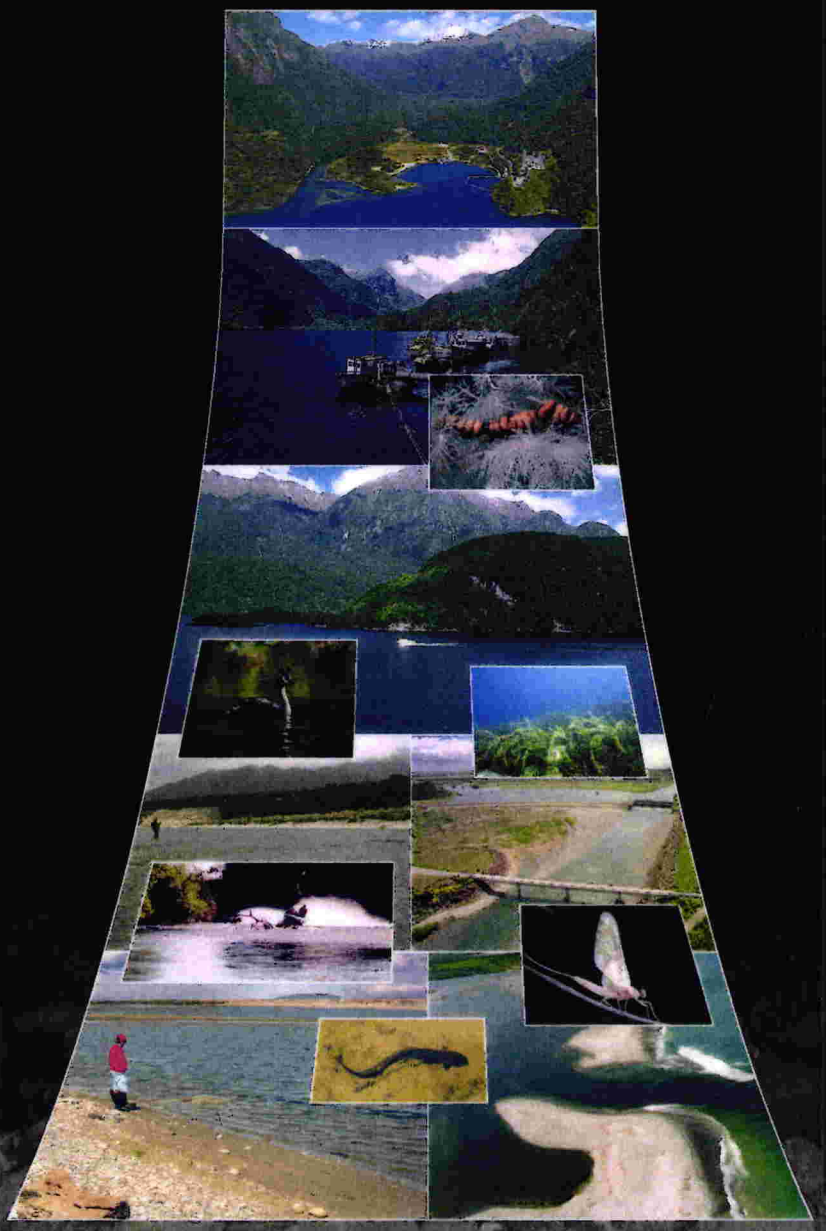
3102

ECNZ

MANAPOURI
POWER SCHEME



ASSESSMENT of EFFECTS on the ENVIRONMENT

Contents

Foreword iii

Executive Summary vi

Acknowledgements vii

List of Figures viii

List of Tables xii

Fourth Schedule Index–Resource Management Act xiii

Abbreviations xiv

Index of Parts xv

Part 1:Introduction and Project Description 1

Part 2: Environmental and Socio-economic Setting 23

Part 3: Public Consultation and Issues Identification 61

Part 4: Impact Assessment 83

Part 5: Outcomes 147

Bibliography 171

References 181

Appendices 187

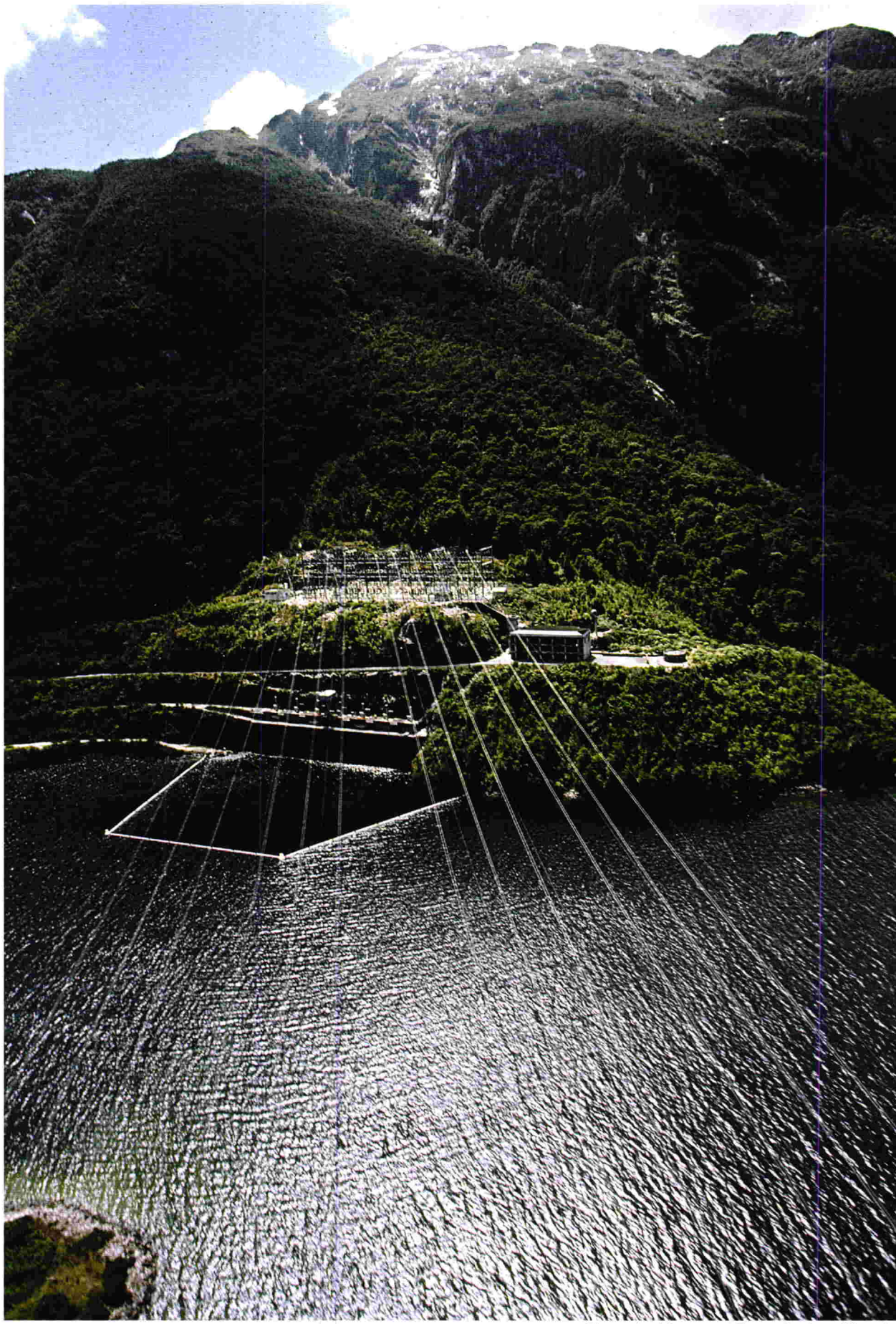


Figure 1 – Manapouri Power Station–West Arm

Foreword

Manapouri Power Station produces, on average, 4300 GWh per year. Though figures can sometimes be taken for granted, this does represent 15% of the total of New Zealand's electricity consumption—more than twice the output of the Clyde Dam.

The station was built, amid controversy, under the authority of the Manapouri-Te Anau Development Act of 1963. In the intervening period, Manapouri has become an essential part of the nation's generating system. Because of the high differential in levels between the intake at Lake Manapouri and the outfall at Deep Cove, one cubic metre per second of water can produce enough power to supply 160 households. The passage of the Resource Management Act (RMA) meant the rights to use water became deemed permits under RMA and had to be replaced before 1 October 2001.

The Waiau catchment has nationally significant environmental values. The lakes are part of Fiordland National Park, New Zealand's largest, and a part of the area designated as a World Heritage Park. Before the control structure at Mararoa was built, the Lower Waiau River was the second largest river in New Zealand. The swiftness of its dark green water was legendary. Since control in 1976, this spectacle is largely only a memory, although large flows are returned to the river when lake levels are high.

The initial task of this assessment has been to identify and document the environmental effects which electricity generation at Manapouri Power Station has had on the water resources of the Waiau catchment. The next step was to determine which of these effects should be avoided, remedied or mitigated in accordance with the principles of sustainable management. Finally, measures were proposed which ECNZ, as applicant, could adopt to achieve the required standard of avoidance, remediation or mitigation.

The assessment has been complex. Because the matters to be balanced are of such national significance, it was considered essential that a wide-ranging, well-resourced and careful programme of expert studies be carried out. It was equally essential that this process be public.

The Waiau Working Party was established by the Southland Regional Council and funded by the ECNZ to carry out research into all issues of concern raised by interested parties. To date, this process has been underway for six years with a wide range of issues identified and studies conducted. At the same time, consultation with other parties such as local iwi, the Fish and Game Council, Department of Conservation, and local communities has led to further studies commissioned directly by ECNZ. The methods and outcomes of all studies have been made available for public scrutiny.

I would like to record my profound admiration for the manner in which the members of the Waiau Working Party have carried out this exhaustive study of the Waiau catchment, its values and the effect on it of the Power Scheme's use of water. Out of commitment to addressing the concerns and representing the interests of their respective groups, and out of a collective concern for the community and nation, they have, over a period of six years, attended numerous one or sometimes two-day meetings, field trips and task groups and studied enough reports to make

a stack of paper several metres high. Over this time, they have individually and collectively moved from representing a position, through a process of gaining knowledge, to an understanding of issues and, in the end, to a consensus on a package of measures that addresses these issues. I regard their work and the outcome they have achieved as internationally outstanding. I feel privileged to have known and worked with them.

While the Working Party has been the main vehicle of consultation, and most of the studies and reports on which this assessment is based were commissioned by the Working Party, this Assessment of Effects on the Environment is the product of ECNZ and the Corporation is solely responsible for its adequacy. Some effects, particularly those relating to the discharge into Deep Cove, were not addressed directly by the Working Party. Members have, however, had the opportunity to read the reports ECNZ has commissioned and consider the measures proposed to avoid adverse effects.

I believe the package proposed will lead to an outcome that is truly sustainable and which will provide for values in keeping with the pristine character of this part of New Zealand. Features are:

- The Lake Operating Guidelines which have been developed and tested over 21 years are to be preserved as conditions on the water permits. The Guardians will retain their advisory function to the Regional Council.
- A new fish pass suitable for brown trout will be constructed at Manapouri Lake Control (Mararoa Weir) and native fish passes installed on both Te Anau and Manapouri Lake Control Structures.
- Minimum flows and rates of change in respect of the Upper Waiau River, which have been trialed for two years, will be formalised as conditions on water permits.
- A minimum flow, averaging 14 cumecs with seasonal variation, will be maintained at all times in the Waiau River below Manapouri Lake Control. This flow will provide habitat potential for native and sports fish equal to the top ten rivers in New Zealand.
- A condition on the discharge right to Deep Cove will ensure that the Power Station does not discharge more water to the sound than its maximum discharge to date of 510 cumecs.
- While these flow and flow-related conditions will provide appropriate mitigation of the significant effects of the power development, the Corporation has agreed to a series of measures which will provide for the environmental values of the modified Waiau catchment in a better way than could be achieved by greater flow constraints. Funding will be provided totalling $7.5M to provide for:
  - *Wildlife and Fisheries Habitat* - over the term of the water right, this fund will restore habitat in tributary streams, enhance wetland areas and support planting of hundreds of thousands of native trees.

Foreword

- *Mahika Kai* - carefully selected wetland development will provide for areas where native fish and plants can thrive while ensuring secure access for local runaka to traditionally valued food sources.
- *Community Amenities* - a fund will provide Tuatapere with a secure water supply and empower this community to provide for amenities and development opportunities which may otherwise have been affected by the reduced flow in the Waiau River.
- *Southland District Facilities Funding* - the Southland District Council will use funds provided to extend and repair boat ramps on the lakes and at the Waiau Mouth; provide new boat ramps at Owen's Reach, Monowai and Tuatapere; and, repair the retaining wall and maintain other facilities at Manapouri.
- *Agreement with Lower Waiau landowners* - to continue to fund the annual spraying of vegetation in the flood channel and maintain fences between the Mararoa Weir and the river mouth in a stock proof condition. Should a rating district be established, ECNZ will contribute to the rating district rather than undertake the above work.

- The entire package will be underpinned by a comprehensive monitoring programme, the results of which will be published annually. The Regional Council will have the power to review conditions if the results of monitoring indicate that this is necessary.

ECNZ is proud to have been part of the Waiau Working Party. I am confident that the Waiau River will, as a result of the agreements reached, be a better place for native flora and fauna, for recreationalists - particularly sports fishers and hunters - and, most importantly, for people because of the continued presence of the Manapouri Power Scheme.



Mark France
Hydro Resource Manager S.I.
ECNZ Fuel Resource Group S.I.

Executive Summary

The Manapouri power scheme captures and uses waters from the Waiau River catchment for power generation at West Arm, Lake Manapouri. Such use of water over more than 20 years has created change within the catchment and the creation of a new equilibrium which encompasses a reduction of flow in the Lower Waiau River and an increase in freshwater discharge into Deep Cove. Major changes have occurred and have now stabilised to establish a modified environmental baseline.

Throughout the consultation programme, initiated in 1990 to identify and address issues and opportunities raised by the operation of the Manapouri power scheme, issues have been assessed in terms of their actual or potential effects on the bio-physical and socio-cultural environments. Some of those issues raised have been found not to be consequences of the power scheme. Other issues have led to detailed study, the acknowledgement of their impacts and the delineation of future management plans and agreements designed to avoid, remedy, or mitigate the effects and monitor the effectiveness of such measures.

The Lower Waiau River was a "big river" which, as a result of the Manapouri power scheme, has been reduced in flow. The challenge of the Waiau Working Party has been to strike a balance between the change in the river and the generation of power. It has been acknowledged that, while preserving the national benefits of power generation from a renewable resource, the regional and local effects on the Lower Waiau River must be mitigated. The most significant element in the strategy to mitigate such effects is the proposal for provision of a new minimum flow regime for the Lower Waiau to achieve a substantial continuous flow, thus restoring some of the river's former physical and cultural values.

