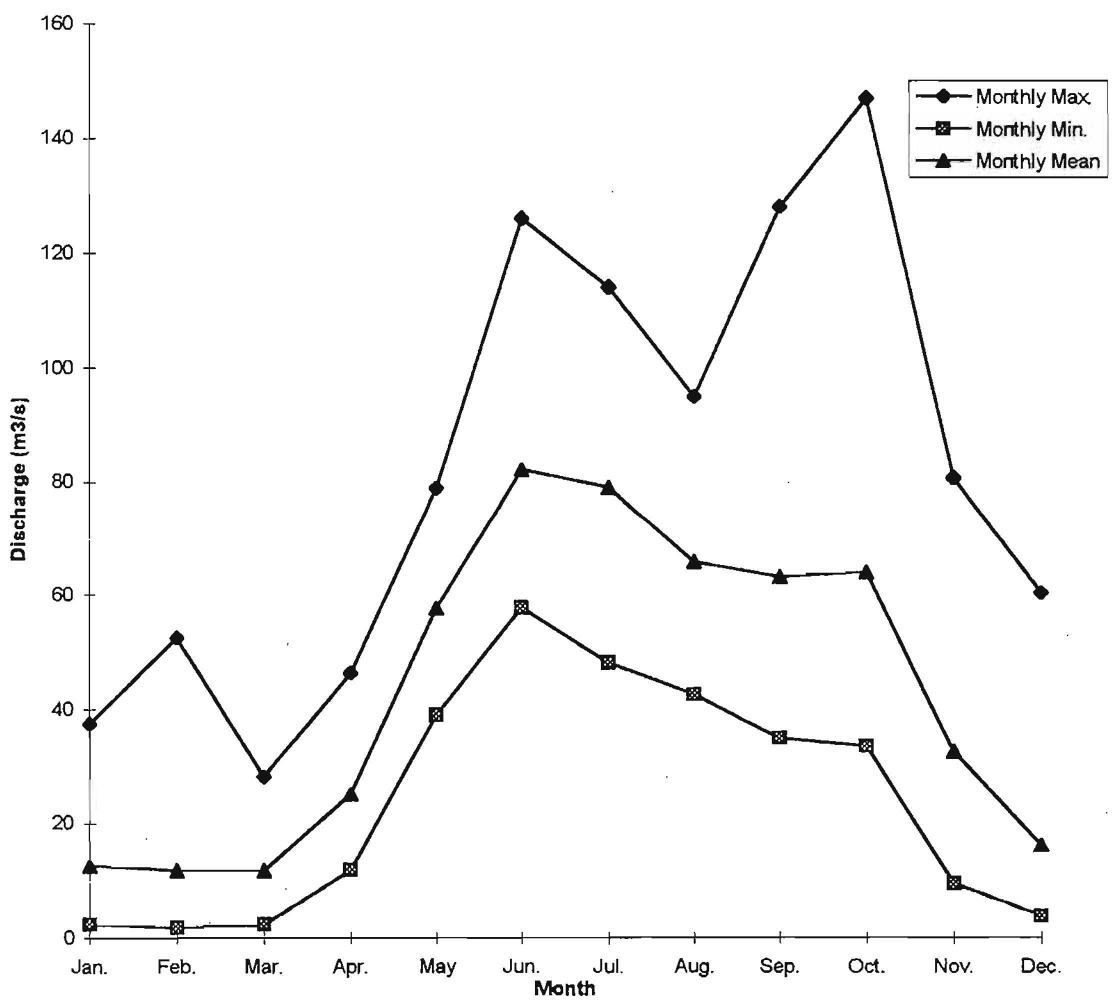


Table 11.2 Monthly discharge summary Exchamsiks River near Terrace, Station 08EG012

Latitude: 54 21 47 N
Longitude: 129 18 41 W
Drainage Area Gross: 370 km2
Period of Record 1962-1993

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Max.	37.5	52.5	28.1	46.3	78.9	126	114	95	128	147	80.8	60.5
Monthly Min.	2.22	1.71	2.32	11.8	39.0	57.8	48.0	42.5	34.9	33.5	9.35	3.79
Monthly Mean	12.5	11.7	11.7	25.1	57.6	82.2	79.0	65.9	63.2	64.0	32.5	16.1

Figure 11.3 Discharge envelope Exchamsiks River near Terrace



11.2 LAND USE HISTORY

11.2.1 Settlements

Ten groups of Coast Tsimshian people had winter villages on the lower Skeena (Sturtevant 1990). In late prehistoric times, they extended their territories coastward and built new villages on the islands of Venn Passage near Prince Rupert, continuing to return to the Skeena in the summers for salmon fishing. After the Hudson's Bay Company moved Fort (later Port) Simpson to its present location in 1834, they moved to the area surrounding the fort.

In the 1870's the Skeena River had been shown to be navigable route to the Omineca gold fields of the northern interior (Large 1957). The trading post of Port Essington was built on the south bank of the Skeena just below the mouth of the Ecstall River. The traffic of prospectors up the Skeena soon petered out, but Port Essington became the site of three canneries, a hotel and a thriving village. Another cannery was founded at the mouth of the Khyex River, and three on the Ecstall River. With the completion of the railway, Port Essington's importance in the river trade disappeared, and eventually the up-river canneries also closed. There are no permanent settlements remaining on the lower Skeena.

11.2.2 Forestry

The Skeena watershed east of the Khyex River is within the Kalum Forest District. The major forestry operators are West Fraser's Skeena Sawmills Ltd. and Skeena Cellulose Inc. both with mills in Terrace. TFL 1, held by Skeena Cellulose Inc., covers the tributaries entering the south side of the river between the Lakelse and Gitnadoix watersheds. A LRMP planning process is underway for the Kalum TSA, which will also encompass TFL 1. Most of the major tributaries have seen roadbuilding and logging in the past.

The lower reaches of the Skeena are in the North Coast Forest District. International Forest Products (Interfor) operates in the Khtada River, Scotia River and Ayton Creek watersheds. Interfor operates a camp at the mouth of the Scotia River, where they also hold foreshore leases for log handling and storage. Logs are transported by barge to mills on the south coast. Boyle & Dean operate in the Big Windsor, Little Windsor, LachMach River and Green River watersheds.

11.2.2.1 Application and effectiveness of the Coastal Fisheries Forestry Guidelines in the Kalum and North Coast Forest Districts

Tripp and others (1993) conducted an assessment of the effectiveness of the Coastal Fisheries Forestry Guidelines (see section 2.2.7) in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts, as part of a coastwide audit. Results of a survey of 50 cut blocks, in the fall of 1992, showed there was considerable variation between forest districts and logging companies in compliance with either site specific stream prescriptions, or the more general Coastal Fisheries Forestry Guidelines.

Hill slope accounted for a large part of the variation - the steeper the slopes, the poorer the compliance and the more frequent the impacts. The steep blocks in the Kalum District (average block slope 35.1%) and North Coast districts (average block slope 40.3%) had 2.20 and 3.35

impacts per 100 ha, respectively. The Kalum and North Coast Districts had two and three times the number of impacts recorded per unit area in the QCI District and were also considerably higher than the average recorded on Vancouver Island. In Class IV streams, the number of major/moderate alterations to the channel was approximately 2.2 times higher in both the Kalum and North Coast Districts than on Vancouver Island.

Amount of habitat lost in fish bearing Class I-III streams was 15.7% of the total habitat inspected on the North Coast. Stream areas affected in Class IV streams with moderate to high transport potentials were much higher (88.7%). Estimated reductions in stream stability were higher in Kalum (50.0%) and North Coast (71.4%) than in QCI or on Vancouver Island.

Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts, followed by bank scouring and channel scouring.

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO was 57.1% in Kalum and 86.2% in North Coast. Overall compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was assessed at 65% in Kalum and 53% in North Coast. The differences were significant, and consistent with the degree of impact observed in streams in each district, particularly fish-bearing streams. When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams in 214 out of the 217 cases (98.6%).

11.3 WATER WITHDRAWALS

A summary of licensed water withdrawals from the Skeena River in this reach is found in Table 11.3. Water withdrawals are low in this reach, with only one irrigation and 12 domestic licenses. Shames Mountain Ski Corporation holds a license on Galloway Creek, and Interfor holds a license for a work camp on the Scotia River.

Table 11.3 Licensed water withdrawals lower Skeena River

Input streams							
Domestic/stock watering			Waterworks				
GD	m3/d	m3/s	License	Licensee	GD	m3/d	m3/s
(12 licences)			C072694	Shames Mtn. Ski Corp.	66000	300.0	3.47E-03
18000	81.8	9.47E-04		(Galloway Cr.)			
Irrigation*			Work Camp				
AF	m3/d	m3/s	License	Licensee	GD	m3/d	m3/s
(1 licence)			C056895	International Forest Products Ltd.	10000	45.5	5.26E-04
10	205.6	2.38E-03		(Scotia R.)			

11.4 LIQUID WASTE DISCHARGES

11.4.1 Shames Mountain PE-11570

11.4.1.1 Background

The Shames Mountain ski area is located 35 km northwest of Terrace, B.C. with the access road located 20 km west of Terrace on Highway 16. The ski area was opened for business on November 13, 1991. The average number of skiers for the 1991/1992 season was 267/day.

11.4.1.2 Permitted discharge

Permit PE-11570 allows for a maximum discharge rate of 27 m^3/day. The average authorized rate of discharge is 4.5 m^3/day. The operating period during which the effluent will be discharged is from November 1 to August 30 each year.

The required characteristics of the effluent are based the following dilution ratios:

Dilution >20:1 but <200:1	Dilution >200:1 but <2000:1
BOD 30 mg/L	BOD 45 mg/L
TSS 40 mg/L	TSS 60 mg/L

The permit also requires a Rainbow Trout 96 hr LC50 of 100%.

The works authorized are a grease tank, a septic tank, a primary settling tank, a complete-mix aeration tank, a final clarification tank, a sludge recycling pump and pipeline, an outfall and related appurtenances.

The effluent monitoring requirements are as follows:

Parameter	Sample Type	Sampling Frequency	Reporting Frequency
Effluent Flow Rate, m^3/day	Field measurement	Continuously	M*
Effluent Temperature, C	Field Measurement	Monthly (M)	M**
Dissolved Oxygen, mg/L	Field Measurement	M	M**
pH	Field Measurement	M	M**
BOD, mg/L	Composite, lab analysis	M	M**
TSS, mg/L	Composite, lab analysis	M	M**
Ortho-Phosphorus, mg/L	Composite, lab analysis	Quarterly (Q)	Q**
NH3 - N, mg/L	Composite, lab analysis	Q	Q**
96-hour LC50	Static bioassay	A (Annually)	A***

* At the end of each month, the maximum hourly and the average daily discharge rates of the preceding 30 days are recorded, and the effluent flow data submitted within 31 days of the end of the monitoring period.