Acknowledgements

ECNZ wishes to acknowledge the interest and contribution made by all parties involved in this consultative process. A great deal of enthusiasm, time and commitment, aimed at achieving appropriate outcomes for the Waiau catchment, has been of vital importance.

In particular, we would like to take this opportunity to thank all the members of the Waiau Working Party, the Southland Regional Council for convening Working Party meetings, Teri McClelland for her administrative support and Jan Riddell for her guidance as chairperson.

It is also appropriate to acknowledge the input of the various consultants without whose expertise and quality research we would not have achieved the outcomes outlined in this document.



Figure 2 – Waiau Working Party meeting–Invercargill

List of Figures

1. Manapouri Power Station–West Arm . . . ii
2. Waiau Working Party meeting–Invercargill . . . vii
3. Biota study . . . xxii
4. Waiau Working Party meeting – Invercargill . . . 3
5. Location of power scheme components and resource consents . . . 5
6. Lake Te Anau Control Structure (TLC) . . . 9
7. Lake Manapouri Control Structure (MLC) . . . 9
8. Elements of the Manapouri Power Station . . . 11
9. Tailrace channel . . . 13
10. Tunnel Boring Machine (TBM) . . . 15
11. Machine hall, Manapouri Power Station . . . 17
12. Tourist Launch on Lake Manapouri . . . 21
13. Cleve Garth Falls as seen from Wilmot Pass Road . . . 24
14. Looking south towards Mararoa Weir and Lower Waiau River valley . . . 25
15. Lake Manapouri Monthly Mean Inflows . . . 29
16. Lake Te Anau Daily Outflow Distribution . . . 31
17. Lake Manapouri Outflows . . . 32
18. Mararoa Weir (Manapouri Lake Control – MLC) . . . 34
19. Mararoa Weir under flood . . . 37
20. Tuatapere flood, January 1984 . . . 37
21. Waiau Catchment – Water Quality Classification . . . 39

List of Figures

22. Nitella, an aquatic plant . . . 40

23. Typical Manapouri / Te Anau shoreline vegetation pattern . . . 41

24. Giant Kokopu (Galaxies argenteus) . . . 42

25. Lower Waiau River, a natural boundary between developed and undeveloped catchments . . . 45

26. Waiau Catchment – Relative abundance of benthic algal growths in rivers and streams during low February flows (Robertson, 1993). . . . 46

27. Adult Stonefly (Stenoperla prasina) . . . 47

28. Waiau Catchment – Quantitative Macroinvertibrate Community Index (QMCI) of rivers and streams during low flows (Robertson, 1993). . . . 48

29. Calendar of seasonal fish migrations in the Waiau River (McDowall 1994b) . . . 49

30. Spur-winged Plover . . . 50

31. Banded Dotterel . . . 51

32. Te Waewae Lagoon and Waiau River Mouth . . . 53

33. Profile of LSL effect . . . 54

34. Black Coral with Snake Starfish . . . 55

35. Southwest New Zealand World Heritage Area . . . 56

36. Artistic impression of early Maori life – Otago Museum . . . 57

37. Tourist boats at the Deep Cove wharf . . . 60

38. Iwi visit to Deep Cove . . . 65

39. Early airing of concerns and identification of issues . . . 67

40. Whitebaiting near the Waiau River Mouth . . . 68

41. Waiau Working Party inspecting riverbank erosion . . . 80

List of Figures

42. Syd Cormack on the bank of the Lower Waiau River . . . 81

43. Tourist operations at West Arm . . . 87

44. Lake Te Anau Annual Mean Levels . . . 89

45. Lake Manapouri Annual Mean Levels . . . 89

46. Lake Operating Guidelines – Lakes Manapouri and Te Anau . . . 91

47. Beach slumping caused by low lake levels . . . 93

48. Inspection of Lake Manapouri shoreline . . . 95

49. Wave-cut platforms and mini-cliffing caused by steady lake levels . . . 96

50. Isoetes with Milfoils . . . 97

51. Southern Crested Grebe (Podiceps cristatus australis) . . . 98

52. Upper Waiau River channel changes (from Brierley 1994) . . . 100

53. Mayfly nymph (Coloburiscus humeralis) . . . 102

54. Brown Trout . . . 104

55. Dewatered Trout redd . . . 105

56. Lower Waiau River flood peaks . . . 108

57. Sediment build-up above and below Mararoa Weir . . . 113

58. Adult Mayfly (Ameletopsis sp.) . . . 115

59. Variation in the weighted usable area of adult brown trout habitat with flow. . . . 116

60. Variation in the weighted usable area of food-producing habitat with flow. . . . 117

61. Variation in the weighted usable area of Deleatidium habitat with flow. . . . 117

62. Variation in weighted usable area of food-producing habitat with flow . . . 118

List of Figures

63. Mararoa Weir – entrance to existing fish pass highlighted . . . 121

64. Native fish (Galaxies sp.) . . . 122

65. Whitebait habitat and whitebait (inset) . . . 123

66. Native fish pass, Matahina Dam, Bay of Plenty . . . 125

67. Discharge of tailrace channel and Lyvia River into Deep Cove . . . 129

68. Intertidal biota near the junction of Crooked Arm . . . 131

69. Whitebaiting hut – Lower Waiau River . . . 136

70. New Zealand Long-finned Eel (Anguilla dieffenbachii) . . . 138

71. Fencing along the Lower Waiau River . . . 139

72. River character comparison – Lower Mataura (above) and Lower Waiau (below) . . . 141

73. Kayaking the Lower Waiau River . . . 143

74. Jetboating on the Lower Waiau River . . . 144

75. Angling near Redcliffs . . . 145

76. The consultation process . . . 152

77. 16 cumec flow release – Mararoa Weir . . . 156

78. Operation of a proposed Borland fishpass for Mararoa Weir . . . 158

79. Intertidal biota . . . 160

80. Subtidal rock wall biota . . . 161

List of Tables

1. Lake Characteristics . . . 28

2. Lake Te Anau Inflow Summary . . . 30

3. Lake Manapouri Inflow Summary . . . 30

4. Lake Te Anau Outflow Summary . . . 31

5. Lake Manapouri Total Outflow Summary . . . 32

6. Power Station Outflow Summary . . . 33

7. Mararoa Weir Outflow Summary . . . 34

8. Analysis of the Components of Water Spilled at the Mararoa Weir . . . 35

9. Flow Summary for Waiau River at Tuatapere . . . 36

10. Fish Species Known to Occur in the Waiau Catchment . . . 43–44

11. Birds of the Waiau Catchment . . . 50–52

12. Waiau Working Party Reports Commissioned . . . 68–71

13. Publications Relating to Guardians Issues . . . 72–74

14. Publications Relating to Additional Issues Identified by ECNZ . . . 75–76

15. Operating Guidelines for the Levels of Lakes Manapouri and Te Anau . . . 90

16. Fish Maximum Swimming Speed and Endurance . . . 103

17. Flows (cumecs) Required to Provide Optimum Habitat (WUA%) and Flows Below Which Habitat Begins to Decline Sharply in the Three Surveyed Reaches of the Lower Waiau River . . . 119

18. Numbers of Trout Found Using the Borda Fish Pass . . . 120

19. Native Fish Captured in the Mararoa Fish Pass . . . 124

20. Effects of New Flow Regime on Electricity Generation . . . 164

Fourth Schedule Index — Resource Management Act

Index of matters covered by the Fourth Schedule
Resource Management Act 1991. Section(s)

1 Matters that should be included in an assessment of effects on the environment.

(a) Description of the proposal . . . 2
(b) Alternative locations or methods . . . 1.3
(c) (Repealed)
(d) Assessment of actual or potential effects . . . 7,8,9,10,11,12
(e) Hazards risk assessment . . . N/A
(f) Discharge of contaminants -
Nature of the discharge . . . 11.2
Sensitivity of the receiving environment . . . 3.9.3, 11.1.3
Any possible alternative discharge methods . . . 1.3
(g) Mitigation measures to prevent or reduce the actual or potential effect . . . 14
(h) Consultation . . . 5,6
(i) Monitoring . . . 14, App. 4

2. Matters that should be considered when preparing an assessment of effects on the environment.

(a) Any effect on the neighbourhood, and wider community, socio-economic and cultural effects . . . 12
(b) Physical effects on locality, including landscape and visual effects . . . 8,9,10,11,12
(c) Effects on ecosystems, including plants, animals and physical effects . . . 8,9,10,11
(d) Aesthetic, recreational, scientific, historic, spiritual, cultural or special resources . . . 7,8,9,10,11,12
(e) Discharge of contaminants, including noise and options for disposal of contaminants . . . 11
(f) Risks to the neighbourhood, community or environment through hazards etc. . . . 10.3.2, 12.3.4

Abbreviations

AEE	Assessment of Environmental Effects
CO	Carbon Dioxide
CUMECS	Cubic Metres per Second
DOC	Department of Conservation
ECNZ	Electricity Corporation of New Zealand
EECA	Energy Efficiency Conservation Authority
FCCC	Framework Convention on Climate Change
FNPMP	Fiordland National Park Management Plan
GWh	Gigawatt Hour
HVDC	High-Voltage Direct Current
Hz	Hertz
IFIM	Instream Flow Incremental Method
$KtCO_2yr$	Kilotons of Carbon Dioxide per Year
kVA	Kilovolts
LSL	Low Salinity Layer
M2TT	Manapouri Second Tailrace Tunnel
MAF	Ministry of Agriculture and Fisheries
MfE	Ministry for the Environment
MLC	Manapouri Lakes Control or Mararoa Weir
MTADA	Manapouri Te Anau Development Act 1963
NTU	Nephelometric Turbidity Units
NWASCA	National Water and Soil Conservation Authority
RL	Mean Sea Level
RMA	Resource Management Act 1991
SDC	Southland District Council
SFGC	Southland Fish and Game Council
SRC	Southland Regional Council
TBM	Tunnel Boring Machine
Tpa	Tonnes per annum
WUA	Weighted Useable Area
WWP	Waiau Working Party

Part 1 – Introduction and Project Description

Chapter 1–Introduction . . . 2

1.1 Purpose of this Document . . . 2

1.2 Purpose of this Application . . . 2

1.3 Alternatives to the Proposal . . . 2

1.4 Nature and Scope of the Assessment of Environmental Effects . . . 2

1.5 The Consultation Process . . . 3

Chapter 2 – The Manapouri Power Scheme . . . 4

2.1 Location and Access . . . 4

2.2 Background . . . 6

2.3 System Components . . . 8

2.3.1 Lake Te Anau Control (TLC) . . . 8

2.3.2 Manapouri Lake Control (MLC and also called the Mararoa Weir) . . . 8

2.3.3 Manapouri Power Station . . . 10

2.3.4 Second Tailrace Tunnel . . . 14

2.4 Description of Operations . . . 16

2.4.1 Generating Capacity and Output . . . 17

2.4.2 Operation . . . 18

2.4.3 General Specifications . . . 18

2.5 Risk Management . . . 18

2.6 Statutory Framework (for Water, Coastal and Discharge Permits) . . . 19

2.6.1 Manapouri-Te Anau Development Act 1963 (MTADA) . . . 19

2.6.2 Resource Management Act 1991 (RMA) . . . 20

2.6.3 The National Parks Act 1980 and Fiordland National Park Management Plan 1991 . . . 21

2.6.4 Relationship Between the MTADA, the RMA and the National Parks Act 1980 . . . 22

Part 2 – Environmental and Socio-economic Setting

Chapter 3–The Bio-physical Environment . . . 24

3.1 Geography and Landscape . . . 24

3.2 Geology . . . 26

3.3 Soils and Vegetation . . . 27

3.4 Climate . . . 27

3.5 Hydrology . . . 28

3.5.1 Lake Levels . . . 28

3.5.2 Te Anau and Manapouri Inflows . . . 29

3.5.3 Lake Te Anau Outflows and Upper Waiau River Flows . . . 30

3.5.4 Lake Manapouri Outflows . . . 32

3.5.5 Mararoa Weir (Manapouri Lake Control) Outflows . . . 34

3.5.6 Tuatapere Flows . . . 36

3.6 Water Quality . . . 38

3.7 Erosion and Channel Morphology . . . 38

3.8 Freshwater Ecosystems . . . 40

3.8.1 The Lake Ecosystems . . . 40

3.8.2 River Ecosystems . . . 45

3.9 Coastal Ecosystems . . . 53

3.9.1 Te Waewae Lagoon . . . 53

3.9.2 Te Waewae Bay . . . 53

3.9.3 Doubtful Sound . . . 54

Chapter 4 –The Cultural Environment . . . 56

4.1 Historical Resources . . . 57

4.1.1 Maori History . . . 57

4.1.2 European History . . . 58

4.2 Cultural and Economic Resources . . . 59

4.2.1 Land Uses . . . 59

4.2.2 Infrastructure . . . 59

4.2.3 Recreation and Tourism . . . 60

Part 3 – Public Consultation and Issues Identification

Chapter 5 – The Public Consultation Programme 62

5.1 Waiau Working Party 62

5.2 Tangata Whenua 65

5.3 Other Statutory Authorities 66

5.4 Information Dissemination 66

5.5 Conclusion 66

Chapter 6 – Issues Identification 67

6.1 Scoping 67

6.1.1 Waiau Working Party 67

6.1.2 Guardians of Lakes Manapouri, Te Anau and Monowai 72

6.1.3 ECNZ 74

6.2 National Issues 77

6.3 Issues Associated with the Damming and Discharge of Water at the Te Anau Control Structure 77

6.4 Issues Associated with the Damming, Diversion and Discharge of Water at the Mararoa Weir 77

6.4.1 Reduced Flow in the Lower Waiau River 77

6.4.2 Altered Flow Regime of Lower Waiau River 78

6.4.3 Fish Habitats 79

6.4.4 Recreation 79

6.4.5 Riparian Management 80

6.4.6 Iwi Issues 81

6.4.7 Tuatapere Amenities 82

6.5 Lake Level and River Management Issues Identified by The Guardians of Lakes Manapouri and Te Anau 82

6.6 Issues Covering West Arm Powerhouse and Deep Cove Discharge 82

Part 4 – Impact Assessment

Chapter 7 – National and Regional Importance of the Manapouri Power Scheme 84

7.1 National Contribution of the Manapouri Power Scheme . . . 85

7.2 National Cumulative Benefits . . . 86

7.3 Other National Economic Benefits . . . 86

7.4 Regional Benefits . . . 87

7.4.1 Tourism . . . 87

7.4.2 Industry and Employment . . . 87

Chapter 8 – Environmental Effects of Lake Control . . . 88

8.1 Lake Levels . . . 88

8.2 Gazetted Lake Level Guidelines . . . 88

8.2.1 Ecological Basis for Guidelines . . . 88

8.2.2 Basic Elements of Operating Guidelines . . . 91

8.2.3 Monitoring by Guardians . . . 92

8.3 Lakeshore Erosion . . . 93

8.4 Shoreline Vegetation . . . 95

8.5 Aquatic Macrophytes . . . 97

8.6 Aquatic Birdlife . . . 98

Chapter 9 – Environmental Effects of Flow Control on the Upper Waiau River 99

9.1 Te Anau Control Gate Operating Procedures . . . 99

9.2 Erosion and Sedimentation . . . 101

9.3 Macroinvertebrates . . . 102

9.4 Native and Introduced Fisheries . . . 102

9.4.1 Native and Introduced Fish Passage . . . 102

9.4.2 Trout Fisheries . . . 104

9.4.3 Trout Spawning . . . 105

Part 4–Impact Assessment (continued)

Chapter 10 – Environmental Effects of Flow Control on the Lower Waiau River 106

10.1 Introduction 106

10.2 New Flow Regime 106

10.3 Physical Effects 107

10.3.1 Flow Reversal at the Mararoa Weir 107

10.3.2 Flood Control 108

10.3.3 "Flushing" Flows 109

10.3.4 Flow Fluctuations 110

10.3.5 Rivermouth Closure 110

10.3.6 Channel Erosion and Deposition 111

10.3.7 Deposition Above and Below the Mararoa Weir 112

10.4 Ecological Effects 114

10.4.1 Periphyton 114

10.4.2 Macroinvertebrates 115

10.4.3 Trout Habitat 116

10.4.4 Trout Passage 120

10.4.5 Native Fish Habitat 122

10.4.6 Whitebait Habitat 123

10.4.7 Native Fish Passage 124

10.4.8 Birds 126

10.4.9 Te Waewae Bay Marine Environment 126

Chapter 11 – Effects of Freshwater Discharge into Deep Cove 128

11.1 Circulation in Doubtful Sound 128

11.1.1 Freshwater Influence in the Sound 128

11.1.2 Surface Flow Velocity 130

11.1.3 Ecological Effects of Increased Freshwater Discharge 131

11.2 Water Quality 133

Part 4 – Impact Assessment (continued)

Chapter 12 – Social Impact Assessment . . . 135

12.1 Iwi Issues . . . 136

12.1.1 Introduction – The Mauri of the River . . . 136

12.1.2 Mahika Kai . . . 137

12.1.3 Downstream Migration of the Heke (Mature Eels) . . . 138

12.2 Community Issues . . . 139

12.2.1 Riparian Issues . . . 139

12.2.2 Natural Character and Amenity Values . . . 140

12.2.3 Tuatapere Water Supply . . . 141

12.2.4 Groundwater . . . 142

12.2.5 General Amenity Effects . . . 142

12.3 Recreation . . . 143

12.3.1 Access . . . 143

12.3.2 Jetboating . . . 144

12.3.3 Angling . . . 145

12.3.4 Public Safety . . . 146

Part 5 – Outcomes

Chapter 13 – Summary of Environmental Effects . . . 148

13.1 National and Regional Effects . . . 148

13.2 Effects of Flow Control on Upper Waiau . . . 149

13.3 Effects of Manapouri Power Station and Deep Cove Tailrace . . . 149

13.4 Effects of Flow Control on Lower Waiau River . . . 150

Chapter 14 – Summary of Outcomes of Consultation . . . 153

A. Introduction . . . 153

B. Future ECNZ Management of Effects . . . 153

Part 5 – Outcomes (continued)

Chapter 14 – Summary of Outcomes of Consultation (continued)

14.1 Lakes . . . 154
14.1.1 Lake Control . . . 154
14.1.2 Monitoring . . . 154
14.2 Upper Waiau River . . . 154
14.2.1 Minimum Flows . . . 154
14.2.2 Flow Fluctuations . . . 154
14.2.3 Native Fishpass Installation . . . 154
14.2.4 Monitoring . . . 155
14.3 Lower Waiau River . . . 155
14.3.1 Gate Control . . . 155
14.3.2 Erosion . . . 155
14.3.3 New Flow Regime . . . 156
14.3.4 Native Fishpass Installation . . . 157
14.3.5 Trout Fishpass Installation . . . 158
14.3.6 Monitoring . . . 159
14.4 Doubtful Sound . . . 160
14.4.1 Freshwater Influence . . . 160
14.4.2 Water Quality . . . 162
14.4.3 Monitoring . . . 163
14.5 Cost . . . 164
C. Agreements/Trusts . . . 165
14.6 The Waiau Mahika Kai Trust Agreement . . . 165
14.7 The Waiau Habitat Enhancement Trust Agreement . . . 166
14.8 The Tuatapere Amenities Trust Agreement . . . 167
14.9 The Waiau Amenities Payment . . . 167
14.10 Agreement between ECNZ, Federated Farmers of NZ Limited and the SRC . . . 169

Chapter 15 – Conclusion . . . 170

Bibliography, References, Appendices

Bibliography 171

References 181

Appendices 187

Appendix I – Gazetted Lake Level Guidelines–NZ Gazette 29 April 1993

Appendix II – Classification of "Class C and SB" Waters

Appendix III – Macroinvertebrate Records from Lakes Manapouri and Te Anau (from Stark 1993)

Appendix IV – Monitoring Programme



Figure 3 – Biota study

Part 1

Introduction and Project Description

Chapter 1 – Introduction

1.1 Purpose of this Document

The Manapouri Power Scheme has been in operation since 1969. Waters from the Waiau River catchment, which includes Lakes Manapouri and Te Anau, is being diverted through the hydroelectric power station at West Arm. This use of water resources has been authorised by the Manapouri - Te Anau Development Act 1963. As directed by the Resource Management Act 1991 (RMA), existing water use permits expire on 1 October, 2001 necessitating renewed consents for continued operation of the Manapouri Power Scheme.

An assessment of effects on the environment (AEE), as required by the RMA, has been prepared by the Electricity Corporation of New Zealand (ECNZ) to accompany its application for the water consents. The AEE fully considers the requirements set out in the Fourth Schedule of the RMA (see Index, page xiii).

1.2 Purpose of this Application

ECNZ is applying for the renewal of water rights to dam, divert, take, use and discharge water in the Waiau catchment as is required for the Manapouri Power Scheme. The application outlines measures that are or will be taken to maximise benefits to the economy and minimise negative effects to the environment by utilising water in a balanced, efficient manner.

Environmental effects of the existing scheme have been considered and measures, existing and proposed, to avoid, remedy or mitigate any effects have been detailed. Notable among these measures are proposed changes to the flow regime in the Lower Waiau River.

1.3 Alternatives to the Proposal

Practically, there are no available alternatives to the continued resource use within the existing infrastructure of the Manapouri Power Scheme. Rather than change the existing scheme, it is proposed the system be modified to remedy and mitigate environmental effects and, where possible, enhance the resource for other users.

1.4 Nature and Scope of the Assessment of Environmental Effects

All resource consents included with the application are covered by this AEE. To prevent repetition of information and to allow a more comprehensive approach to the consent process, assessment of effects, mitigation and monitoring are identified within the context of the Manapouri Power Scheme as a whole, rather than for each individual resource consent. ECNZ's statutory obligations in applying for resource consents and the environmental effects associated

with the Waiau catchment are dealt with in this assessment. Environmental effects include physical and ecological processes as well as socio-cultural issues. Mitigation measures and the consultation processes adopted during the preparation of this AEE are discussed.

A full reference list and a bibliography are appended. Copies of all technical documents referred to are held by ECNZ, the Waiau Working Party and Southland Regional Council.

1.5 The Consultation Process

As part of the assessment of environmental effects, ECNZ has chosen to engage in extensive consultation to ensure a thorough canvassing of issues of concern to those local, regional and national bodies which have chosen to participate. A full review of the public consultation programme is provided in Section 5.



Figure 4 – Waiau Working Party meeting – Invercargill

Chapter 2–The Manapouri Power Scheme

The Manapouri Power Scheme is a critical component of New Zealand's electricity system. The power station is ECNZ's largest individual hydro station and second largest station overall both in terms of installed, usable capacity and annual generation[1].

The Manapouri Scheme uses the water stored in Lakes Manapouri and Te Anau for the generation of power at an underground hydro power station some 180m below the West Arm of Lake Manapouri. Storage is effected by control structures at each of the lake outlets. The Manapouri Lake Control structure (Mararoa Weir) also diverts the flow of the Mararoa River into the lake.

The water used by the power station is discharged via a 10 km tailrace tunnel into Doubtful Sound to the west. This diversion has resulted in the normal flow of the Lower Waiau River being substantially reduced.

2.1 Location and Access

Lake Te Anau, Lake Manapouri and the Waiau River into which they drain are located in the south west corner of the South Island along the eastern margin of Fiordland National Park. This national park, New Zealand's largest, is also designated as a World Heritage Area. To the west, it is bounded by the Tasman Sea and is characterised by fiords that deeply incise its coastline.

The components of the power scheme are dispersed geographically within Fiordland as follows (see figure 5):

- *Te Anau Lake Control* - at the southern end of the lake at its outlet.
- *Manapouri Lake Control* - on the Lower Waiau River 10km downstream of the natural lake outlet and immediately below the confluence with the Mararoa River.
- *Manapouri Power Station* - at the head of West Arm on Lake Manapouri but 180m underground. (The control building and switchyard are surface installations.)
- *The tailrace tunnel* - beneath the mountains between the power station and the tailrace outlet channel at Deep Cove in Doubtful Sound.

The townships of Manapouri and Te Anau are located on the south eastern shore of each lake respectively. The city of Invercargill is about 160km away by road to the southeast. Dunedin lies on the east coast approximately 290km away.

The power station is approximately 32km west of Manapouri township. The main access is from the east across Lake Manapouri, either by boat from Pearl Harbour at the township or, for vehicles and heavy loads, on a barge from Supply Bay further north. From the west, access can be gained by sea around the Fiordland coast to the wharf at Deep Cove in Doubtful Sound. From here, a steep alpine road leads 20km over the Wilmot Pass to the power station.

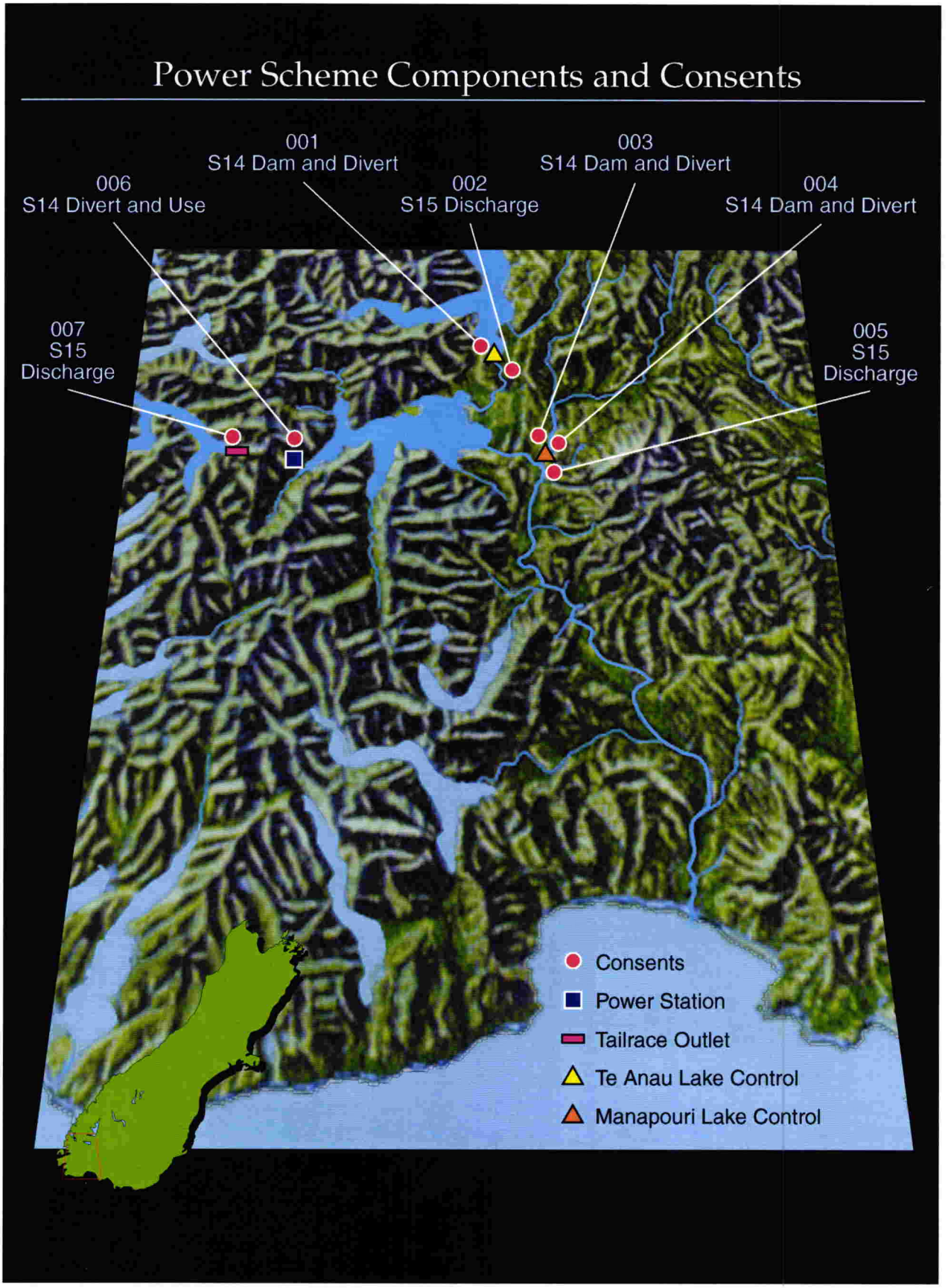


Figure 5 – Location of power scheme components and resource consents

2.2 Background

In 1904, Government Engineer-in-Chief Mr P. S. Hay recognised the potential for energy generation from the lakes and rivers of the Waiau catchment. The most economic but challenging option, proposed in the early 1960's, was the diversion of Lakes Te Anau and Manapouri through the Southern Alps. The proposal involved a series of intake shafts hewn out of hard rock to eventual discharge from the turbines through a 10km long tailrace tunnel to Deep Cove in Doubtful Sound.

Following initial assessment, further feasibility studies confirmed the potential to generate electricity by diverting Lake Manapouri to the sea. The utilisation of the 178m head difference between the lake and Doubtful Sound together with the substantial water storage of the lakes made Manapouri an attractive hydro-electric generating option.