** Monthly (M) or quarterly (Q) within 31 days of the end of the monitoring period. Quarterly samples are to be taken on the same date as the monthly samples.

*** Annual composite sample shall be taken on the same date as the monthly sample(s).

11.4.1.3 Receiving Environment Monitoring

According to the technical report for Permit PE-11570, the discharge at this site is to Galloway Creek which drains into the Shames River. The distance from the creek to Shames River is about 1 km. From there it is another 9 km to the Skeena River. Galloway Creek is not considered fish producing due to its steepness. However, the Shames River has an annual average escapement of 2500 chum and 200 pink salmon near its confluence with the Skeena River, and a few hundred coho near the confluence with Galloway Creek.

The permittee is required to obtain a grab sample of Galloway Creek at 2 sites: 30 m upstream and 980 m downstream of the outfall. Receiving environment monitoring required for permit PE-11570 is as follows:

Parameter	Sample Type	Sampling Frequency	Reporting Frequency
Temperature, C	Field Measurement	Monthly (M)	M**
Dissolved O2, mg/L	Field Measurement	M	M**
pH	Field Measurement	M	M**
Ortho-Phosphorus, mg/L	Composite, lab analysis	Quarterly (Q)	Q**
NH3 - n, mg/L	Composite, lab analysis	Q	Q**

** Monthly (M) or quarterly (Q) within 31 days of the end of the monitoring period. Quarterly samples are to be taken on the same date as the monthly samples.

Sampling results for the 1993-1994 season were considered inaccurate due to the fact that the effluent was discharged during the night and samples were taken the following day.

11.4.2 Minor Discharges

Permit	Permittee	Location	Waste discharge	Discharge rate
PE-5901	International Forest Products	Scotia River	Sewage treatment plant discharge to Skeena River	Maximum 27 m^3/day
PR-6262	International Forest Products	Scotia River	Industrial refuse to ground	Maximum 5.5 m^3/day

11.5 SUMMARY AND REVIEW OF MONITORING NEEDS

There are no settlements in this reach and forestry is the main land use activity.

11.5.1 Interaction of forestry and water quality

11.5.1.1 Stream protection practices

An audit of the effectiveness of the Coastal Fisheries Forestry Guidelines was conducted in the Queen Charlotte Islands (QCI), North Coast and Kalum Forest Districts in 1992. Amount of habitat lost in fish bearing Class I-III streams was 15.7% of the total habitat inspected on the North Coast. Stream areas affected in Class IV streams with moderate to high transport potentials were much higher (88.7%). Estimated reductions in stream stability were higher in Kalum (50.0%) and North Coast (71.4%) than in QCI or on Vancouver Island. Increases in the debris load due to logging was the most prevalent type of impact. Sediment aggradation was the next most common cause of major or moderate impacts, followed by bank scouring and channel scouring.

Compliance with site specific prescriptions for streamside treatments provided by MOELP or DFO was 57.1% in Kalum and 86.2% in North Coast. Overall compliance with the Coastal Fisheries Forestry Guidelines, in the absence of specific prescriptions, was assessed at 65% in Kalum and 53% in North Coast. When followed, site specific prescriptions and Coastal Fisheries Forestry Guidelines were found to be effective in reducing or eliminating impacts to streams.

11.5.1.2 Monitoring needs

There have been few data collected to assess forestry interactions with water quality, although forestry is the major land use activity in this reach. A 1992 audit of stream protection practices in the Kalum and North Coast TSAs found inconsistent compliance with stream protection guidelines, and indicated that impacts were occurring and resulting in loss of fish habitat. The FPC is expected to improve compliance with stream protection guidelines and the Watershed Restoration Program is intended to address problems such as lack of road maintenance and deactivation.

There is a need, in this reach as in others, for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change. Suspended sediment monitoring, carried out during road building and logging, has been used successfully to identify problem areas and recommend immediate remedial actions. Implementation monitoring, such as the audit mentioned, is also necessary to ensure that management prescriptions are carried out on the ground and are achieving desired results. Strategies for both short- and long-term monitoring of streams in forested ecosystems are discussed in section 12.2.

12. OVERVIEW OF WATER QUALITY IN THE SKEENA WATERSHED WITH IDENTIFICATION OF DATASETS CRITICAL TO THE ASSESSMENT OF LONG-TERM/CUMULATIVE IMPACTS

12.1 WATER QUALITY IN THE SKEENA WATERSHED

In general, water quality in the Skeena River watershed can be described as very good and, in the mountainous headwaters of the upper Skeena, as pristine. Monthly monitoring at seven sites within the watershed conducted by EPP during 1983-1987 found, in general, that the waters are soft, with neutral pH, moderately low alkalinity, and with low dissolved solids and nutrients. Most sub-basins have moderately coloured waters, believed to be due to natural organic compounds contributed by decaying vegetation in swamps and wetlands. While this natural colouration may be aesthetically undesirable for drinking water, it is not at all harmful to human health. High total suspended solids and turbidity are characteristic during freshet for all streams which are not lake headed. This is attributed to erosion caused by glaciated headwaters and runoff during spring snowmelt from mountainous terrain. Total metals concentrations often exceed the MOELP criteria levels for the protection of aquatic life, particularly during freshet. Dissolved metals concentrations are, in many cases, less than their minimum detectable concentrations. The exception to above general description of water quality at that time was the upper Bulkley River which, prior to the upgrading of the municipal sewage treatment plant at Houston, experienced elevated nutrient levels.

Analysis of biweekly monitoring data collected from the Skeena at Usk (upstream of Terrace) during 1984-1992 indicated that no significant trends in water quality occurred on the mainstem Skeena during the study period. With the exception of this one station, long-term trend monitoring studies, which are critical to detecting change in water quality over time, have largely been discontinued in the Skeena watershed.

There has been increasing anthropogenic pressure on water quality due to resource extraction industries, particularly the expansion of these industries into the formerly remote higher elevation headwaters of the Skeena and its tributaries. Although north-central British Columbia has a relatively low population, population density continues to grow and the watershed must supply waters for domestic and agricultural use, as well as assimilate wastes from agriculture, urban development and industry.

12.2 LONG-TERM WATER QUALITY TREND MONITORING NEEDS

At present, there is only one long-term trend monitoring station in operation in the entire watershed, the Skeena River at Usk. There is, in the author's opinion, a need for more long term water quality data than provided by this single site. It is suggested that some of the EPP sites monitored for five years in the 1980's should be returned to for a year of monthly monitoring about every 10 years, in order to detect long-term trends. Baseline data is needed in a number of other tributaries as well; the Babine, upper Skeena (above the confluence of the Babine), Zymoetz and Kitsumkalum Rivers are all watersheds which are receiving increasing anthropogenic pressure and for which there is essentially no water quality data.

12.3 FORESTRY INTERACTION WITH WATER QUALITY

Until recently there have been few monitoring data available with which to assess forestry interactions with water quality, although forestry is the most widespread land use activity in the Skeena watershed. A new Forest Practices Code has been legislated, largely to improve compliance with stream protection guidelines, and the Watershed Restoration Program is intended to address such problems as sedimentation due as lack of road maintenance and deactivation. Community groups and management agencies are preparing Land and Resource Management Plans for nearly every forest district in the watershed. These plans often have specific objectives for stream and water quality protection. There is a need for both short- and long-term water quality and watershed processes monitoring in order to assess the effectiveness of new management practices and monitor for long-term/cumulative change.

12.3.1 Short-term stream monitoring

The most direct form of monitoring during the course of active logging in a watershed is implementation monitoring to determine whether management prescriptions were carried out on the ground. Suspended sediment, turbidity, and bedload monitoring are also applicable to short-term monitoring efforts. For example, one of the recommendations of the Babine Corridor LRUP was the implementation of multi-year monitoring of forestry impacts on suspended sediment loadings in the upper Babine watershed. This study has identified a number of cases of noncompliance with LRUP prescriptions and also identified two road locations which were contributing suspended sediment to streams during rainfall events. As a result, remedial action was taken immediately and site specific recommendations concerning road construction, maintenance and deactivation were prepared.

12.3.2 Long-term stream monitoring

Index streams, considered typical of a regional situation, can be monitored as a check on policy similar to the ambient water quality monitoring of many states and provinces, and the index survey streams of the US Geological Survey. When carried out over several decades (as, for example, in Carnation Creek), these assessments would focus discussion on processes and practices amenable (or not) to change.

Wissmar (1993) recommends careful planning of monitoring programs in order to provide information feedbacks that can be used to evaluate management prescriptions and policies. They include reviews of background and historical information to provide precise definitions of long-term planning objectives, planning considerations and monitoring methods. MacDonald and others (1991) provide guidance for designing water quality monitoring projects and selecting monitoring parameters. The selection of monitoring parameters is defined as a function of the designated uses, management activities, sampling frequency, monitoring costs, access and the physical environment.

For long-term monitoring of forest management activities, most of the traditional physical and chemical parameters have only limited usefulness because of their relative insensitivity, their high cost of monitoring, or both. The parameters related to channel characteristics are promising because of their relative sensitivity and low measurement costs. Examples are: 1) large woody debris; 2) channel morphology, including channel thalweg stability, channel area and side channel length by class; 3) spawning gravel quality/budgets; 4) bank stability and 5) temperature regime. Biological monitoring programs such as periphyton and benthic invertebrate studies may also prove useful.

12.4 AGRICULTURAL INTERACTION WITH WATER QUALITY IN THE BULKLEY RIVER WATERSHED

12.4.1 Identification of sources of nutrients to the upper Bulkley River

Relative to other Skeena tributaries, elevated nutrients, particularly orthophosphate, have been identified upstream of Houston; resulting in a stream which is susceptible to nuisance algae growth. The upper Bulkley in the vicinity of Houston is dominated by course fish species which may be indicative of low stream velocities, warm temperatures, and eutrophication in this section of the river. This pattern occurs upstream and downstream of the only point source for nutrients, the sewage treatment plant.