The Government signed an agreement in 1960 granting Consolidated Zinc Pty. Ltd. a 99 year exclusive water right to the two lakes. The electricity generated was to be used at an aluminium smelter to be built in Southland. The only restriction on the water use was that Te Anau township not be flooded. This meant that Lake Manapouri could be raised to the same level as Lake Te Anau.[2] The company decided not to proceed but, in 1963, the Government agreed to build the scheme as originally proposed. Instead of water rights, Consolidated Zinc received power rights.[3] Subsequent legislation in the latter half of the decade allowed surplus Manapouri power to be fed into the national grid.

Construction of the power station commenced in 1963-64. The tailrace tunnel was completed in August 1969 and, on 14 September 1969, the first power from the station was transmitted to the national grid. Three further generators were commissioned later that year and all power station installation was completed by September 1971.

At this time, a rock weir was constructed across the Lower Waiau River below its confluence with the Mararoa River to provide limited control of the level of Lake Manapouri and a small increase in the amount of water available for power generation. The rock weir was a temporary measure prior to the installation of a permanent control structure for Lake Manapouri.

Public opposition to proposals to raise Lake Manapouri, in particular, was launched in 1960 by a petition seeking that the agreement entered into by the government not be validated. Debate continued through the 1960's leading to the 1969 election campaign claim by Prime Minister Holyoake that no decision to raise Lake Manapouri had been made and the promise of a Commission of Inquiry if returned to office. A nation-wide "Save Manapouri" campaign began and large public meetings were held in most centres throughout the country over the next three years. A second petition of more than 250,000 signatures, organised by the Forest and Bird Protection Society, was submitted to Parliament in late 1970. A Parliamentary Select Committee recommended that the petition receive favourable consideration and the lake not be raised meanwhile. This recommendation was accepted.

The controversy became a major issue in the 1972 general election. The Labour opposition undertook unequivocally to operate both lakes within their natural range and to reject plans for the wide-based dam at Mararoa for future lake raising. Shortly after winning the election, the Labour Government established the Guardians of Lakes Manapouri and Te Anau from leading campaigners. Six people were appointed for an initial two year term to advise the Government on the management of the lakes in such a way to avoid environmental damage. The decision to operate the lakes within their natural range meant that the Guardians' main task was to develop guidelines for managing the lake levels to safeguard the natural environmental features and stability of the vulnerable shoreline while optimising the hydro-electric potential of the water resources. The basis for these guidelines is outlined in Section 8.

The decision to operate within natural levels meant that the Mararoa Weir, originally intended to effect raising the lake, required re-design. Although Lake Manapouri was no longer to be raised, there was still a need to control both lake levels to maintain them in their natural range in conjunction with effective operation of the station.

Construction of both the Te Anau Lake Control structure (TLC) at the outlet of the lake and the Manapouri Lake Control Structure (MLC, also called the Mararoa Weir), at the confluence of the Lower Waiau and Mararoa Rivers, began in 1972. The Te Anau Lake Control structure was completed on 8 December 1975 and the Manapouri Lake Control structure one year later. In addition to controlling the lake level, this structure enabled the Mararoa River to be fully diverted into Lake Manapouri, although subsequent operating rules have modified the extent to which this is possible. December 1976, therefore, marks the physical completion of the components of the Manapouri Power Scheme.

The Guardians had prepared interim operating guidelines in 1973. In 1977 they released their final guidelines which were endorsed by Government on 22 December 1977. The operating guidelines are contained in the Manapouri - Te Anau Development Act (Operating Guidelines) Notice 1992, gazetted in the New Zealand Gazette dated 29 April 1993 (Appendix I). These guidelines will be referred to hereafter as "the gazetted guidelines". Since implementation, with both lakes being operated within their natural ranges, the guidelines have proven successful in protecting the lake environments. The Guardians continue to monitor this situation and recommend changes to the guidelines when appropriate.

A conclusion to the Manapouri debate became possible in January 1978 when it was announced by Government that re-negotiation of some aspects of the agreement with COMALCO meant "that the Government is no longer under an obligation to raise the level of Lake Manapouri". This statement came soon after Government's formal acceptance of the Guardians' operating guidelines. Final realisation, however, was achieved when the Manapouri-Te Anau Development Amendment Bill was passed in late 1981. The amendment revoked the original lake raising clauses and replaced them with a commitment to lake management "aimed to protect the existing patterns, ecological stability and recreational values of their vulnerable shorelines and to optimise the output of the Manapouri Power Station". The Guardians role was subsequently given a statutory basis in the Conservation Law Amendment Act of 1992.

2.3 System Components

2.3.1 Lake Te Anau Control (TLC)

The TLC structure (Figure 6), built a short distance to the east of the original lake outlet, controls the level of Lake Te Anau via its outflow into the Upper Waiau River and subsequent entry into Lake Manapouri. Storage of water can be held within the operating range prescribed by the gazetted guidelines until required for electricity generation.

2.3.2 Manapouri Lake Control (MLC and also called the Mararoa Weir)

The Lower Waiau River is dammed immediately below its confluence with the Mararoa River. The Manapouri Lake Control (MLC) (Figure 7), often called the Mararoa Weir, was designed to:

- Allow storage of Lake Manapouri water within the operating range prescribed by the gazetted guidelines until required for electricity generation by preventing or releasing flow down the Lower Waiau River.
- Divert the water discharged from the Mararoa River upstream of the weir, back into Lake Manapouri. Diversion, in terms of the gazetted guidelines, occurs only when the Mararoa River is not discoloured. Discoloured water is released through MLC.
- Ensure excessive inflows into Lake Manapouri which cannot be utilised for electricity generation, or stored within the limits set by the guidelines, are safely spilled down the Lower Waiau River.

The structural elements of MLC are:

- The Left Abutment Dam—an earth core dam forming the left abutment of the control structure.
- The Right Abutment Overflow Weir—also known as the Mararoa Weir, allows discharge of inflows that exceed the capacity of the control structure gates.
- The Control Structure— forms a spillway between the abutment dams. The gates are cable operated from winches located on the bridge over the gates. For maintenance purposes, the gates can be sealed off from the water upstream by stoplogs installed in slots upstream of the gate.

There is a stilling basin downstream of the gates designed to dissipate the energy of the water released when the gates are open.

- The Trout Fishpass—a Borda Orifice fishpass located within the right hand wall of the stilling basin that climbs to a resting chamber 28.7m from the entrance at the stilling basin's downstream end. From the resting chamber a 0.9m diameter pipe leads along an almost flat slope to the waters behind the weir.
- The Mararoa Diversion Cut ("Mararoa Cut")—a straight channel excavated from the Mararoa River to the MLC to reduce sediment deposits in the outlet channel from Lake Manapouri. The natural confluence of the Mararoa and Waiau Rivers is about 600m upstream of the weir.

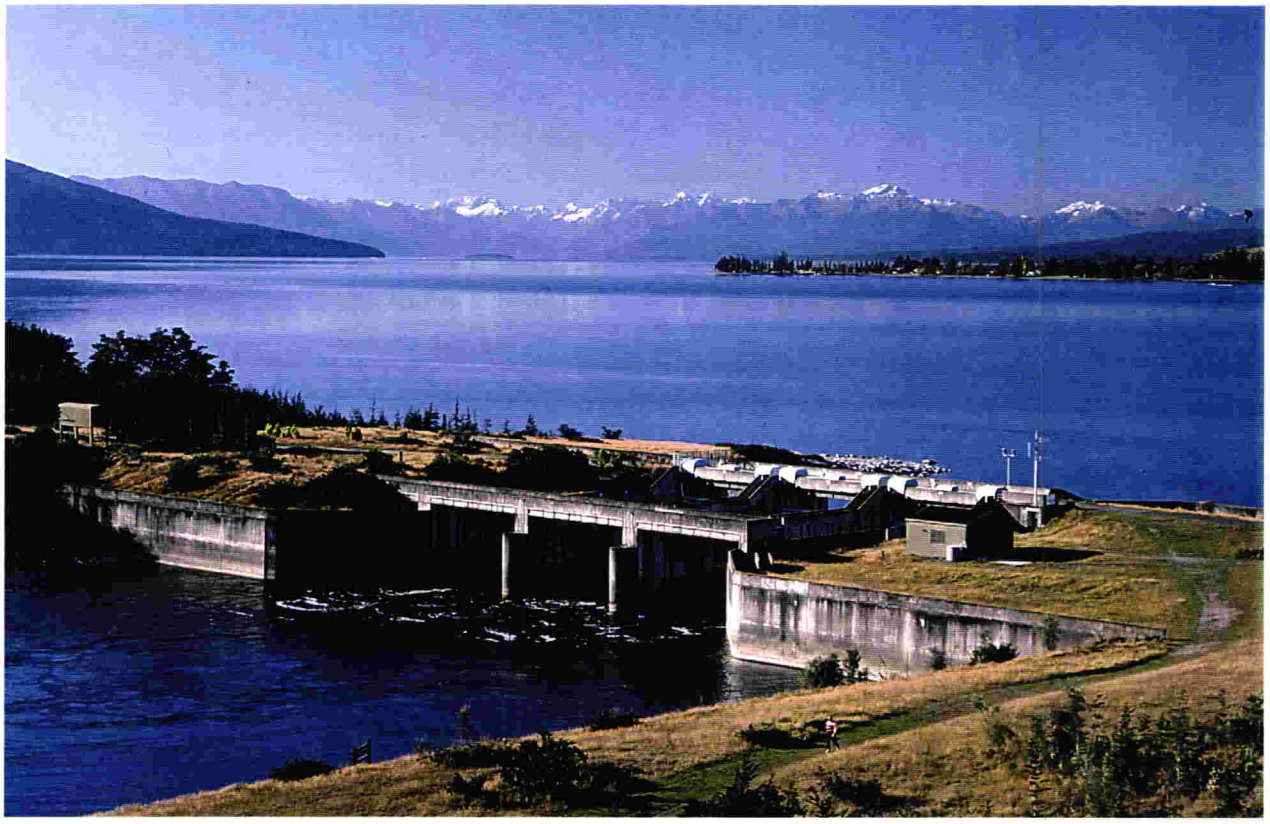


Figure 6 – Lake Te Anau Control Structure (TLC)

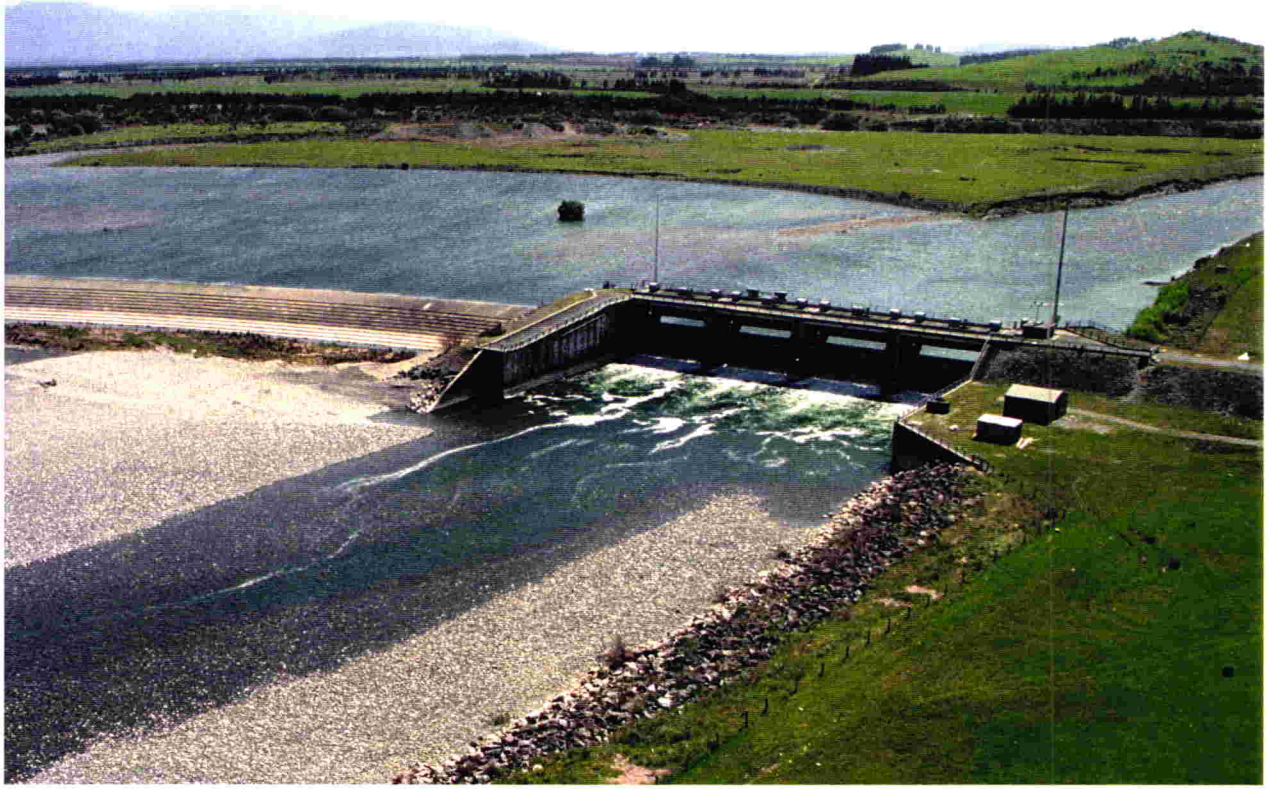


Figure 7 – Lake Manapouri Control Structure (MLC)

2.3.3 Manapouri Power Station[4]

The Manapouri Power Station is built at the head of West Arm of Lake Manapouri (Figure 8). Water is drawn from the lake[5] into the intake structure and flows down 7 vertical penstocks to the turbines located 178m underground. The water is discharged from the bottom of the turbines into the draft tubes and flows through 10km to the tailrace tunnel to exit via a 1.1km tailrace channel that connects the tunnel to the sea in Deep Cove.

The generating units are located in vaults directly above the turbines and the transformers. The transformers convert the electricity generated from the generating voltage of 13.8kV to the transmission voltage of 220kV. Seven vertical cable shafts link the transformer vaults to the surface switchyard from where four 220kV transmission circuits connect the station to the North Makarewa substation and the national electricity grid.