Limited data from tributary streams suggest that agricultural practices may be contributing to elevated nutrient and bacterial concentrations. Identification of the sources of nutrient loading to the upper Bulkley is a research priority. Monitoring should be conducted in all major tributaries and related to soil types and land-use activities within the watershed: particularly agriculture, forestry, and settlements using septic tanks.

12.4.2 Assessment of agricultural interaction with water quality

12.4.2.1 Runoff of manure and leachate from agricultural areas

Runoff of manure and leachate from confined and high-use livestock areas may affect water quality by direct toxic effects of ammonia and nitrates, by creating oxygen demand and by the addition of nutrients and bacteria. While it is known that agriculture is the major land use activity in the Bulkley valley, there are little current data on number of livestock, farm waste management practices or stream protection practices. An identification of sources and contaminants from agricultural runoff is critical to the reduction in the loading of nutrients and other contaminants to the watershed. Waste management practices can be correlated to stream and lake nutrient and bacterial levels, and to changes in trophic status demonstrated by nuisance algae growth in streams and lakes.

12.4.2.2 Water withdrawals for irrigation

There are 13 irrigation licenses on the upper Bulkley River, mostly from tributary streams. Estimates indicate that licensed water withdrawals from the upper Bulkley and tributaries may comprise 46% of the summertime 7 day average 10 year low flow at Houston. There are 93 irrigation licenses on the mainstem Bulkley below Houston, again drawing water mainly from tributary streams. Canyon Creek, the only stream in this reach with a hydrometric gauge, may be one of the most heavily utilized. The estimated water withdrawals from Canyon Creek, mostly for irrigation, nearly equal the summertime 7 day average 10 year low flow for this stream. This raises a concern as to whether remaining flows in this and other tributary streams are adequate for other water users, for assimilating agricultural wastes and for in-stream flow needs of fish. At present there are no data on the actual water volume withdrawn for irrigation, and this is a monitoring need. Further monitoring is also required to assess the adequacy of instream flows and water temperatures for fish in the most heavily utilized tributaries.

12.5 MUNICIPAL SEWAGE TREATMENT FACILITIES AND THEIR IMPACTS ON WATER QUALITY

There are 12 villages or municipalities discharging treated sewage into the watershed, ranging in size from small villages to the City of Terrace. The quality of effluent varies widely, and a number of facilities are planning upgrades. The smaller plants generally rely on one or more facultative lagoons for secondary treatment, while the larger plants have one or more aerated lagoons. In general, disinfection is not a requirement, except in discharges to lakes and smaller streams such as the upper Bulkley River. The only community employing tertiary treatment, with phosphorus removal, is the District of Houston. Phosphorus removal is also sometimes required for resort complexes discharging to Babine Lake and Lakelse Lake.

12.5.1 Effluent and receiving environment monitoring

There is considerable variation in the amount and type of monitoring data collected for each of these plants. Additional data, particularly for toxicants, nutrients and microbial indicators, are necessary for the assessment of the cumulative impacts of these discharges, and for the assessment of treatment needs as contributing populations increase. While BOD and TSS give a good indication of the degree of biological treatment achieved by a sewage treatment facility, additional data are required to assess possible effects within the receiving environment.

Ideally, effluent and receiving environment monitoring would take place monthly (quarterly at smaller plants and weekly at larger plants) and include the following parameters: BOD, TSS, total nitrogen, ammonia-N, nitrate-N, nitrite-N, total phosphorus, orthophosphate, temperature (field), dissolved oxygen (field), pH (field) and microbial indicators, such as fecal coliforms and enterococci. In addition, it is recommended that rainbow trout 96 hr LC50 bioassay be conducted at least twice per year during winter/early spring and late summer low flow periods. Discharge and in-stream flow measurements are recommended as well. It is recognized that monitoring frequency may be adjusted down for the smaller facilities and those with higher dilution ratios.

12.5.2 Assessment of potential acute and/or chronic toxicity within the mixing zones of sewage effluents

There is a concern with many of these discharges that acute and/or chronic toxicity to fish may exist within the effluent mixing zones. The Skeena River is one of few river systems globally in which summer-run steelhead trout are known to overwinter. These fish are in a holding pattern through the winter months when river temperature and flow are at annual minimum values. The concern is that fish may be attracted into and remain in the effluent mixing zone due to warmer wastewater temperatures.

Two new or recently upgraded facilities (Kispiox and Houston) are required by permit to monitor for aquatic toxicity (using rainbow trout 96 hr LC50 bioassay). Little monitoring data are available for Kispiox to date. The Houston discharge has demonstrated acute toxicity (defined as less than 100% concentration 96 hr LC50) during the winter and early spring months for several consecutive years. The acute toxicity appears to be correlated to elevated ammonia concentrations in the effluent during the winter months. This finding is similar to those of municipal effluent toxicity studies in the Prince George Region and in northern Ontario. In the absence of a high proportion of industrial discharges to wastewater entering a STP, effluent toxicity is commonly the result of elevated concentrations of un-ionized ammonia. The Ontario review (MISA 1990) found that, in plants having secondary treatment and in spite of high BOD removal efficiencies, effluents were frequently toxic if the total ammonia-N concentration exceeded 10 mg/L. This was very often the case during winter operation, due to reduced nitrification at lower wastewater temperatures.

A philosophical difference of opinion exists between provincial and federal agencies on regulation of toxicity within the mixing zone. This author would suggest that a site specific approach be taken; with further sampling within the mixing zones, if possible, of those plants which 1) prove to have toxic effluents, 2) have moderate to low dilution ratios and 3) discharge to stream segments known to have high fisheries values, particularly over winter.

It would be of interest to conduct a rigorous monitoring program of effluents from all the STPs in the watershed during the winter months. It is generally understood that transit time, refrigeration, and bioassay lab temperature, pH, and method of oxygenation may add considerable analytical error to un-ionized ammonia measurement, therefore careful consideration should be given to methods. In the Skeena watershed, salmonids are the receiving environment receptor of greatest concern, therefore the rainbow trout 96 hr LC50 bioassay test is generally recommended in preference to other bioassay tests.

12.6 WATER AND SEDIMENT QUALITY OBJECTIVES FOR THE BUCK CREEK/GOOSLY LAKE AND FOXY CREEK/MAXAN CREEK/BULKLEY LAKE WATERSHEDS

The Equity Silver Mine south of Houston is in the process of reclamation of a minesite encompassing 85 million tonnes of waste rock and currently producing over 800,000 m^3 of ARD per year. The mine's owners have posted a security bond for financing the long-term (centuries) ARD treatment cost upon completion of reclamation. Lime treatment is required to neutralize acidity and precipitate metals before effluent is released into the Buck Creek/Goosly Lake and Foxy Creek/Maxan Creek/Bulkley Lake watersheds.

This author considers the development of Water and Sediment Quality Objectives for both the Buck Creek/Goosly Lake and Foxy Creek/Maxan Creek/Bulkley Lake watersheds to be essential in order to set discharge criteria and to focus monitoring during the prolonged period of ARD generation and management from this mine, and perhaps additional mines in the watersheds.

12.6.1 Acute and chronic toxicity of treated ARD to stream and lake biota

When reclamation of the site is complete, and the treated ARD discharge has stabilized considering the suite of metals present, mesocosm and bioassay fish and benthic invertebrate studies could be utilized in establishing both discharge limits and water quality objectives. Both acute and chronic toxicity data will be required for objectives setting, utilizing a battery of biological assessment tests. Factors such as the multiple metals found in the treated ARD and the organic complexing capacity of the waterbodies need to be addressed. Therefore, *in-situ* bioassays are suggested using varying dilutions to represent the range of metal concentrations in proposed discharges and to establish dose/response relationships.

Water quality objectives have recently been developed for the ARD impacted Tsolum River watershed on Vancouver Island (Deniseger and Pommen 1995). This study recommends monitoring for "free" copper, which is an estimate of the amount of dissolved copper which is not organically bound, and proposes an analytical method. In addition to detailed analysis of total and dissolved metals concentrations, analysis should include humic acid, dissolved organic carbon and "free" copper to further develop the relationship between these parameters.

The most promising and proven biological monitoring techniques (EVS 1990) are benthic community responses and growth and reproductive parameter of fish populations. The benthic invertebrate community may be particularly useful in lake situations, since benthic response may relate both to changes in water and sediment quality. The use of mesocosm studies, such as the trough apparatus used the minesite previously and/or constructed ponds, is suggested as the most direct means of measuring benthic and fish community responses to a gradient of ARD additions.

12.6.2 Sediment quality objectives

The establishment of lake sediment quality objectives is deemed particularly important, since it is assumed that the bottom sediments of Goosly and Bulkley Lakes will be the long term receptor sites of heavy metal contamination. Sequential extractions have been performed on recently deposited sediments in Goosly Lake. Cadmium content in the sediments showed a large proportion in the easily exchangeable fraction, indicating that this is a metal of concern.

The minimum toxicological dataset recommendations for derivation of freshwater sediment quality guidelines for the protection of aquatic life (CCME 1995) are:

- At least four studies are required on two or more sediment-resident invertebrate species that occur in North American waters. There must include at one benthic crustacean species and one benthic arthropod species other than a crustacean.
- At least two of these studies must be partial or full life-cycle test that consider ecologically relevant end points (e.g., growth, reproduction, developmental effects).

The Sediment Quality Triad approach (Chapman and others 1987) consists of three components: sediment chemistry which measures contamination; sediment bioassays which measure toxicity; and biological community structure (in situ or field parameters) which measures alteration.

Sediment toxicity bioassays ideally would include a range of tests including acute lethal, acute sublethal and chronic tests. Tests and test organisms recommended for ARD (EVS 1990) are:

- *Daphnia magna*: both acute (48 hr) and chronic (7 day);
- *Hyallela azteca*: sublethal acute (10 day) lethality; and
- *Chironomus tentans*: chronic (10 day) partial life-cycle.

Spiked-sediment toxicity tests may be necessary to further refine dose/response relationships. Consideration should be given to conducting all bioassays over a longer timeperiod than 10 days. In an assessment of hardness and humic concentration effect on the bioaccumulation and toxicity of copper, Winner (1985) noted that, in bioassays using *Daphnia* spp., a 21 day exposure period was not long enough for determining an ecologically relevant no effect concentration.

12.7 WATER AND SEDIMENT QUALITY OBJECTIVES FOR THE BABINE WATERSHED

The development of Water and Sediment Quality Objectives for the Babine watershed has been recommended by MOELP in order to set discharge criteria and to focus monitoring during the prolonged period of ARD generation and management from Granisle and Bell copper mines. The MOELP water quality criteria for copper are thought to be more stringent than necessary for Babine Lake because toxicity is believed to be reduced by the relatively high copper complexing capacity of natural dissolved organic ligands in the lake water.

12.7.1 Mass balance for copper and other metals

Babine Lake, which is oligotrophic and dystrophic, presents a somewhat unusual situation compared to literature studies on the cycling of metals in soft-water lakes. It appears that not all of the ionic copper entering Babine Lake is immediately complexed by organic ligands and rendered biologically unavailable; since higher copper concentrations are found in the top centimeter of Rum Bay and Hagan Arm sediments, zooplankton, and fish tissues in the vicinity of the mines compared to those in the Main Arm. However, the presumption is that an adequate supply of complex organics exist and will continue to exist in Babine Lake waters to complex, and thus render non-toxic, a large amount of ionic copper.

Some studies have found that the result of formation of copper complexes with soluble organic substances is an increase in solubility, rather than sedimentation. In a study of copper and zinc budgets in a soft-water lake with high complexing capacity, Reynolds and Hamilton-Taylor (1992) found virtually no sedimentation of copper; rather the entire calculated annual copper input was found to leave via the outlet (largely in solution, some as algae), whereas more than half the dissolved input of iron, lead and zinc was retained in the lake via sedimentation. It would be very helpful to have modeling as to the eventual fate of soluble copper-organic compounds in the Babine watershed.

To date there has been little or no water quality sampling at the lake outlet or in Babine River. However, it seems logical that sampling of Babine River, particularly during periods of spring and fall overturn, might prove to be a cost effective, long-term method of monitoring for water quality change in the lake.

12.7.2 Acute and chronic toxicity of ARD to Babine Lake biota

Both acute and chronic toxicity data will be required for objectives setting, utilizing a battery of biological assessment tests. Factors such as the multiple metals found in ARD from both mines and the organic complexing capacity of Babine Lake waters (which varies seasonally) need to be addressed. Therefore, *in-situ* bioassays using Babine Lake water as diluent are suggested. The toxicant should be treated and untreated mine drainage waters of varying dilutions to represent the range of metal concentrations in proposed discharges and to establish dose/response relationships.

Water quality objectives have recently been developed for the ARD impacted Tsolum River watershed on Vancouver Island (Deniseger and Pommen 1995). This study recommends monitoring for "free" copper, which is an estimate of the amount of dissolved copper which is not organically bound, and proposes an analytical method. In addition to detailed analysis of total and dissolved metals concentrations, analysis should include humic acid, dissolved organic carbon and "free" copper to further develop the relationship between these parameters.

The most promising and proven biological monitoring techniques (EVS 1990) are benthic community responses and growth and reproductive parameter of fish populations. The benthic invertebrate community may be particularly useful in this lake situation, since benthic response may relate both to changes in water and sediment quality. The use of mesocosm studies, in this case using constructed or artificial ponds, is suggested as the most direct means of measuring benthic community responses to a gradient of ARD additions.

Young sockeye (fry, fingerlings and smolts) are the fish species of greatest interest: however, kokanee, lake trout, rainbow trout, burbot, lake whitefish and peamouth chub are also expected to be impacted by mine discharges. The fish species used would preferably be a Babine Lake stock, or acclimated to ambient lake water prior to testing. Both 96 hr LC50 to assess acute toxicity, and 21 day LC50 (including measurement of growth rate) to assess chronic toxicity are suggested. The following studies are suggested for additional assessment of chronic toxicity: histological examination of gills; growth and saltwater survival in smolts exposed to sublethal ARD concentrations; and hepatic biochemical response (metallothionein concentration and distribution).

12.7.3 Sediment quality objectives

The minimum toxicological dataset recommendations for derivation of freshwater sediment quality guidelines for the protection of aquatic life (CCME 1995) are outlined in section 12.6.2. Also discussed is the Sediment Quality Triad approach (Chapman and others 1987) consisting of three components: sediment chemistry which measures contamination; sediment bioassays which measure toxicity; and biological community structure (in situ or field parameters) which measures alteration. Sediment toxicity bioassays ideally would include a range of tests including acute lethal, acute sublethal and chronic tests. Spiked-sediment toxicity tests may be necessary to further refine dose/response relationships.

13. REFERENCES

Abelson, D. 1976. Lakelse Lake water quality study. Technical Report, Water Resour. Serv., Pollut. Control Branch, Prov. of B.C.

Anonymous. 1981. The Global 2000 report to the president, entering the twenty-first century. Volume II the technical report. Council on Environmental Quality and State Department, Washington DC.

Beaudry, P.G. and J.W. Schwab. 1989. Telkwa watershed: a forest hydrology analysis. MOF Forest Sciences Section, Smithers, B.C.

Beaudry, P.G., J.W. Schwab and D. Septer. 1991. Suspended sediment Telkwa River watershed: data report April to October, 1990. MOF Forest Sciences Section, Smithers B.C.

Berris, S.N. and R.D. Harr. 1987. Comparative snow accumulation and melt during rainfall in forested and clearcut plots in the western Cascades of Oregon. Water Resour. Res. 23: 135-142.

Bhangu, I. and P.H. Whitfield. 1994. Seasonal and long-term variations in water quality of British Columbia rivers: the Skeena River at Usk, B.C. (DRAFT). Environment Canada, North Vancouver B.C.

Boyd, I.T., C.J.P. McKean and R.N.Nordin. 1984. Skeena-Nass area: Kathlyn, Seymour, Round and Tyhee Lakes: Water quality assessment and objectives. Water Management. Branch, MOEP, Victoria B.C.

B.C. Ministry of Aboriginal Affairs. 1992. The aboriginal peoples of British Columbia: a profile. Victoria B.C.

B.C. Ministry of Agriculture and Foods. 1984. Agriculture profile Smithers District. Policy Development and Economics Division, Victoria B.C.

B.C. Ministry of Agriculture, Fisheries and Food. 1993. Environmental Guidelines for Dairy Producers in British Columbia. Soils and Engineering Branch, Abbotsford, B.C.

B.C. Ministry of Environment, Lands and Parks. 1947 - 1994 (continues). Snow survey bulletin. Hydrology Branch, Water Management Division, Victoria B.C.

_________. 1982. Provincial guidelines and laboratory procedures for measuring acute lethal toxicity of liquid effluents to fish. Bioassay Task Force, Waste Management Branch, Victoria B.C.

_________. 1983. Strategic environmental management plan Skeena-Nass planning unit, Skeena Region. Skeena Region and Planning and Assessment Branch, Smithers B.C.

_________. 1989 - 1992. Water quality in British Columbia: objectives attainment in 1989...- 1992 (continues). Water Quality Branch, Victoria B.C.

_________. 1993. Landfill criteria for municipal solid waste. Municipal Waste Reduction Branch, Environmental Protection Program, Victoria B.C.

B.C. Ministry of Forests. 1992. Thunderbird integrated resource management plan. Kalum Forest District, Terrace, B.C.

_________. 1994. Sustut local resource use plan: draft consensus report. Fort St. James Forest District, Fort St. James, B.C.

_________. 1995. Fiddler creek total resource plan. Kalum Forest District, Terrace, B.C.

B.C. Ministry of Forests and Ministry of Environment, Lands and Parks. 1993. British Columbia coastal fisheries/forestry guidelines, 3rd Edition. Crown Publication Inc.

_________. 1994. DRAFT British Columbia interior fisheries, forestry, wildlife guidelines.

_________. 1994. Babine River interim local resource use plan. Smithers B.C.

_________. 1994. Kispiox Forest District consensus management direction. Kispiox B.C.

Brownlee, M.J. and B.G. Shepherd. 1975. Effects of forest harvesting on water quality in the Slim Creek watershed in the central interior of British Columbia. Unpublished report, Fisheries and Marine Serv., Vancouver B.C, 52 p.

Bruce Geotechnical Consultants Inc. 1994. Action plan for preliminary investigation of tailings at Silver Standard Mine, Hazelton, BC. Contract report prepared for Silver Standard Resources Inc.

Buchanan, R.J. 1987. Water quality management in British Columbia: a summary. Resource Quality Section, Water Management Branch, MOELP, Victoria B.C.

Burns, D.C. 1991 Cumulative effects of small modifications to habitat: AFS Position Statement. Fisheries 16(1):12-17.

Bustard, D. and associates. 1985. Aquatic resource assessment of the Telkwa Coal Project 1984 studies. Contract report prepared for Crows Nest Resources Ltd., Smithers B.C.

_______. 1986*a*. Assessment of fish populations in Waterfall and Station Creeks near New Hazelton BC. Contract report prepared for District of New Hazelton B.C.

_______. 1986*b*. Assessment of stream protection practices in the interior of the Prince Rupert Forest Region and future research recommendations. Contract report prepared for Forest Hydrology Research Section of the BC Forest Service, Smithers B.C.

_______. 1992. Adult steelhead studies in the upper Sustut River 1992. Contract report prepared for B.C. Environment, Smithers B.C.

_______. 1993*a*. Fish and water quality sampling results from a wetland near Telkwa. Contract report prepared for McElhanney Engineering Services Ltd., Smithers B.C.

_______. 1993*b*. Juvenile steelhead surveys in the Kitwanga, Morice, Sustut and Zymoetz River, 1992. Contract report prepared for Fisheries Branch, MOELP, Smithers B.C.

_______. 1994. Fish population monitoring in Foxy and Buck Creeks September 1993. Contract report prepared for Equity Silver Mines Ltd. and Homestake Canada Inc.

Canadian Council of Resource and Environment Ministers (CCREM). 1987 (updates annually). Prepared and updated by the Task Force of Water Quality Guidelines. IWD, Environment Canada, Ottawa.

Canadian Council of Ministers of the Environment (CCME). 1995. Protocol for the derivation of Canadian sediment quality guidelines for the protection of aquatic life. Rep.CCME EPC-98E. Ottawa.

Carrier, R. 1991. Trace metals and metallothioneins in rainbow trout (*Oncorhynchus mykiss*) exposed to various concentrations of acid rock drainage. MSc. thesis Faculty of Graduate Studies, Bio-Resource Engineering, U.B.C., Vancouver, B.C.

Cassidy, M. and F. Cassidy. 1980. Proud past: a history of the Wet'suwet'en of Moricetown, B.C. Moricetown Band, Moricetown B.C., 48 pp.

Chamberlin, T.W., R.D. Harr and F.H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. American Fisheries Society Special Publication 19:181-206.