The Manapouri Power Station comprises a complex array of elements both on the surface and underground, extending from the intake at West Arm to the tailrace channel 10km (20km by road) away at Deep Cove. These elements are grouped as follows:

2.3.3.1 Major Generating Elements

- *Intake Structure*–at West Arm consists of a trash rack structure, seven hydraulically operated fixed wheel intake gates, their associated gate shafts and maintenance bulkheads. A debris boom surrounds the area immediately in front of the intake structure. During generator operation, the intake gates are at or near the fully open position. The gates can be dewatered for inspection and maintenance by lowering a bulkhead into position immediately upstream.
- *Penstocks*–are located 52m behind the intake gates via the inlet tunnels. The seven 3.7m diameter concrete-lined vertical penstocks convey the water to the turbine intakes 178m below.
- *Machine Hall*–is a reinforced rock structure 200m underground. Above the operating floor two 150T cranes traverse the length of the machine hall with sufficient height under the hook to lift the generator rotors from their casings. The service bay at the end of the machine hall connects to the various galleries and floors below the operating level. Seven turbine unit bays and a service bay housing the draft tubes, turbines and generators are located below the operating floor within a large reinforced concrete structure.
- *Generators*–The generator floor is at RL -0.3m. The generators are three-phase 50 Hz machines with a generating voltage of 13.8 kVA and a maximum output of 120,750kVA. The turbo-alternator units are suspended from a combined thrust and upper guide bearing at the operating floor level of the machine hall. The machines are totally enclosed within a reinforced concrete housing and are temperature-controlled with a water-cooled air circulation system.
- *Turbines and Draft Tubes*–the draft tubes descend from the bottom of the vertical shaft Francis turbines. There is a hydraulically operated hinged gate within each draft tube to permit isolation and dewatering of the draft tube elbows and turbine spiral cases for inspection and maintenance.

- *Transformers*–are located in vaults (reinforced rock excavations) to the downstream side of the machine hall.
- *Cable Shafts*–link the transformer vaults with the switchyard on the surface. Within each of the seven shafts, cables connect the transformer to its corresponding unit circuit breaker in the switchyard.
- *Switchyard*–is located on an excavated rock platform. Four 220kVA transmission circuits take off from the south side and eventually feed into the North Makarewa substation near Invercargill.

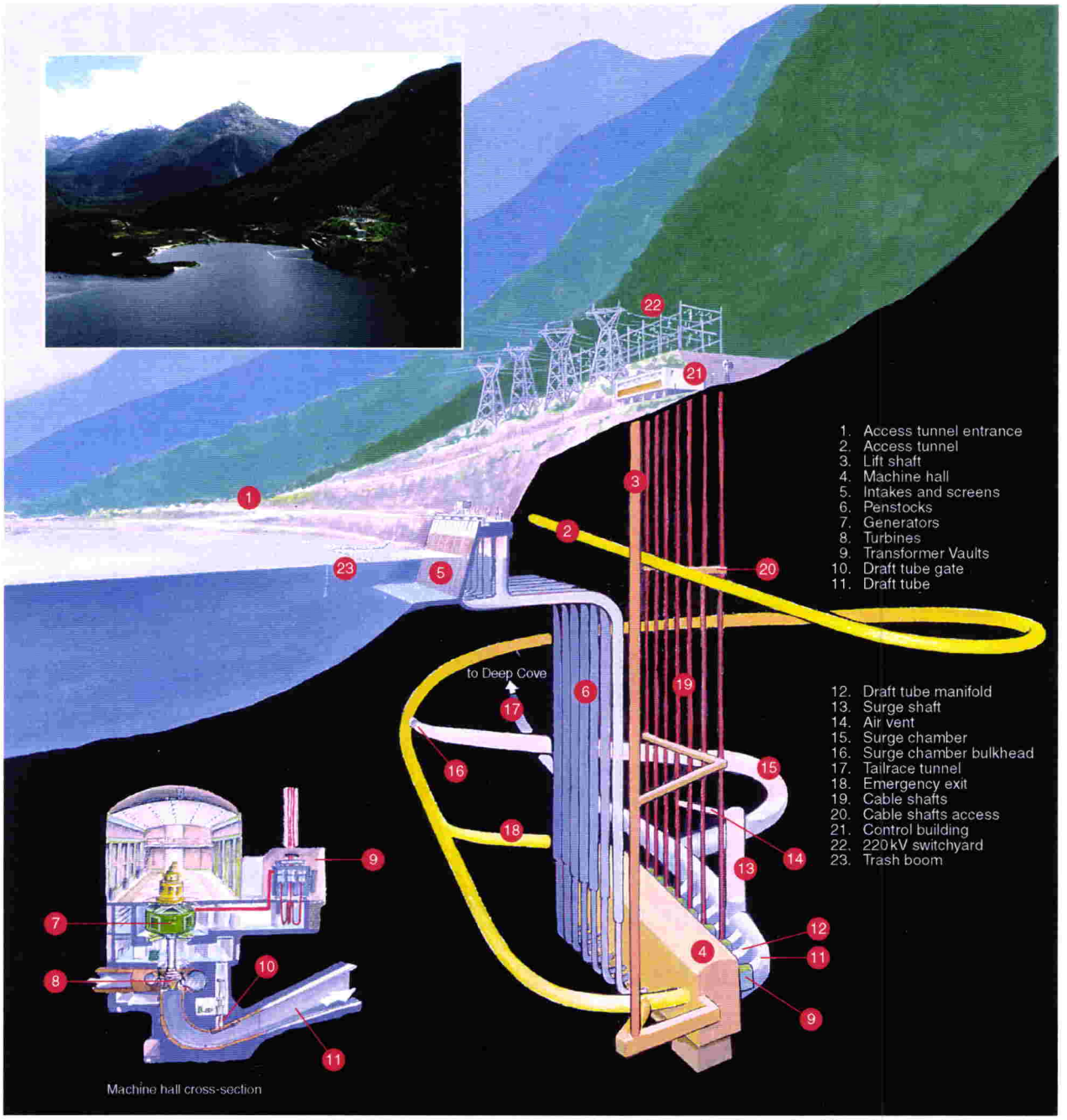


Figure 8 – Elements of the Manapouri Power Station

2.3.3.2 Ancillary Elements

- *Access Tunnel*—provides vehicular access to the machine hall. The 2.04km access tunnel spirals from the surface on a 10% down grade to the end of the machine hall 200m under the control building.

  Connected to the access tunnel are:

  - the construction access tunnel to the intake structure (now used for storage).
  - the surge chamber tunnel.
  - the machine hall roof arch access tunnel. This is now used for access by tour parties to the mezzanine viewing platform at the end of the downstream end of the machine hall.

  The access roadway drains into the surge chamber above its intersection with the surge chamber tunnel. Below this point it drains into the power station sump.

- *Control Building*–located on the surface immediately downslope and to the east of the switchyard. A sealed road links this with the access tunnel portal and the West Arm wharf.

- *Workshop & West Arm Accommodation Hostel*–the power station workshop and store is located about 100m from the access tunnel portal. The station accommodation hostel is approximately 1km from the control building on the right bank of the Spey River. This accommodates contractors and other temporary workers carrying out maintenance and associated work for the power station.

- *Deep Cove Wharf*–originally built for construction, this pre-cast, pre-stressed concrete structure is cantilevered from the steep rock walls of Deep Cove and was designed to accommodate ocean going vessels. By arrangement and when not required by ECNZ, the wharf is used by the tourist boats which operate on Doubtful Sound.

2.3.3.3 Tailrace Elements

- *Draft Tube Manifold, Surge Shaft and Chamber*–water exhausted from the draft tubes is recombined in the draft tube manifold at the upstream end of the tailrace tunnel. A surge shaft is located directly above the centre of the manifold to prevent the development of damaging hydraulic pressures following a sudden decrease in load on the turbines.

  An inclined surge chamber tunnel accommodates hydraulic surges caused by changes in load during normal operation of the station.

- *Tailrace Tunnel*–is 9.2m in diameter and 9817m in length. The roof arch is reinforced with rock bolts. The concrete lining is for hydraulic reasons - to reduce turbulence and friction - not strength.

  For the first 105m downstream from the draft tube manifold, the tailrace tunnel descends on a relatively steep 10% grade so the tunnel operates as a surge chamber and creates a rapid imbalance of head between the downstream water level at the portal and upstream water surface level during down surges[6]. The next 670m descent is on a 3% grade. At the bottom of this grade the elevation of the tunnel roof has been designed to coincide with the water surface elevation during maximum down surge.

For the following 6906m the tunnel descents is on a 0.1% grade towards Deep Cove. At its lowest point, the base of the tunnel is 40.4m below sea level. From this low point, the main tunnel rises on a 1.67% grade to a short flat section at the Deep Cove portal at RL - 9.2m.

- *Tailrace Channel* (Figure 9) is 1.1km in length and conveys the tunnel power station discharge waters from the tunnel portal to Deep Cove. Originally, only a pilot channel was constructed on the assumption that erosion would develop the required full channel in what were perceived to be glacial outwash and alluvial deltaic deposits from the Lyvia River. Spoil from the tailrace tunnel excavation was used to build rockfill embankment along the sides of this tailrace channel to prevent meandering during the development of the channel.

  Full erosion of the channel was prevented due to the unforeseen presence of rock fall boulders within the finer glacial and alluvial deposits, causing the development of rapids in the channel. These rapids hold the effective outlet level of water from the station higher than the water in Deep Cove and consequently add to the loss of generating head due to friction loss in the tunnel. Attempts were made in 1973, 1976 and again in 1979 to clear the rapids but with only limited success.



Figure 9 – Tailrace channel

2.3.4 Second Tailrace Tunnel

2.3.4.1 The Current Tailrace Inefficiency

The original tunnel design estimated a free water surface would be retained in the draft tube manifold for station outputs of less than 540MW. Soon after the station was commissioned, it was found that hydraulic head loss in the tailrace system was higher than assumed and outlet water levels higher than the design allowed. More friction than anticipated in the system means that water is likely to flood the power house at outputs greater than 585MW. The potential energy gain is therefore reduced from the ideal of 178m (difference between the level of Lake Manapouri and the Deep Cove) to 148m. Sudden increases in the station load from lower outputs to 585MW could cause a surge to higher levels, overtopping the surge chamber and flooding the machine hall. Therefore, to allow a safety margin, the station output is limited to 585MW of electricity, despite having an installed capacity of 700MW.

2.3.4.2 The Benefits from Improving the Tailrace Efficiency

To overcome the generation limitation at Manapouri, various options were studied. The conclusion of these investigations is that a 10m second tunnel, constructed south of and roughly parallel to the first tunnel, combined with lowering the outlet level by removing the rapids and deepening the tailrace channel, will provide the optimum reduction of the current head loss of 30m.

The benefits in terms of increase in electricity output will be obtained in two ways:

- The current effective head of 148m will be increased, but not to the theoretical 178m as there will still be normal friction losses. It is estimated that approximately 80% of the total energy gain will be obtained in this way.
- The water throughput capacity of the station can potentially be increased from the present maximum of 509 cumecs to 630 cumecs, allowing a greater proportion of the intermittent high Manapouri inflows (floods) to be captured than is presently possible.

No change in the current operating regime is required to achieve this through flow. No more water will be stored and the lakes will still be operated under the gazetted guidelines.

2.3.4.3 The General Arrangement[7]

The 10m diameter second tailrace tunnel will intersect the centre line of the existing tunnel at an angle of 45 degrees about 18m downstream of the intersection with the existing surge chamber. Sixty metres from the bifurcation, the second tunnel will curve and then run almost parallel to the existing tunnel to exit from the rock face at Deep Cove approximately 90m to the south of the existing portal. The average separation between the two tunnels will be about 75m.

2.3.4.4 The TBM Driven Tunnel

It is proposed to drive most of the second tunnel from the Deep Cove end using a full face tunnel boring machine (TBM). The TBM will link up with the headworks section of the tunnel at a point downstream from the bifurcation intersection point on the existing tunnel. The TBM will produce a 10m diameter circular tunnel cross section. Much of the tunnel will be in sound rock and essentially unlined with only occasional rock bolting. However, where rock is more fractured, particularly in the region of the known faults, a greater degree of rock bolting in conjunction with a shotcrete lining or steel sets and concrete lining is proposed.

Spoil from the tunnel and tailrace channel excavation will be deposited on the right bank of the existing tailrace channel. The final shape of the spoil landform and its revegetation will be carried out to plans approved by the Department of Conservation.

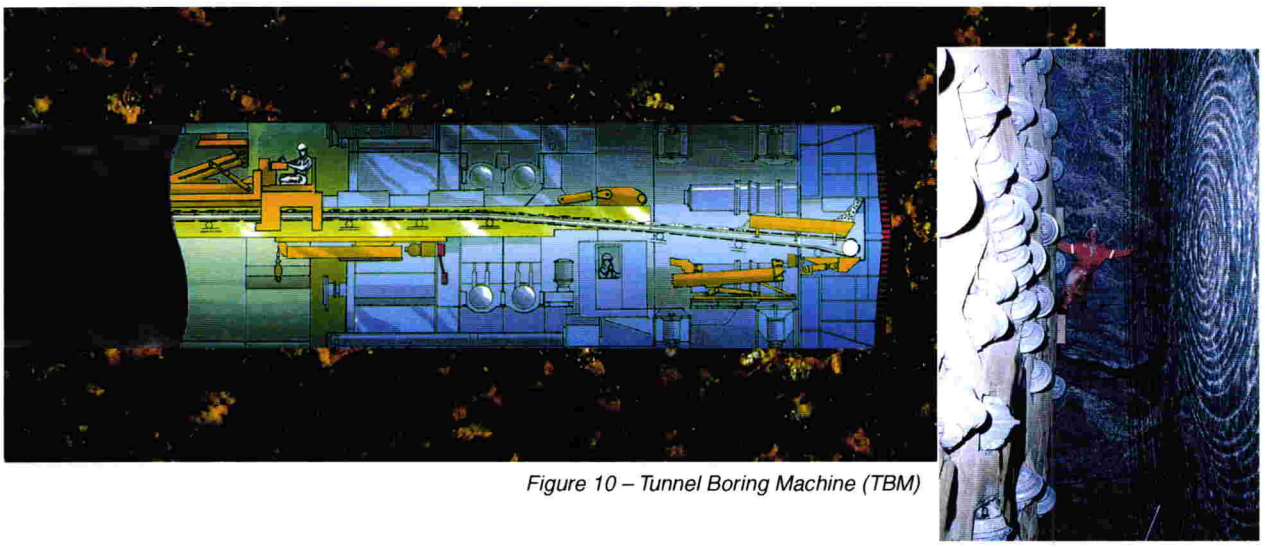


Figure 10 – Tunnel Boring Machine (TBM)

2.3.4.5 The Dewatering Facilities

For the purposes of construction drainage and as a permanent facility to permit future dewatering for maintenance purposes, a drainage adit will be driven from a point about 40m to the south of the second tunnel portal at Deep Cove.

During construction, water flowing from the main tunnel into the pump chamber will be pumped up the shaft, treated and discharged into the tailrace. Water discharged from maintenance dewatering is expected to be of the same quality as that normally discharged when the tunnel is in operation.

2.3.4.6 The Portal Outlet Works at the Deep Cove End

At the second tunnel portal a stoplog structure will be constructed to allow the tunnel to be sealed off and dewatered for maintenance purposes. Immediately downstream of the rockface at the portal, reinforced concrete retaining walls will extend for some distance. Slots in these walls will allow stoplogs to be installed to seal the tunnel off from the water in the tailrace channel. A bridge will be incorporated into the structure to facilitate lifting the stoplogs into position.

2.3.4.7 The Headworks at the Station End of the Tunnel

It will be important to minimise station downtime while the join between the two tunnels is constructed. This outage will occur at a time when the demand, and therefore the value of the power that would otherwise have been generated, is minimal. Consequently it is a design requirement that the first section of the tunnel be constructed separately so that once the join is formed it can be sealed off by gates and thus allow the TBM to complete the remainder of the tunnel without further disruption to the normal station operation. This first 138m section of new tunnel, plus the access adits and shafts leading to it from the existing access tunnel, are referred to as the headworks.

Stop logs will allow the second tunnel to be sealed off from the existing tunnel while the TBM completes its work and later for maintenance purposes.

Spoil from the headworks excavation will be removed to the surface and deposited on a designated area in the south corner of the West Arm flats. The final shape of the spoil landform and its revegetation will be carried out to plans approved by the Department of Conservation.

2.3.4.8 Removal of the Plug Between Tunnels, Near the Headworks

The plug, the first 10 to 20 metres of rock in the second tunnel excavation at the join between the two tunnels, will be excavated during the station outage after the downstream main tunnel headworks excavation is completed. The time allowed for excavation, strengthening and concreting of the join is 21 days. Concurrently, the rock forming the rapids in the existing tailrace channel at Deep Cove will be removed and the channel deepened. On completion of this work, the stoplogs will be placed in the shaft and station operation will resume.

2.4 Description of Operations

The Manapouri Power Scheme develops power by diverting the flow from Lake Manapouri through the underground power station at West Arm and discharging it to the sea in Deep Cove. This process converts some of the potential energy represented by the 178m difference in level between the lake and the sea into electricity. The power station has an installed generating capacity of 700MW. For the reasons outlined in section 2.3.4.1, the actual head difference able to be utilised is only 148m and consequently the station's capacity is limited to 585MW.

Lakes Manapouri and Te Anau are used as storage buffers to maintain the generation output between high inflow events. Water stored in Lake Te Anau is released at the TLC and flows into Lake Manapouri via the Upper Waiau River. Water from the Mararoa River is diverted into the system at MLC, 10 km downstream from Lake Manapouri outlet at the confluence of the Mararoa and Lower Waiau Rivers. MLC also controls the level and thus the storage in the lake. The total water storage within permitted operating levels in both lakes is only equivalent to 381GWh/yr or about 9% of Manapouri's total annual generation[8].

2.4.1 Generating Capacity and Output

The original design of the Manapouri Power Station was based on raising the level of Lake Manapouri by 8.2m. It was estimated this would have provided sufficient storage to allow continuous output of 450MW of electricity from 350 cumecs of flow. The annual energy generation output from this was calculated to be 3900GWh.

However, the record showed lake inflows exceeded 350cumecs for sufficient periods and justified a power station with a generating capacity of 600MW for an annual electricity output of 5000GWhr. Therefore, six 100MW generating units were provided with an additional unit added as a spare.[9] Thus, Manapouri Power Station has seven generating units with a total installed capacity of 700MW.



Figure 11 – Machine hall, Manapouri Power Station

Although the station has 7 generators with a nominated maximum capacity of 700MW, tailrace inefficiency has limited production to 585MW of electricity using 6 generators (see Section 2.3.4.1). The water available for generation restricts the annual generation of electricity further. The average annual output for the years 1992 to 1994 was 4271GWh, compared to 5125gwh if the machines could be run continuously to produce 585MW, and a theoretical 6132GWh with all 7 machines at full capacity.

2.4.2 Operation

The operation of Lake Manapouri is largely dictated by the catchment hydrology factors of:

- lake inflows
- and lake level.

The gazetted lake level guidelines (see Section 8.2) directly impact on the amount of electricity that can be generated from the station.

Both lakes have highly variable and volatile inflows, arising from heavy rain causing high inflows over short periods of time. As far as possible, within the operating rules, the high inflows are captured into the lakes' storage for use as a buffer during times of low inflow. Not all inflows can be captured. When the lake levels rise rapidly and approach the high range set by the gazetted lake level guidelines, water must be released from MLC. Consequently this water spilled into the Lower Waiau River is lost for generation. The gazetted lake level guidelines also dictate that water from the Mararoa River can only be diverted into Lake Manapouri, and thus be available for generation, when it is not discoloured. The discoloured water is released into the Lower Waiau River by opening the MLC gates and, apart from times when Lake Manapouri is very low, this procedure is effective.

The nature of the hydrology and the complexity of the operating procedures require the operation of the Manapouri Power Station be closely controlled and monitored. The guidelines are designed to protect important environmental attributes while allowing for optimisation of energy output. Therefore, the rules for operating the station are the most detailed and restrictive of any power station in New Zealand.

2.4.3 General Specifications

The following details outline the general specifications of the existing Manapouri Power Scheme:

Operating head - lake to sea	178 metres nominally
Average intake (1969-1992)	343 cumecs (Median flow = 392 cumecs)
Installed capacity (megawatts-nominal)	700MW
Current Peak station output (megawatts)	585MW
Annual power generation (Gigawatt hours)	4271GWh (average 1992 - 1994)

2.5 Risk Management

ECNZ is conscious of its responsibilities as owner and operator of New Zealand's largest dams, some of which have the potential for serious economic loss, and loss of human life, in the event of failure. The Corporation has therefore adopted the world recognised Safety Evaluation of Existing Dams (SEED) programme for examination and evaluation of its water impounding structures. Additional procedures are in place to cover the full range of operating conditions for

hydraulic facilities, including earthquakes and other emergencies. (These procedures are explained in more detail in ECNZ Generation Production Memoranda 5.01 and 5.02).[10]

As part of its commitment to dam safety ECNZ has a programme of on-going monitoring. This programme takes place at two levels:

(i) surveillance monitoring of seepage and ground water levels on an on-going basis to detect changes in the medium and long term behaviour of various structural elements

(ii) comprehensive assessments of the structure and its various components every 5-6 years in accordance with the requirements of the SEED Manual.

Where, as a result of these monitoring programmes, a deficiency is identified, it is investigated and remedied as soon as possible.

Additionally, Emergency Preparedness Plans are prepared for major hydraulic structures. These plans typically include the following information:

- Emergency and response procedures
- Communication networks
- Power sources
- Inundation maps (where available)
- Warning systems
- Emergency equipment and resources
- Communication directory.

The Emergency Preparedness Plans are part of the Corporation's Civil Defence Plan.

2.6 Statutory Framework (for Water, Coastal and Discharge Permits)

2.6.1 Manapouri-Te Anau Development Act 1963 (MTADA)

The operation of the Manapouri Power Station by ECNZ and its use of the water resources of Lakes Manapouri and Te Anau, the Waiau and Mararoa Rivers and their tributaries, is provided for by the Manapouri-Te Anau Development Act 1963 (MTADA) and the Resource Management Act 1991 (RMA). Section 4 of the Manapouri-Te Anau Development Act 1963 provides:

(1) The Electricity Corporation of New Zealand Limited shall have.... full power and authority -

(a) To erect, construct, provide, use and operate all works, appliances and conveniences which may be necessary or requisite for or in relation to -

(i) The utilisation of water power from the said water resources for the generation of electrical power....

(d) For the purposes of this Act, to construct tunnels under private land ....

The *"said water resources"* refers to: Lakes Te Anau and Manapouri, the Waiau and Mararoa Rivers and their tributaries.

MTADA therefore gives ECNZ the authority to use the lakes and rivers for the purposes of generating electricity. The operation of the power station is subject to gazetted guidelines for the levels of the lakes, as lawfully promulgated.

The guidelines are based on recommendations from the Guardians of Lakes Manapouri, Monowai and Te Anau and from ECNZ. The guidelines are aimed at protecting the existing patterns, ecological stability and recreational values of the shorelines of the lakes, and optimising the energy output of the power station. The guidelines are contained in the Manapouri - Te Anau Development Act (Operating Guidelines) Notice 1992 gazetted in the New Zealand Gazette dated 29 April 1993 (Appendix I).

Before exercising any power conferred on it, ECNZ must consult with the Minister of Conservation on measures to be taken with a view to preserving natural scenery and/or minimising any adverse effects on the trout fishery of Lakes Manapouri and Te Anau that might arise as a result of exercise of that power.

In summary, the MTADA gives ECNZ the authority to carry out activities which are *"necessary or requisite"* to the operation of the power station, and the authority to conduct such activities in the future.

2.6.2 Resource Management Act 1991 (RMA)

The purpose of the RMA is to promote the sustainable management of natural and physical resources. *"Natural and physical resources"* under the RMA includes land, water, air, soil, minerals, and energy, all forms of plant and animals (whether native to New Zealand or introduced), and all structures. The RMA deems the rights to "use and operate all works" in respect of water under MTADA to be coastal, water and discharge permits (sections 365(d)(iv), 386(1)(c)(ii)) respectively, where they relate to a coastal marine area or authorise something that would otherwise contravene sections 14 or 15 of the RMA.

The operating guidelines and requirement to consult the Minister of Conservation are deemed to be conditions of these permits (section 386(1)(c)(ii)). Also, a condition of these water, coastal and discharge permits is that they expire on 1 October 2001 (section 386(3)), and therefore need to be renewed by that date for the continued operation of the power station. Water, coastal and discharge permits are granted by the Southland Regional Council.

2.6.3 The National Parks Act 1980 and Fiordland National Park Management Plan 1991

- National Parks are established under the National Parks Act 1980 for the general *"purposes of preserving in perpetuity....for their intrinsic worth and for the benefit, use and enjoyment of the public, areas of New Zealand that contain scenery of such distinctive quality, ecological systems, or natural features so beautiful, unique or scientifically important that their preservation is in the national interest"* (Section 4, National Parks Act 1980).

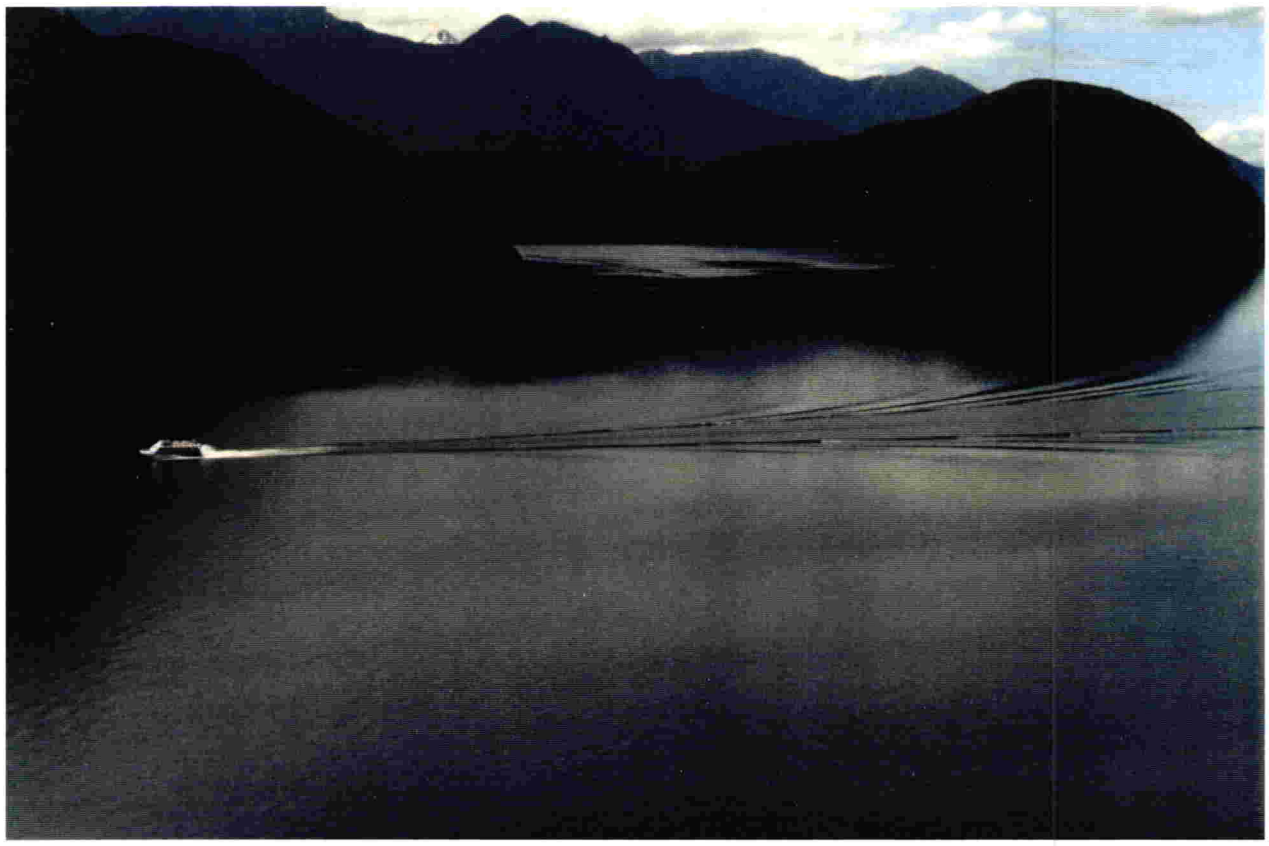


Figure 12 – Tourist Launch on Lake Manapouri

Fiordland National Park, having been a public reserve under the Public Reserves, Domains and National Parks Act 1928 was designated under the National Parks Act 1952, and subsequently the National Parks Act 1980. Because national parks were created by proclamation out of Crown Land, the Public Works Act 1928 applied. Section 10 of that Act exempted the works required for electricity generation from the requirements of the proclamation. Therefore, the MTADA only provided that, in Fiordland National Park, particular account was to be taken of preserving the natural scenery and fishery of the area and that all the provisions of the Public Works Act 1928 shall operate as if conferred on ECNZ by Order in Council.

The Park includes the beds and waters of all lakes, rivers and streams contained within its boundaries (fiords excluded) with the seaward boundary being mean high water mark.

The Department of Conservation administers and manages Fiordland National Park in accordance with the Fiordland National Park Management Plan 1991 (FNPMP). The plan provides for the management of the park in accordance with the National Parks Act and sets out management policy for water resources and hydro-electric power development. Two objectives of the FNPMP are to *"Prevent hydro-electric power developments from further adversely impacting on the waterways and other natural features of the Park"* (4.4), and to *"Prevent water resource users from adversely impacting on the waterways, ecology and other natural features of the Park"* (4.3).

The FNPMP recognises existing hydro-electric power schemes in the Park and provides that, generally, large scale projects will be opposed. Section 104(2) RMA, however, provides that the management plan must be considered only when section 13 consents are being applied for in respect of the bed of a lake or river which adjoins the National Park. Because ECNZ's rights over land and the beds of lakes and rivers are covered by MTADA (see Section 2.5.4), the FNPMP does not apply to these activities.