Chau, Y.K., and P.T.S. Wong. 1975. Chemical and biological studies of Babine Lake, B.C. (unpublished report) C.C.I.W. Dept. Environ., Burlington Ontario.

Chilibeck, B. 1992. Land development guidelines for the protection of aquatic habitat. Co-published by MOELP, Integrated Manage. Branch. and DFO Habitat Manage. Div., 128 pp.

Clague, J.J. 1984. Quaternary geology and geomorphology, Smithers-Terrace-Prince Rupert area, British Columbia. Memoir 413 Geological Survey of Canada, Ottawa.

Cleugh, T.R., C.C. Graham, and R.A. McIndoe. 1978. Chemical, biological and physical characteristics of Lakelse Lake, B.C. Fish. Mar. Ser. Man. Rep. 1472. Dept. of Fisheries and the Environment, Vancouver, B.C.

Cooke, G.D., E.B. Welch, S.A. Peterson and P.R.Newroth. 1986. Restoration and management of lakes and reservoirs. Lewis Publishers 548 pp.

Coulson, H. 1989. The impact of climate variability and change on water resources in British Columbia, p. 41-49 *In:* Taylor, E.; Johnstone, K. (eds), Proceedings of the sumposium on the impacts of climate variability and change on British Columbia, 14 December 1989, Vancouver. 87 pp. Sci. Ser. Div. Rep. PAES-89-1, Atmos. Env. Ser. Vancouver, B.C.

Davis, J.C. and I.G. Shand. 1978. Acute and sublethal copper sensitivity, growth and saltwater survival in young Babine Lake sockeye salmon. Fish. Marine Ser. Tech. Rep. 847,55p.

Demarchi, D.A. 1993 An introduction to the Ecoregions of British Columbia. Wildlife Branch, MOELP, Victoria B.C.

Deniseger, J.H. and L. W. Pommen. 1995. Water quality assessment and objectives for Tsolum River Basin, Vancouver Island. Water Quality Branch, MOELP, Victoria B.C.

Environment Canada and Fisheries and Oceans. 1995. The Fraser River action plan: 1994-1995 progress report. Catalogue No. EN37-99/1995E.

Equity Silver Mines Ltd. 1992. Annual report 1992. Equity Silver Mines Ltd, Houston B.C.

Equity Silver Mines Ltd. 1993. Annual report 1993. Equity Silver Mines Ltd, Houston B.C.

E.V.S. Consultants. 1990. Review of sediment monitoring techniques. Contract report prepared for B.C. Acid Mine Drainage Task Force 87pp.

Feng, J.C., P.E. Reynolds and H.D. Klassen. 1986. Persistence of Glyphosate in streamwater following aerial application with a microfoil boom at Carnation Creek, British Columbia, 1984. For. Pest Manage. Inst., Can. For. Ser., Sault Ste. Marie, Ontario. File Report No. 73.

Forstner U. and G.T.W. Wittmann. 1981. Metal pollution in the aquatic environment, second revised edition. Springer-Verlag 486 pp.

Gartner Lee Ltd. 1993. Leachate assessment field manual and preliminary landfill leachate assessment reports. Contract report prepared for Skeena Region MOELP, Smithers B.C.

Geocon. 1992. Bell 92 project closure plan progress report decommissioning and closure studies. Contract report prepared for Noranda Minerals Inc.

_______. 1992. Bell 92 project closure plan support document F: water management. Contract report prepared for Noranda Minerals Inc.

Godin, B. 1992. Water quality and sediment analysis Equity Silver Mines: data from 1988, 1989 and 1990 surveys. Environment Canada, EPS, Pacific and Yukon Regional Program Report 92-02. North Vancouver. 112p.

Godin, B., M. Hagen and G. Mitchell. 1992. Babine Lake monitoring June 19-22, 1990. Environmental Protection Service Canada, Pacific Yukon Region.

Godin, B., M.Ross and M. Jones. 1985. Babine Lake data from chemical and biological surveys May 1983, May 1984, July 1984. Environmental Protection Service Canada, Pacific Yukon Region.

Gottesfeld, A. 1985. Geology of the northwest mainland. Kitimat Centennial Museum Assoc. Kitimat, B.C. 114 p.

Hall, K.J., editor. 1987. Log handling in the aquatic environment: impact assessment and research on Babine Lake. Westwater Research Centre, University of B.C., Vancouver B.C.

Hallam, R. 1975. A brief of EPS water quality monitoring and surveillance activites on Babine Lake, 1974-1975.

Hamilton, S.J. and P.M. Mehrle. 1986. Metallothionein in fish: review of its importance to assessing stress from metal contaminants. Trans. Amer. Fish. Soc. 115:596-609.

Hartman, G.F. and J.C. Scrivener 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Can. Bull. Fish. Aquat. Sci. 223: 148 p.

Hatfield Consultants Limited. 1989. Babine Lake near the Bell Mine: water/sediment quality and benthic macroinvertebrate communities. Contract report prepared for Noranda Minerals Inc.

Hellawell, J.M. 1986. Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science London.

Hillcrest Recreation Consulting. 1995 Babine River LRUP monitoring study: 1995 results. Contract report prepared for BC Environment, Smithers BC.

Holland, S.S. 1976. Landforms of British Columbia. BC Dept. Mines and Petrol. Res., Bull. 48, 138p.

Hooten, R.S. and D.S. Reid. 1975. Impact of stream channelization on fish and wildlife. Habitat Protection Section, Fish and Wild. Br., Victoria B.C.

KWLG & S. 1993. Memorandum on upgrading of Hazelton/Gitanmaax wastewater treatment plant. Kerr Wood Leidel Gore & Storie Inc.

Large, R.G. 1957. The Skeena - river of destiny. Mitchell Press Ltd, Vancouver BC.

Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1889 96pp.

Levy, D.A. and K.J. Hall. 1985. A review of the limnology and sockeye salmon ecology of Babine Lake. Westwater Research Centre, University of British Columbia, Westwater Tech. Rep. No.27, Vancouver B.C.

Limnotek Research and Development Inc. 1992. Stream community responses to a gradient of acid mine drainage additions. Contract report prepared for the B.C. Acid Mine Drainage Task Force, 60pp.

MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA 910/9-91-001.

MacLaren Forest Products Inc. 1993. Granisle mine environmental report 1993.

MacLaren Plansearch Services Ltd. 1985. Crows Nest Resources Ltd. water quality investigation. Contract report prepared for Crows Nest Resources Ltd. Calgary, AB.

Maclean, D.B. 1983. Aldrich Lake: a data report on water quality and biological data from the receiving waters of the area around the abandoned Duthie Mine. MOELP Waste Manage. Branch Skeena Region Rep. 83.05. Smithers, B.C.

_________. 1985. Seymour Lake:1984 data summary and recommendation. Skeena Region Waste Mange. Report No. 85-02. Smithers, B.C.

Maclean, D.B. and K.A. Diemert. 1987. The effects of the District of Houston sewage discharge on downstream water quality and periphyton (algal) biomass. Environ. Sec. Rep. 87-04, MOELP, Smithers B.C.

McBean, G.A., O. Slaymaker, T. Northcote, P. Leblond and T.S. Parsons. 1992. Review of models for climate change and impacts on hydrology, coastal currents and fisheries in BC. Climate Change Digest.

McCarter, J.A., and M. Roch. 1982. Hepatic metallothionein and resistance to copper in juvenile coho salmon. Comp.Biochem. Physio. C, Comparative Pharmacology 74:133-137.

McKean, C.J.P. 1986. Lakelse Lake: water quality assessment and objectives. Water Manage. Branch, MOELP, Victoria B.C.

McNeely, R.N., V.P. Neimanis and L. Dwyer. 1979. Water quality sourcebook: a guide to water quality parameters. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Meehan, W.R., editor. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Miles, M. 1991. Linear developments: innovative techniques for sediment control and fisheries habitat re-creation. *In* Yuzyk, T.R. and B. Tassone, editors. Proceedings of the BC-Yukon sediment issues workshop: April 24-26, 1990 Vancouver BC. Water Resour. Branch, Pacific and Yukon Region, Environment Canada, Vancouver BC.

Morris, M. and B. Eccles. 1975. Morice River stream surveys. Fish and Wildl. Branch, MOELP, Smithers BC.

Morwijk Enterprises Ltd. 1992. Bell 92 project closure plan support document E: mine rock and tailings geochemistry and prediction of water chemistry. Contract report prepared for Noranda Minerals Inc.

Mould, J. 1976. Stump farms and broadaxes. Hancock House 101 pp.

Municipal/Industrial Strategy for Abatement (MISA). 1990. Review of aquatic toxicity and environmental impact of Ontario sewage treatment plant effluents. Ministry of the Environment, Ontario.

Nagpal, N.K. 1994. Approved and working criteria for water quality. Water Quality Branch, EPP, MOELP, Victoria B.C.

Netboy, A. 1980. Salmon: the world's most harassed fish. Andre Deutsch, London.

Nijman, R. 1986. Bulkley River basin: water quality assessment and objectives. Water Manage. Branch, MOELP, Victoria B.C.

Noranda Minerals Inc. 1992. Bell 92 project closure plan summary. Report prepared by Noranda Minerals Inc., Geocon, Rescan Environmental Services Ltd. and Morwijk Enterprises Ltd. for the Northwest Mine Development Review Committee, Smithers B.C.

_________. 1993. Bell Mine environmental report 1993.

Nordin, R.N. 1985. Water quality criteria for nutrients and algae. Water Manage. Branch, MOELP, Victoria B.C.

Norris, L.A., H.W. Lorz and S.V. Gregory. 1991. Forest chemicals. American Fisheries Society Special Publication 19:207-296.

Northcote, T.G. 1992. Prediction and assessment of potential effects of global environmental change on freshwater sport fish habitat in British Columbia. GeoJournal 28(1):39-49.

PAC-RIM LNG Inc. 1995. Project approval certificate application PAC-RIM LNG Inc. Calgary AB.

Portman, D. 1995. DRAFT District of Houston: sewage outfall data review and recommendations. Memo to file PE-287. EPP, MOELP, Smithers B.C.

Quanstrom, C. 1995. Babine River interim local resource use plan: annual report of the monitoring committee 1994. Contract report prepared for BC Environment, Smithers, B.C.

Raible, R. W. 1979. Study of the cumulative growth inhibiting factors in recycled water for catfish coltivation. Arkansas Water Resources Research Center PB 297 117:64. Fayetteville, AR.