2.6.4 Relationship Between the MTADA, the RMA and the National Parks Act 1980

The provisions of the MTADA were not repealed by the RMA and are still in effect in relation to other legislation, including the National Parks Act 1980.

It is a principle of the interpretation of statutes that a general statute, like the RMA, does not override a specific earlier statute, like the MTADA, unless there is a clear indication to the contrary. The MTADA furthermore contains a provision stating it is to override other legislation, which has the effect of overriding the RMA provisions, except for water, discharge and coastal rights, which are dealt with expressly under the RMA (see Section 2.5.2). The effect is that ECNZ's water, discharge and coastal rights are split off and dealt with as deemed rights under RMA, while rights over land, the beds of lakes, and the emission of noise and contaminants are still provided for by MTADA.

The National Parks Act 1980 provides *"Nothing in this Act shall affect the Manapouri Te Anau Development Act 1963 ..."* (Section 79). (Section 8 MTADA provides that the provisions of the MTADA are to have effect notwithstanding anything to the contrary in any other Act). The National Parks Act 1980 is therefore subordinate to MTADA and any other deemed permits arising from the RMA. The FNPMP points out that the Resource Management Act 1991 takes precedence over the National Parks Act 1980 in the taking of, or discharge of water (page 79).

Part 2

Environmental and Socio-economic Setting

Chapter 3 – The Bio-physical Environment

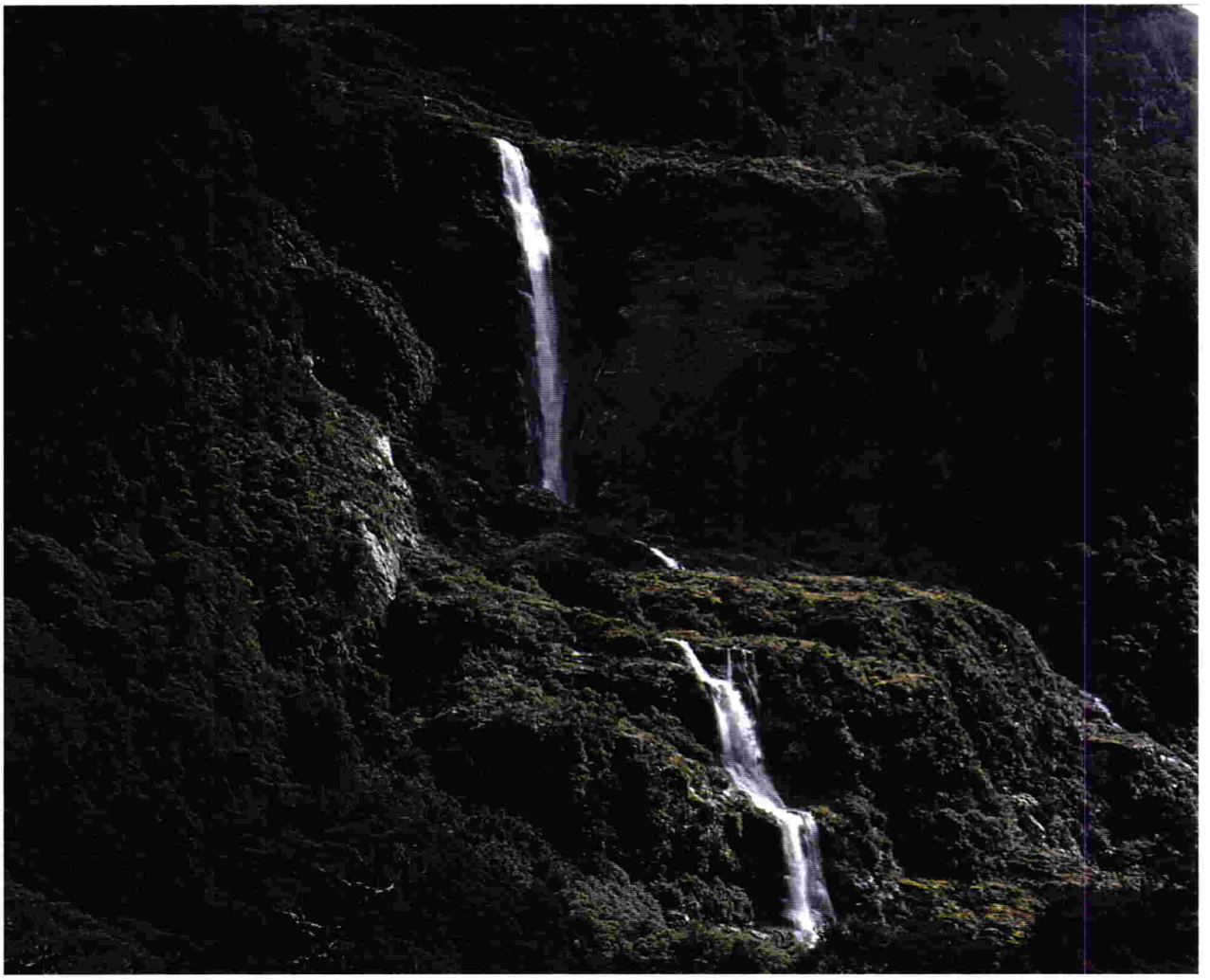


Figure 13 – Cleve Garth Falls as seen from Wilmot Pass Road

3.1 Geography and Landscape

The area utilised and influenced by the Manapouri Power Scheme extends from the southern ranges of the Southern Alps to the west coast at Doubtful Sound and to Te Waewae Bay at the mouth of the Waiau River in the south.

The lakes and power station all lie within Fiordland National Park, an area renowned and highly regarded for its fiords, waterfalls and spectacular mountain scenery.

The Waiau catchment runs virtually the length of Fiordland National Park. From the headwaters of the Eglinton, Clinton and Worsley Rivers, the catchment traverses the glaciated landforms of the Fiordland massif, through the deep glaciated lakes of Te Anau and Manapouri, and south through the lower valley to the exposed shoreline of Te Waewae Bay. The entire length of the Waiau valley forms a frontier between a modified environment to the east, and a natural environment of forest and mountains to the west.

The Upper Waiau catchment is a spectacular landscape, lying in the Te Anau basin between Fiordland National Park to the west and the Snowdon - Takitimu ranges to the east. The basin has a complex geological history, including widespread faulting, ancient granite peaks, limestone caves and glacial moraines. The landscape is strongly influenced by the high rainfall climate, with the rivers playing an important role in shaping the terrain of the basin.

The most dominant features of the upper catchment landscape are the bush and tussock clad Fiordland mountains, and the large glacial Lakes Manapouri and Te Anau. The shoreline interface between lake and mountain is perhaps the most prominent feature of this landscape, with beaches, wetlands and river deltas.

The Lower Waiau features pasturelands grading into the forested hills of the Longwood ranges to the east and the snow capped Fiordland mountains to the west. The Lower Waiau valley is broken with hills, steep valleys, extensive terraces and escarpments for most of its length. From the Mararoa Weir to the Monowai confluence, the river flows through a fairly constricted valley, then widens out into a series of braided channels mainly associated with tributary confluences. It constricts again at Clifden and Tuatapere, before widening out to form a more expansive valley south towards Te Waewae Bay.

Panoramic views of the Lower Waiau River are rarely seen from the Southern Scenic Route (State Highway 99), although the road bridges at Tuatapere and Clifden along with some minor roads and access tracks which approach close to the river do provide views. The most significant is at Monowai where access and views of the river are available at the Monowai Gorge suspension bridge. The Lower Waiau River and immediate river valley cannot be considered outstanding on a national basis, but some areas are arguably outstanding landscapes at a regional and local level.[11] When viewed from the Southern Scenic Route, the river's position is in the foreground of the Fiordland massif and the Takitimu Mountains. This wider landscape is nationally unique and spectacular.



Figure 14 – Looking south towards Mararoa Weir and Lower Waiau River valley

The Manapouri Power Scheme has changed the natural character of the Lower Waiau from a "big river" to a "smaller river" landscape. Despite this, the river still retains many of the elements, patterns and processes that provide its natural character.[12]

Lake Manapouri once drained totally into the Waiau River, but is now diverted through the Manapouri Power Station and discharged into Deep Cove at the head of Doubtful Sound. Doubtful Sound was formed by glaciation and stretches almost 35km to the Tasman Sea. In typical fiord fashion, Doubtful Sound is characterised by a long and narrow inlet with steep walls.

Deep Cove has characteristics which are typical of many embayments at the head of the various sounds in Fiordland. These are spectacular landscapes, with high mountain peaks plunging steeply into deep fiords. These steep slopes are interspersed with slip faces holding varying stages of regenerating native forest. There are few beaches or wave-cut shore lines and stream deltas to interrupt the descent from mountaintop to the waterline.

3.2 Geology

Formations in the catchment represent almost every geological period and epoch since the Precambrian era over 400 million years ago. The most prominent geological features of the area are the ancient granites of the Fiordland massif merging eastwards into sedimentary rocks of more recent Tertiary times.

Robertson (1993) described the rocks of the Waiau catchment as falling into four broad groups, with the oldest rocks listed first:

- The plutonic igneous rocks (granite, gneiss, gabbro) of the Fiordland massif are hard, coarse-grained crystalline rocks, overlain by younger sandstone, limestone and mudstone.
- Late Paleozoic and Mesozoic volcanics are the basis upon which the Livingston, Takitimu and Longwoods ranges are formed. They extend from the Hollyford valley through the Takitimu Mountains to Riverton. These volcanic rocks are basalt, tuff and agglomerate, intermingled with greywacke. They are less hard than the neighbouring granitic rocks of Fiordland and consequently are more eroded.
- Tertiary sedimentary rocks of the lowlands are predominantly marine sandstone, mudstone and limestone laid down approximately 60 million years ago when much of the present Waiau catchment was under sea. Towards the end of the Tertiary period the sea slowly receded, leaving behind estuarine and deltaic deposits in the valley. Regional uplift along the southern coast has caused Te Waewae Bay to erode and a line of cliffs along soft Tertiary rocks at either end of the bay to form.
- Recent gravels, stream alluvium, flood plains and terraces throughout the low-lying areas of the central catchment, from the Eglinton River to Clifden, are the result of glaciation, melt and deposition during the Pleistocene Epoch. More recent alluvium has been deposited in the lower valley as a result of river erosion and deposition. Erosion of outwash gravels is pronounced along terrace edges and stream banks. These gravels, overlain by loess soils, are economically important as they underlie most of the productive land, provide reserves of groundwater and are a source of roading material and gravel.

3.3 Soils and Vegetation

Soils in the Fiordland massif region are poorly formed and, in many areas, are absent because of erosion caused by extreme rainfall. The upland and western areas are characterised by podzolised yellow-brown soils. Yellow-brown loams are found in the Upper Waiau River region between Lakes Te Anau and Manapouri.

Of the natural forest within Fiordland, beech predominates with an understory of shrubs and typical rainforest floor species, including mosses, ferns and liverworts. At higher elevations, alpine plants inhabit scree slopes and high meadows.

Soils to the east of Fiordland are better developed and more fertile. These lowland soils, on which the local economy is based, are formed mainly on a blanket of fine loess. However, the high rainfall in the area causes soils to suffer from poor drainage. Although Western Southland is dominated by a lack of highly fertile or deep soils, many areas in the eastern catchment are suitable for arable and pasture farming. Fertilisation with phosphate and lime maintains good pasture production in most areas.

The dominant riparian vegetation in the catchment, native forest, covers 39% of the total catchment area of 8173 km2. Of the remainder, tussock grassland covers 31%, introduced pasture 16%, water bodies 7%, alpine vegetation 1%, scrub 5%, swamp 0.3%, exotic forest 0.4% and permanent ice/rock 0.4%.[13]

The valley sides and high terraces of the Lower Waiau River are mainly pasture with scattered scrub (gorse, broom) and some remnant native forest. Channel bank vegetation is frequently dominated by gorse, broom and willow, and also includes less developed pasture, toetoe and ragwort. Gravel bars in the riverbed have mainly grasses, gorse, broom and willow.[14]

3.4 Climate

The Manapouri Power Scheme utilises freshwater in New Zealand's highest rainfall area. The high mountains intercept the prevailing westerly winds which, in turn, drop their plentiful rain onto the western ranges. Lakes Te Anau and Manapouri are fed by both rainfall and snowmelt. The rivers of the Waiau catchment lie in a transition zone between this area of high precipitation and the low rainfall areas of Central Otago. Annual rainfall in the West exceeds 6400mm, but declines eastwards to between 1600 and 3200mm in the Te Anau basin, and between 1200 and 1600mm at Tuatapere toward the southern reaches of the basin. Rainfall can vary significantly throughout the year, although October-December tends to be wetter, and February-May drier.

Temperatures in the catchment vary widely with elevation and proximity to the coast. Average daily temperatures in Te Anau range from 8-20 °C depending on the season. Sunshine hours are low - restricted by the general cloudiness and steep topography of the catchment. Frosts in the area average 56 days annually. The area is affected by strong westerly winds, often in excess of 50 knots.

3.5 Hydrology

The hydrology of the Waiau catchment has been changed by the introduction of the Manapouri Power Scheme. In its natural state, the catchment was a normal river system dominated by glacial landscapes with precipitation, ground storage and snowmelt running into headwaters, lakes and tributaries. A detailed description of flow regimes and the natural hydrology of the Waiau catchment is provided by Riddell et al (1993). The influences of hydro development in the catchment centre on the levels of Lakes Te Anau and Manapouri, their respective inflows and outflows, (in the case of Lake Manapouri at both Deep Cove tailrace and the Mararoa Weir) and Lower Waiau River flows.

3.5.1 Lake Levels

Variations in level are a function of inflows, outflows and evaporation. Table 1 summarises data for the two lakes.

Table 1 – Lake Characteristics

Description	Te Anau[17]	Manapouri
Lake area	352 km^2	142 km^2
Catchment area	3095km^2	4540km^2 pre-control 5793km^2 post-control*
Pre-control mean level (1926/27 -1973/69)[18]	202.11m	177.49m
Post-control mean level (1974/70 -1991)[20]	202.36m	177.68m
Pre-control range (1926/27 -1973/69)	3.92m ($204.78m_{1928}$ - $200.86m_{1953}$)	4.81m ($180.48m_{1933}$ - $175.67m_{1953}$)
Guidelines* * main range	1.2m (202.7m - 201.5m)	1.8m (178.6m - 176.8m)
Guidelines* * max range	3.44m (204.3m - 200.86m)	4.64m (180.5m - 175.86m)

* Post-control Lake Manapouri catchment area includes the Te Anau catchment (3095m^2), the natural Manapouri catchment (1445km^2), Mararoa (1219km^2) and Home Creek (34km^2) catchments.