Ramamoorthy, S. 1988. Effect of pH on speciation and toxicity of aluminum to rainbow trout (*Salmo gairdneri*). Can. J. Fish. Aquat. Sci. 45:634-642.

Reinhart, K.G., A.R. Eschner and G.R. Trimble, Jr. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. US Forest Service Research Paper NE-1.

Remington, D. and associates. 1991. Environmental assessment of the upper Bulkley River in the vicinity of the District of Houston sewage treatment plant PE-0287. Contract report prepared for District of Houston, B.C.

_______. 1994. Biological monitoring of the upper Bulkley River 1993-94: PE-0287. Contract report prepared for District of Houston, B.C.

Remington, D., D. Bustard, C.J. Perrin, T. Lekstrum. 1993. Receiving environment monitoring of the upper Bulkley River 1991-92: PE-0287. Contract report prepared for District of Houston, B.C.

Rescan Environmental Services Ltd. 1992*a*. Bell 92 project closure plan support document G: review of historical environmental data of Babine Lake. Contract report prepared for Noranda Minerals Inc.

_______. 1992*b*. Bell 92 project closure plan support document H: existing environmental conditions of Babine Lake in the vicinity of Bell Mine. Contract report prepared for Noranda Minerals Inc.

Reynolds, G.L. and J. Hamilton-Taylor. 1992. The role of planktonic algae in the cycling of Zn and Cu in a productive soft-water lake. Limnol. Oceanogr. 37(8) 1759-1769.

Rhebergen, F. 1986. Memo to file re: Equity Silver - worst case prediction. Environmental Protection, MOELP, Smithers, B.C.

Richardson, J.S. and C.J. Perrin. 1990. The effect of treated acid mine drainage on stream macroinvertebrates and periphytic algae: an in situ mesocosm experiment. B.C. Ministry of Energy, Mines, and Petroleum Resources. B.C. Acid Mine Drainage Task Force. Victoria, B.C. 33p.

Roch, M, J. McCarter, A. Matheson, M. Clark and R. Olafson. 1982. Hepatic metallothionein in rainbow trout (*Salmo gardneri*) as an indicator of metal pollution in the Campbell River system. Can.J. Fish. Aquat. Sci. 39:1596-1601.

Ruvio, M. and nine coauthors. 1971. Pollution: an international problem for fisheries. FAO United Nations 4(14):1-85.

Saimoto, R.K. 1994. Morice River watershed assessment 1994: survey of logging related impacts on Cedric, Lamprey, Fenton and Owen Creeks. Contract report prepared for MOELP Watershed Restoration by SKR Environmental Consultants, Smithers B.C.

Sedell, J.R. and F.J. Swanson. 1984. Ecological characteristics of streams in old-growth forest of the Pacific Northwest. Pages 9-16 *in* Fish and wildlife relationships in old-growth forests. Amer. Inst. Fish. Res. Bio., Morehead City NC.

Sedell, J.R. and J.L. Froggatt. 1984. Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, USA from its floodplain by snagging and streamside forest removal. Verhandlugen International Verein Limnology 22:1828-1834.

Sedell, J.R., F.N. Leone, and W.S. Duval. 1991. Water transportation and storage of logs. American Fisheries Society Special Publication 19:325-368.

Sharpe, I. 1993. Equity Silver Mines Ltd. permit amendment receiving environment assessment. EPP, MOELP, Smithers B.C.

Silver Standard Resources. 1994. Duthie Mine Smithers, B.C. tailings reclamation study: 1994 Action Plan. Contract report prepared in conjunction with Bruce Geotechnical Consultants and Karwandt Wilmer Wise.

Singleton, H.J. 1987. Water quality criteria for copper: technical appendix. Water Manage. Branch, MOELP, Victoria, 121p.

Slaney, P.A., T.G. Halsey and H.A. Smith. 1977*a*. Some effects of forest harvesting on salmonid rearing habitat in two streams in the central interior of British Columbia. Fish Wildl. Branch, MOELP, Fish. Manage. Rep. 71, Victoria B.C.

Slaney, P.A., T.G. Halsey and A.F. Tautz. 1977*b*. Effects of forest harvesting on spawning habitat of stream salmonids in the Centennial Creek watershed British Columbia. Fish Wildl. Branch, MOELP, Fish. Manage. Rep. 73, Victoria B.C.

Slaney, P.A., H.A. Smith and T.G. Halsey. 1977*c*. Physical alterations to small stream channels associated with streamside logging practices in the central interior of British Columbia. Fish Wildl. Branch, MOELP, Fish. Manage. Rep. 31, Victoria B.C.

Slaymaker, H.O. 1972. Physiography and hydrology of six river basins. Pages 32-68 *in* J.L. Robinson, ed. Geography of British Columbia.

Smith and Co. 1992. Preliminary environmental evaluation of proposed sewage treatment plant effluent on instream resources values at Kispiox, B.C. Draft Report.

Smith, R.A., R.B. Alexander, and M.G. Wolman. 1987. Water quality trends in the nation's rivers. Science (Washington, DC) 235:1606-1615.

Steffen, Robertson and Kirsten (SRK) Inc. 1989. Draft acid rock drainage technical guide: Vol. 1. Prepared for the B.C. Acid Mine Drainage Task Force.

________. 1994. Evaluation of acid rock drainage potential Granisle Mine, BC. Contract report prepared for Noranda Minerals Inc.

Stockner, J.G. and K.R.S. Shortreed. 1976. Babine Lake monitor program; biological and physical data for 1974 and 1975. Fish. Res. Board Can. MS Rep. 1373:34 pp.

________. 1978. Limnological surveys of Babine Lake, British Columbia: results of the monitoring program, 1974-78. Fish. Res. Board Can. MS Rep. 1494:35 pp.

Sturtevant, W.C., ed. 1990. Handbook of North American Indians, V. 7 northwest coast. Smithsonian Institution, Washington DC.

Tamblyn, G. 1989. The utilization of wetlands as tertiary sewage treatment systems and potential environmental impacts: a preliminary case study of a New Hazelton bog. Work term report, Biology Co-op Program, Dep. of Biol., University of Victoria, B.C.

Terracon Geotechnique Ltd. 1994. Conceptual design for leachate management and site remediation West Fraser Mills Ltd., Smithers BC. Draft contract report prepared for West Fraser Mills Ltd.

Town of Smithers. 1993. Town of Smithers sewage treatment plant evaluation. Smithers B.C.

Tripp, D., A. Nixon and R. Dunlop. 1993. The application and effectiveness of the Coastal Fisheries Forestry Guidelines in the Queen Charlotte Islands, North Coast and Kalum Forest Districts. contract report prepared by D Tripp Biological Consultants Ltd. for Ministry of Forests Integrated Resources Branch, Victoria, B.C.

Wangersky, P.J. 1986. Biological control of trace metal residence time and speciation: a review and synthesis. Mar. Chem. 18:269-297.

Warrington, P.D. 1988. Water quality criteria for microbiological indicators. Water Management Branch MOELP, Victoria B.C.

Wetzel, R.G. 1983. Limnology: second edition. CBS College Publishing. 767pp.

Wilford, D. 1982. Harold Price Creek watershed: forest hydrology input into planning management. Unpublished report MOF, Smithers B.C.

Wilford, D. 1985. A forest hydrology overview of the Kispiox River watershed. Unpublished report MOF, Smithers B.C.

Wilford, D. 1987. Watershed workbook: forest hydrology sensitivity analysis for coastal British Columbia watersheds. MOF, Smithers, B.C.

Wilkes, B. 1985. Prediction of environmental impacts at a silver-gold mine. Prepared for the Followup/Audit of Environmental Assessment Results Conference, October 13-16, 1985, Banff, Alberta.

Wilkes, B. and R. Lloyd. 1990. Water quality summaries for eight rivers in the Skeena River drainage, 1983 - 1987: the Bulkley, upper Bulkley, Morice, Telkwa, Kispiox, Skeena, Lakelse and Kitimat Rivers. Skeena Region MOELP, Environmental Section Report 90-04.

Winner, R.W. 1985. Bioaccumulation and toxicity of copper as affected by interactions between humic acid and water hardness. Water Res. 19:4: 449-455.

Wissmar, R.C. 1993. The need for long-term stream monitoring programs in forest ecosystems of the Pacific Northwest. Environ. Monit. Assess. 26: 219-234.

Wojdak, P. 1995. Exploration and development highlights northwestern British Columbia - 1994. Ministry of Energy, Mines and Petroleum Resources Information Circular 1995-6.

Table 1 BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines

	BC MOELP Approved and Working Criteria	CCREM Water Quality Guidelines
ALKALINITY, TOTAL mg/L $CaCO_3$		
Aquatic life - fresh	<10, highly sensitive to acid inputs 10-20, moderately sensitive to acid inputs >20, low sensitivity	
ALUMINUM mg/L Dissolved Al		**mg/L Total Al**
Aquatic life -fresh	0.1 Dissolved Al (at pH $\geq$ 6.5), maximum; Dissolved Al = $\exp[1.209-2.426(pH) + 0.286 (pH)^2]$ at pH <6.5	0.005 Total Al, maximum (at pH<6.5; $[Ca^{2+}]<4.0$ mg/L; DOC<2.0 mg/L 0.1 Total Al, maximum (at pH$\geq$6.5; $[Ca^{2+}]\geq4.0$ mg/L; DOC$\geq$2.0 mg/L
30-day average	0.05 Dissolved Al (at median pH $\geq$ 6.5); Dissolved Aluminum = $\exp[1.6-3.327 (\text{median pH}) + 0.402 (\text{median pH})^2]$ at median pH <6.5	
Drinking	0.2 mg/L Dissolved Al, maximum	
Recreation	0.2 mg/L Dissolved Al, maximum	
ANTIMONY, TOTAL ug/L Sb		
Aquatic life - fresh	50, maximum (proposed) 610, chronic effect on algae	
Drinking	6, proposed maximum acceptable concentration	
ARSENIC, TOTAL ug/L As		
Aquatic life - fresh	50, maximum 3.5 ug/g (wet wt.) in fish protein to protect humans	50, maximum
Drinking	50, maximum (may cause skin cancer, hence under review)	50, maximum acceptable
Recreation	50, maximum (based on drinking criterion)	
CADMIUM, TOTAL ug/L Cd		**(CCREM Guidelines under review)**
Aquatic life - fresh	0.2 at hardness <60 mg/L $CaCO_3$ 0.8 at hardness 60-120 mg/L $CaCO_3$ 1.3 at hardness 120-180 mg/L $CaCO_3$ 1.8 at hardness >180 mg/L $CaCO_3$	0.2 at hardness <60 mg/L $CaCO_3$ 0.8 at hardness 60-120 mg/L $CaCO_3$ 1.3 at hardness 120-180 mg/L $CaCO_3$ 1.8 at hardness >180 mg/L $CaCO_3$
Drinking	5, maximum (health)	5, maximum (health)
Recreation	10, maximum (based on drinking water criterion)	
CHLORINE, RESIDUAL ug/L TRC[4]		
Aquatic life - fresh	100 maximum, regardless of the duration of exposure (controlled intermittent exposures) For aquatic life, the total duration of exposure in any consecutive 24-hour period should not exceed 2 hours. This is the threshold of acute toxicity.	2, maximum
average	2, average (continuous exposure) The average should be based on at least 5 samples, equally spaced in time, and the averaging period should not be less than 4 days nor more than 30 days for freshwater. This is the threshold of chronic toxicity. $[1074(\text{duration})^{-0.74}]$, average (controlled intermittent exposure) Duration is the exposure period in minutes. This is the threshold of acute toxicity.	

The 30-day average is calculated from at least 5 approximately weekly samples taken in a period of 30 days.

Table 1 (continued) BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines

	BC MOELP Approved and Working Criteria	CCREM Water Quality Guidelines
CHLOROPHYLL-a (The lake chlorophyll-a values are equivalent to the Ministry criteria for phosphorus.)		
Aquatic life - fresh	1-3.5 ug/L, lakes, summer average 100 mg/m^2, maximum, flowing water	
Drinking	2-2.5 ug/L, lakes, summer average (based on bi-weekly samples at several depths in the photic zone)	
Recreation	2-2.5 ug/L, lakes, summer average 50 mg/m^2, maximum flowing waters	
CHROMIUM, TOTAL ug/L Cr		
Aquatic life - fresh	2, maximum (to protect phyto- and zooplankton) 20, maximum (to protect fish)	2, maximum (to protect phyto- and zooplankton) 20, maximum (to protect fish)
Drinking	50, maximum (health)	50, maximum (health)
Recreation	100, maximum (based on drinking water criterion)	
COLOUR True Colour Units (Ministry criteria for colour are in preparation)		
Drinking (aesthetics)	15, maximum, true colour without colour removal 75, maximum, true colour with colour removal	15, maximum (aesthetic objective)
COPPER, TOTAL ug/L Cu		
Aquatic life - fresh 30-day average	[0.094(hardness)+2], maximum where water hardness is reported as mg/L $CaCO_3$ ≤2, (when average water hardness is ≤ 50 mg/L $CaCO_3$) ≤ [0.04 (average hardness)], (when average water hardness >50 mg/L $CaCO_3$)	2 (hardness 0-120 mg/L $CaCO_3$) 3 (hardness 120-180 mg/L $CaCO_3$) 4 (hardness >180 mg/L $CaCO_3$)
Drinking	500 maximum	1.0 mg/L maximum (aesthetic objective)
Recreation	1000 maximum	
CYANIDE ug/L as CN		
Aquatic life - fresh	10, maximum Weak-acid dissociable cyanide ≤ 5, 30-day average Weak-acid dissociable cyanide	5, maximum Free cyanide as CN
Drinking	200, maximum Strong-acid dissociable cyanide plus Thiocyanate	200, maximum (health) Free cyanide as CN
IRON, TOTAL mg/L Fe		
Aquatic life - fresh	0.3, maximum	0.3, maximum
Drinking	0.3, maximum (aesthetics)	0.3, maximum (aesthetics)

The 30-day average is calculated from at least 5 approximately weekly samples taken in a period of 30 days.

Table 1 (continued) BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines

	BC MOELP Approved and Working Criteria	CCREM Water Quality Guidelines
LEAD, TOTAL ug/L Pb		
Aquatic life - fresh	3 maximum, at hardness ≤8 mg/L $CaCO_3$; exp(1.273 In (hardness)-1.460) at hardness >8 mg/L $CaCO_3$	1 (hardness 0-60 mg/L $CaCO_3$) 2 (hardness 60-120 mg/L $CaCO_3$) 4 (hardness 120-180 mg/L $CaCO_3$) 7 (hardness >180 mg/L $CaCO_3$)
30-day average	none proposed at hardness ≤8 mg/L $CaCO_3$; ≤3.31 + exp (1.273 In (average hardness) -4.705), at hardness >8 mg/mL $CaCO_3$; 80% of values ≤1.5 x 30-day average	
Fish consumed by humans	0.8 ug/g (wet weight) (The alert level is 0.8 ug/g (wet wt.). A site-specific investigation should be done if levels approach or exceed this level.)	
Drinking	50, maximum	50, maximum (under review)
Recreation	50, maximum	
MICROBIOLOGICAL INDICATORS See Table 1.4		
NITROGEN, AMMONIA mg/L as N		
Aquatic life - fresh	20.5, maximum (pH 7.0, temperature 10°C) 1.84, 30-day average (pH 6.5-7.5, temperature 10° C) For detailed Provincial Guidelines see Tables 3 and 4 of the Approved and Working Criteria (Nagpal 1994).	2.2, maximum (pH 6.5; temperature 10°C) 1.37, maximum (pH 8.0; temperature 10°C)
NITROGEN, NITRATE mg/L as N		
Aquatic life - fresh	200, maximum ≤40, 30-day average	Concentrations that stimulate prolific weed growth should be avoided.
Drinking	10, maximum (where nitrate and nitrite are present, the total of the two should not exceed 10 mg/L)	10, maximum (where nitrate and nitrite are present, the total of the two should not exceed 10
Recreation	10, maximum	
NITROGEN, NITRITE mg/L as N		
Aquatic life - fresh	0.06, maximum (chloride <2 mg/L) 0.12, maximum (chloride 2-4 mg/L) 0.18, maximum (chloride 4-6 mg/L) 0.24, maximum (chloride 6-8 mg/L) 0.30, maximum (chloride 8-10 mg/L) 0.60, maximum (chloride >10 mg/L)	0.06, maximum
30-day average	0.02, 30-day average (chloride <2 mg/L) 0.04, 30-day average (chloride 2-4 mg/L) 0.06, 30-day average (chloride 4-6 mg/L) 0.08, 30-day average (chloride 6-8 mg/L) 0.10, 30-day average (chloride 8-10 mg/L) 0.20, 30-day average (chloride >10 mg/L)	
Drinking	1, maximum	1, maximum
Recreation	1, maximum	

The 30-day average is calculated from at least 5 approximately weekly samples taken in a period of 30 days.

Table 1 (continued) BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines

	BC MOELP Approved and Working Criteria		CCREM Water Quality Guidelines
OXYGEN, DISSOLVED mg/L O^2 Summary of effects of dissolved oxygen (Ministry criteria for dissolved oxygen are in preparation.)			
Aquatic life - fresh	Salmonid Waters		Cold-water biota
Embryo & Larval Stages	No Production Impairment	11 (8)	9.5 (early life stages)
	Slight Production Impairment	9 (6)	6.5 (other life stages)
	Moderate Production Impairment	8 (5)	
	Severe Production Impairment	7 (4)	
	Limit to Avoid Acute Mortality	6 (3)	
	(These are water column concentrations recommended to achieve the required inter gravel dissolved oxygen concentration shown in parentheses.)		
Other Life Stages	No Production Impairment	8	
	Slight Production Impairment	6	
	Moderate Production Impairment	5	
	Severe Production Impairment	4	
	Limit to Avoid Acute Mortality	3	
Inverte-brates	No Production Impairment	8	
	Some Production Impairment	5	
	Acute Mortality Limit	4	
Recreation	2, minimum, bathing		
PHENOLS, TOTAL ug/L			
Aquatic life - fresh	1, maximum, to prevent fish tainting		1, maximum
Drinking			2, maximum acceptable
PHOSPHORUS, TOTAL ug/L			
Aquatic life - fresh	5 - 15 inclusive, lakes only (with salmonids as predominant fish species). Total phosphorus in lakes during spring overturn.		
Drinking	10, maximum, lakes only		
Recreation	10, maximum, lakes only		
RESIN ACIDS ug/L			
Aquatic life -fresh	Maximum Concentration (ug/L) of		
pH	Dehydroabietic Acid	Total Resin Acids	
5.0	1	1	
5.5	2	3	
6.0	2	4	
6.5	4	9	
7.0	8	25	
7.5	12	45	
8.0	13	52	
8.5	14	60	
9.0	14	62	

The 30-day average is calculated from at least 5 approximately weekly samples taken in a period of 30 days.

Table 1 (continued) BC MOELP Water Quality Criteria and CCREM Water Quality Guidelines

	BC MOELP Approved and Working Criteria	CCREM Water Quality Guidelines
SULPHATE, DISSOLVED mg/L SO_4		
Aquatic life - fresh	100, maximum (tentative, effects on some species/life stages)	
Drinking	500, maximum (proposed aesthetic objective; there may be a laxative effect in some individuals at SO_4 levels>500 mg/L)	500, maximum (aesthetic objective)
TOTAL SUSPENDED SOLIDS mg/L or % increase over background		
Aquatic life -fresh	Induced Non-filterable Residue (NSR)	Total Suspended Solids (TSS)
	10 mg/L (background ≤ 100 mg/L) 10% increase (background >100 mg/L)	increase of 10 mg/L (background ≤ 100 mg/L) increase of 10% (background >100 mg/L)
TURBIDITY NTU		
Drinking -untreated -treated	 1, maximum (based on health considerations) 5, maximum (health, if disinfection is not compromised - also the aesthetic objective)	5, maximum
ZINC, TOTAL mg/L Zn (Ministry criteria are in preparation)		
Aquatic life - fresh	0.03, maximum, tentative (Phytoplankton are affected at levels as low as 0.014mg/L)	0.03, maximum
Drinking	5, maximum (aesthetics)	5, maximum (aesthetics)
Recreation	5, maximum (based on drinking criterion)	

Table 2 BC MOELP Criteria and CCREM Guidelines for Microbiological Indicators
(# of colonies/100 mL)

	MOELP Approved and Working Criteria	CCREM Water Quality Guidelines
Aquatic Life -fresh shellfish harvesting	Fecal coliforms ≤14 (median); ≤43 (90th perc.) *Escherichia coli* ≤14 (median); ≤43 (90th perc.) Enterococci ≤4 (median); ≤11 (90th perc.)	
Raw drinking water -no treatment -disinfection only -partial treatment	 Fecal coliforms 0 ≤10 (90th perc.) ≤100 (90th perc.)	a. No sample should contain >10 total coliform organisms/100 mL; b. not more than 10% of samples taken in a 30-day period should show the presence of coliform organisms; c. not more than two consecutive samples from the same site should show the presence of coliform organisms; and d. none of the coliform organisms detected should be fecal coliforms.
 -no treatment -disinfection only -partial treatment	*Escherichia coli* 0 ≤10 (90th perc.) ≤100 (90th perc.)	
 -no treatment -disinfection only -partial treatment	Enterococci 0 ≤3 (90th perc.) ≤25 (90th perc.)	
 -no treatment	*Pseudomonas aeruginosa* 0	
Recreation - primary contact	Fecal coliforms ≤200 (geom. mean) *Escherichia coli* ≤77 (geom. mean) Enterococci ≤20 (geom. mean) *Psudomonas aeruginosa* ≤2 (75th perc.)	*Escherichia coli* ≤200 (geom. mean 30-day); Resampling should be performed when any sample exceeds 400 *E. coli* /100 mL. Enterococci ≤35 (geom. mean 30-day); Resampling should be performed when any sample exceeds 70 enterococci /100 mL.

Fecal coliform criteria which presently exist will apply on an interim basis until use of the other preferred indicators is adopted.

Medians and geometric means are calculated from at least 5 samples in a 30-day period. Ten samples are required for 90th percentiles.

GLOSSARY AND ACRONYMS

acre foot (AF)	The volume of water which would cover one acre of land one foot deep. 1 acre-foot equals 1.2335 dam^3.
acid rock drainage (ARD) acid mine drainage (AMD)	Acid rock drainage (ARD) is caused by the natural oxidation of sulphide minerals contained in rock that is exposed to air and water. The source of most new acid generating rock is ore and waste rock exposed by mining; ARD caused by mining is also called acid mine drainage (AMD).
animal unit month (AUM)	The amount of food or plant material eaten in one month by an average-weight beef cow, aged six months or older.
biochemical oxygen demand (BOD) (BOD_5)	The biochemical oxygen demand (BOD) of a water is the amount of oxygen required to oxidize the organic matter by aerobic microbial decomposition to a stable inorganic form. BOD is usually reported as the amount of oxygen consumed over a 5-day time period at an incubation temperature of 20 °C, reported as BOD_5.
channelization	Zones of artificially stabilized or diverted channels, usually resulting in a straighter and deeper channel.
Class I and II angling waters	The *Wildlife Amendment Act*, 1989, enabled the designation of Class I and II angling waters in recognition of extremely high sport fishing values. See section 2.2.4 for further explanation of classified waters.
clear-cut equivalency	The measure of hydrologic recovery. As a clear-cut regenerates, the impacts of harvesting decrease and it becomes less of a clear-cut. Such an area is assigned a clear-cut equivalency percentage, which diminishes over time with increasing vegetative cover.
colony forming units (CFU)	CFU/100 mL is sometimes used to report the count of coliform colonies in the direct plating or membrane filter techniques for detecting and estimating coliform densities in water. See also MF/100 mL.
dissolved organic carbon (DOC)	The bulk of dissolved organic carbon in natural waters is composed of humic substances and partly degraded plant and animal material and is resistant to microbial degradation. Anthropogenic sources can contribute organic carbon as well, as runoff from agricultural lands and municipal and industrial waste discharges, especially from the pulp and paper industry.
Environmental Protection Program (EPP)	Division of MOELP responsible for administering the Waste Management Act (formerly called the Waste Management Branch).
ephemeral stream	Refers to flows of water that occur only after precipitation or snow melt and which do not flow long enough or with sufficient volumes to create well-defined channels.
epilimnion	The relatively warm, circulating and fairly turbulent surface layer of water in a lake which thermally stratifies during the summer.
eutrophication	The process by which lakes and streams become biologically more productive due to increased supply of nutrients (phosphorus and/or nitrogen). If sufficiently large amounts of nutrients enter natural waters, negative consequences may result from the presence of excessive amounts of algae.
FPC	Forest Practices Code of British Columbia.

gallons per day (GD) / gallons per year (GY)	1 imperial gallon equals 4.546E-03 m^3.
hypolimnion	The relatively cold, undisturbed deep water of a lake which thermally stratifies in the summer.
initial dilution zone (IDZ)	The zone around a waste discharge in a receiving water that is not subject to MOELP receiving water objectives. The IDZ is defined on a site-specific basis. For point discharges in rivers and streams the IDZ may extend up to 100 metres downstream of the discharge point, but not exceeding 25 % of the width of the waterbody.
IRMP	Integrated Resource Management Plan
Land & Resource Management Plan (LRMP)	A consensus-building process involving a cross section of the public, interest groups, and government agencies to establish resource-management objectives and strategies for a management area (usually a timber supply area).
littoral	The shallow perimeter of a lake basin which supports rooted aquatic vegetation.
Local Resource Use Plan (LRUP)	A resource management plan for a particular geographical area (usually a watershed) which defines management objectives and strategies for all major resources within the planning area.
LC50	The lethal concentration (LC) is described as the toxicant or effluent concentration estimated to produce death in a specified proportion of test organisms in a specified timeperiod. The 96 hr LC50 is the concentration of toxicant estimated to kill 50% of exposed organisms (usually rainbow trout underyearlings) within 96 hours.
machine reserve	A machine reserve is a system of selective cutting along a stream in which leaning commercial trees and immatures are left within a specified distance of the streambank and equipment operation is minimized in this strip.
minimum detectable concentration (MDC)	The minimum concentration of a substance that can be routinely detected by the operating analytical instrument or technique with a high degree of confidence that any reported value is reliable.
membrane filter (MF)	MF/100 mL is used to report the count of coliform colonies in the membrane filter method of detecting and estimating coliform bacterial densities in water. See also CFU/100 mL.
Microtox	The Microtox assay is a bacterial luminescence bioassay that was developed as a rapid screening test. The test is based on the reduction in bioluminescence of a marine bacterium by toxicant, reported as EC50 (the concentration of toxicant causing a 50% reduction in light from baseline).
MOELP	Ministry of Environment, Lands and Parks of British Columbia
most probable number (MPN)	MPN/100 mL is used to report the estimated number of coliform colonies in the multiple-tube fermentation method for detecting and estimating coliform bacterial densities in water.

non-filterable residue (NFR)	A method for measuring the suspended particulates in water (see also TSS). NFR refers to the portion of residue in a sample which retained on a 0.45 μm glass fiber filter and dried at 103-105 °C.
nephelometer turbidity unit (NTU)	Turbidity is a measure of the suspended particles such as silt, clay, organic matter and microscopic organisms in water. The measure of turbidity as the amount of light detected in a sample after it is scattered 90° from the source in a nephelometer, is expressed in NTU units.
NWMDRC	Northwest Mine Development Review Committee (Skeena Region).
oligotrophic	An oligotrophic lake is low in nutrients and productivity, with large amounts of dissolved oxygen in the deepest water. Water clarity is high, as is diversity of phytoplankton, but total algal biomass is low.
organic complexing capacity	One of the principal variables controlling heavy metal speciation in natural waters is the concentration of organic ligands that bind specific metals. The degree to which a given metal will be bound or complexed will depend on competition reactions with other ligands and each metal's affinity for those ligands. Copper and mercury have high affinities for binding to humic materials.
Protected Areas Strategy (PAS)	A provincial land use planning process that was established in 1992 to identify and establish Protected designation for areas representative of the province's diverse natural, cultural heritage and recreational values. Protected areas are areas such as provincial or federal parks, wilderness areas, ecological reserves, and recreation areas in which no industrial resource extraction or development is permitted.
7 day average 10 year low flow	In most jurisdictions in Canada and the US, water withdrawals and minimum dilution requirements for liquid effluents are calculated using the average 7 consecutive day low flow on a 10 year return period (the average low flow of at least one weeks duration which is predicted to occur every 10 years).
STP	sewage treatment plant
stream order	First order channels are non-branching headwater channel segments. Second order channels are those that receive only 1st order channels. Third order channels are those where two 2nd order channels join; fourth order channels are those where two 3rd order channels join, etc. Most salmonid spawning anad rearing takes place in 2nd to 4th order streams.
total dissolved solids (TDS)	TDS is the amount of dissolved substances in water, and gives a general indication of the chemical quality. TDS is defined analytically either by total filterable residue (the portion in a sample which passed through a 0.45 μm glass fiber filter and dried at 180 °C) or by conductivity (specific conductance is a measure of the ability of an aqueous solution to carry an electrical current).
Timber Supply Area (TSA)	An area of the province designated by MOF for the purpose of analysis, planning and management of timber resources. The harvesting limits for TSAs, called allowable annual cuts (AACs) are determined by the chief forester. Many types and sizes of harvesting agreements may exist within a TSA.
total Kjeldahl nitrogen (TKN)	TKN measures both ammonia and organic nitrogen, both of which are important for assessing available nitrogen for biological activities.

Tree Farm License (TFL)	A privately managed, sustained-yield unit area in which the Crown adds forest land to a company's private holdings (if any) sufficient to provide a continuous supply of wood for an existing or planned mill. The harvesting limits for TFLs, called allowable annual cuts (AACs) are determined by the chief forester.
true colour units (TCU)	A measure of the dissolved colouring compounds in water. The colour of water is attributable to the presence of organic and inorganic materials; different material absorb various light frequencies. Water whose colour is less than 10 TCU passes unnoticed to visual inspection; water with a value of 100 resembles tea. Water from swamps and bogs may exhibit values in the 200 to 300 TCU range.
total suspended solids (TSS)	TSS are the particles such as silt, clay, organic matter, plankton and microscopic organisms which are held in suspension by turbulence and Brownian movement in lakes and streams. Particulate matter can be quantified by measuring non-filterable residue (NFR).
water quality criterion	A maximum or minimum physical, chemical or biological characteristic, applicable province-wide, which must not be exceeded to prevent detrimental effects from occurring to a water use, including aquatic life. Water quality criteria are safe levels of contaminants for the protection of a given water use.
Water Quality Objectives (WQO)	Water quality objectives are environmental quality conditions set as targets for specific water bodies based on three main factors 1) the designated uses for the water 2) the water quality criteria that have been adopted for the most sensitive designated use, and 3) the local conditions, including the actual measured water quality in the area.
WRP	Watershed Restoration Program of British Columbia.
WSC	Water Survey Canada