* * Guidelines as gazetted 8 March 1990.

Te Anau outflows have been controlled by the Te Anau control gates since 1974. Manapouri outflows have been controlled since the commissioning of the power station in 1969, although full control was not possible until the completion of the Lake Manapouri Control Structure (Mararoa Weir) in 1976.

The levels of Lakes Te Anau and Manapouri are currently operated within the gazetted guidelines, which are more fully explained in Section 8. The mean level of both lakes has increased since control due to the combined influence of higher than normal rainfall in the catchment augmenting inflows and lake control.

The post control range for the lakes was exceeded during the November 1988 flood when maximum power generation and maximum release of water from MLC (all gates fully open and water spilling over the overflow weir) were insufficient to prevent a breach of the guidelines. This flood, however, was an exceptional event with a return period of greater than 200 years for the 1 month duration inflow. Computer simulation indicates that in the natural pre-control situation (without the benefit of power station outflow), the level of Lake Manapouri would have risen 0.33m higher to 181.93m.

3.5.2 Te Anau and Manapouri Inflows

The pattern of Lake Te Anau and Manapouri inflows generally corresponds to the seasonal rainfall pattern. Inflows are lowest in winter (June to August), and highest in spring (October and November) (Figure 15).

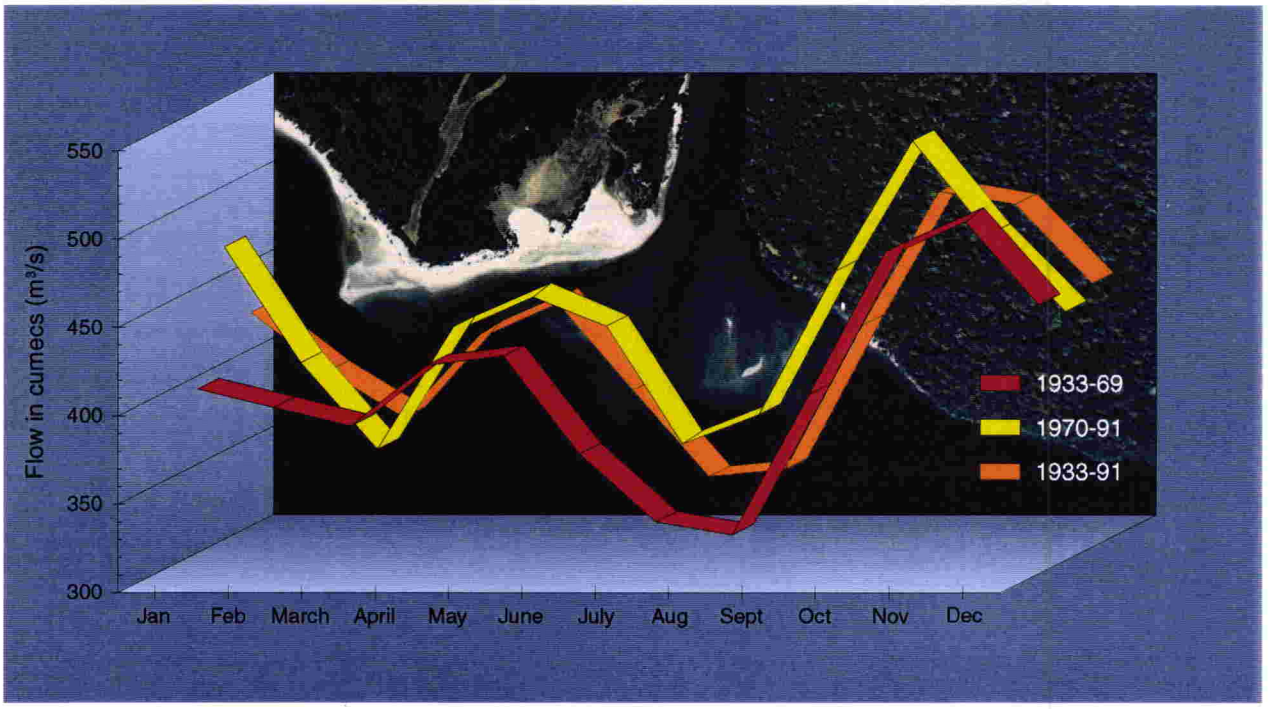


Figure 15 – Lake Manapouri Monthly Mean Inflows

Mean inflows for both lakes have been higher since control due to increased precipitation.

Table 2 – Lake Te Anau Inflow Summary

Inflow	Long Term (1927 - 1991)
Maximum (1 day)	5287 cumecs (1967)
Mean	273 cumecs
Minimum (7 Day)	11 cumecs (1953)

Table 3 – Lake Manapouri Inflow Summary

Inflow	Long Term (1933 - 1991)	Post Control (1969 - 1991)
Maximum (1 day)	3572 cumecs (1984)	3572 cumecs (1984)
Mean	415 cumecs	437 cumecs
Minimum (7 Day)	79 cumecs (1953)	89 cumecs (1977)

Of the mean inflow into Lake Manapouri post control, 343 cumecs is diverted through the power station and 93 cumecs is spilled from MLC.

Te Anau has a large river catchment (eg. Eglinton River) and a relatively small catchment area flowing directly into the lake. In contrast, Manapouri is largely supplied from Lake Te Anau via the Upper Waiau River, but also has a small catchment area flowing directly into the lake. Therefore although Manapouri has a higher mean inflow, Te Anau has a higher 1 day flood inflow; 5287cumecs compared with Manapouri's 3572 cumecs.

3.5.3 Lake Te Anau Outflows and Upper Waiau River Flows

Mean monthly outflows from Lake Te Anau have been greater in the post-control period for all months except March, November and December. Riddell et al (1993) attribute these greater outflows to the naturally higher inflows in the post-control period. They conclude that, in general, the pre and post - control outflows have a similar seasonal pattern and the influence of lake control on outflows is not particularly noticeable.

Changes to the flow regime have occurred since 1974 when lake outflow control began. Figure 10 displays the distribution of the daily Te Anau outflow pre and post-control. Since the revision of the Te Anau Control gate operating procedures in 1993, extreme low flows (less than 99 cumecs) have not occurred because the procedures require flow augmentation of the Upper Waiau River from Lake Te Anau storage.

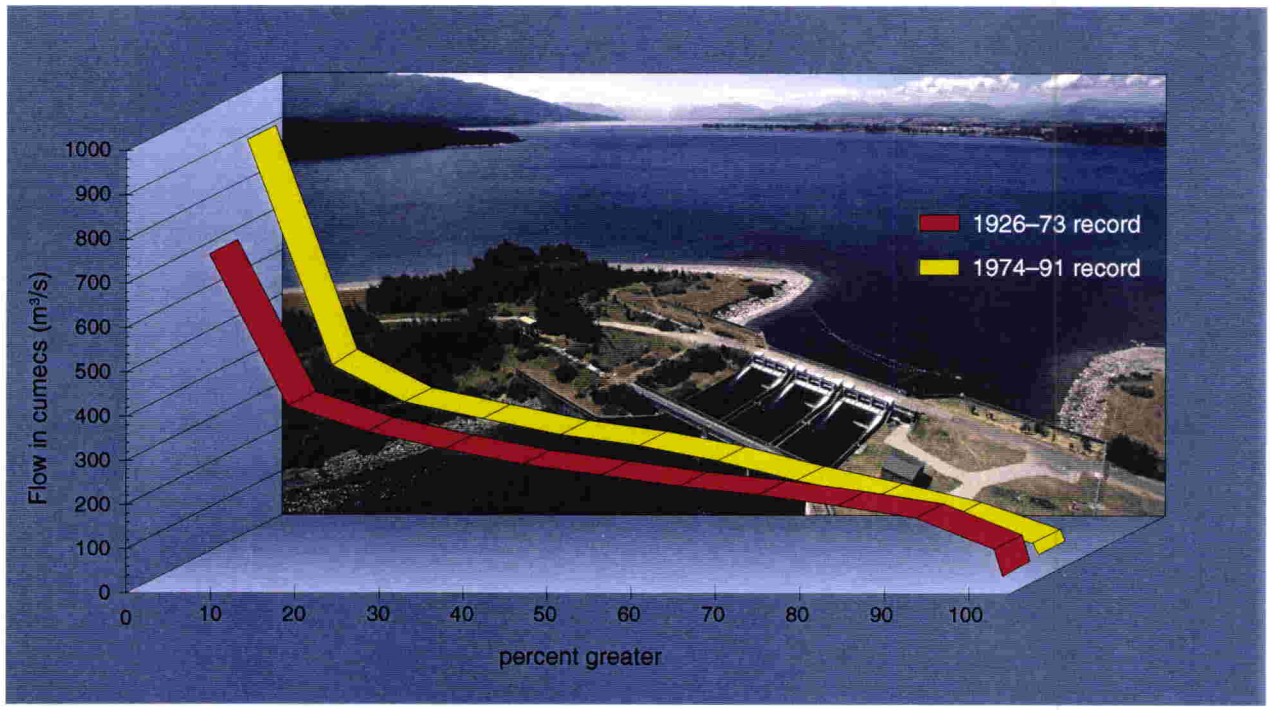


Figure 16 – Lake Te Anau Daily Outflow Distribution

Table 4 – Lake Te Anau Outflow Summary

Outflow	Pre Control (1927 - 1973)	Post Control (1974 - 1991)
Maximum (1 day)		1081 cumecs (1988)
Mean	269 cumecs	286 cumecs
Median	250 cumecs	270 cumecs

3.5.4 Lake Manapouri Outflows

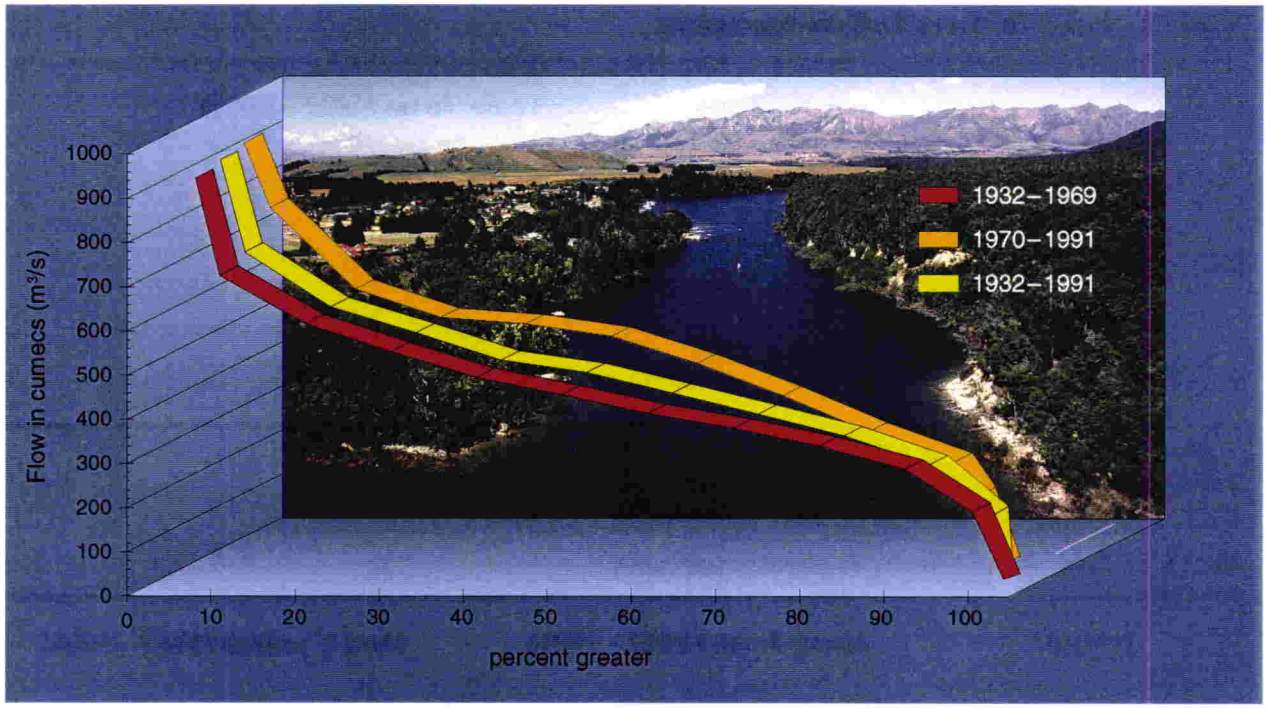


Figure 17 – Lake Manapouri Outflows

Lake Manapouri outflows are made up of flows through the power station at West Arm and flows through the Mararoa Weir.

Table 5 – Lake Manapouri Total Outflow Summary

Outflow	Pre Control (1932 - 1969)	Post Control (1970 - 1991)
Maximum (1 day)		1930 cumecs (1988)
Mean	406 cumecs	437 cumecs
Median	380 cumecs	440 cumecs

The increase in mean and median outflow are a consequence of the Mararoa River flow being diverted into Lake Manapouri and the higher inflows since control. The post-control outflows are less variable than pre-control due to the regularity of the discharge from the power station.

Outflow distribution curves for Lake Manapouri pre and post-control are shown in Figure 17 from which it can be noted:

- About 25% of the time the power station's throughflow capacity of about 480 cumecs is exceeded. This indicates the potential for increasing power output from the station by decreasing the headloss in the tailrace tunnel, permitting more sustained throughflow for power generation. Part of the benefit of a second tunnel would derive from this source of additional water.

- There is an increase in the percentage of the time from pre-control to post-control that outflows are less than 300 cumecs. For example, outflow is less than 200 cumecs for 9% of the time post-control compared with only 3.5% of the time pre-control.

- Since control, Lake Manapouri inflows have increased as a consequence of the Mararoa River being diverted into the lake. Therefore, outflows from the lake have also increased.

Table 6 – Power Station Outflow Summary

Outflow	Post Control (1969 - 1992)
Maximum (1 day)	509 cumecs (1977)
Mean	343 cumecs
Median	392 cumecs
Minimum (1 Day)	0 cumecs (various)

The maximum freshwater discharge into Deep Cove exceeds 460 cumecs for 30% of the time and is less than 200 cumecs for 16% of the time. The power station outflow can often be at flows slightly less than 480 cumecs, because this is the maximum determined by the current "safe operating rule" of the Manapouri station.

Although the maximum outflow recorded is 509 cumecs, current station operating rules limit this to 465 cumecs for safety reasons. Should the 2nd tailrace tunnel be constructed, the mean discharge could increase to 386 cumecs and the maximum discharge to 630 cumecs[19] with corresponding reductions in the mean and flood discharge from MLC.

3.5.5 Mararoa Weir (Manapouri Lake Control) Outflows

The Mararoa Weir dams the entire Waiau River downstream of the Mararoa River confluence and controls the natural outflows of Lake Manapouri through release of water from the lake, and release of turbid water from the Mararoa River.

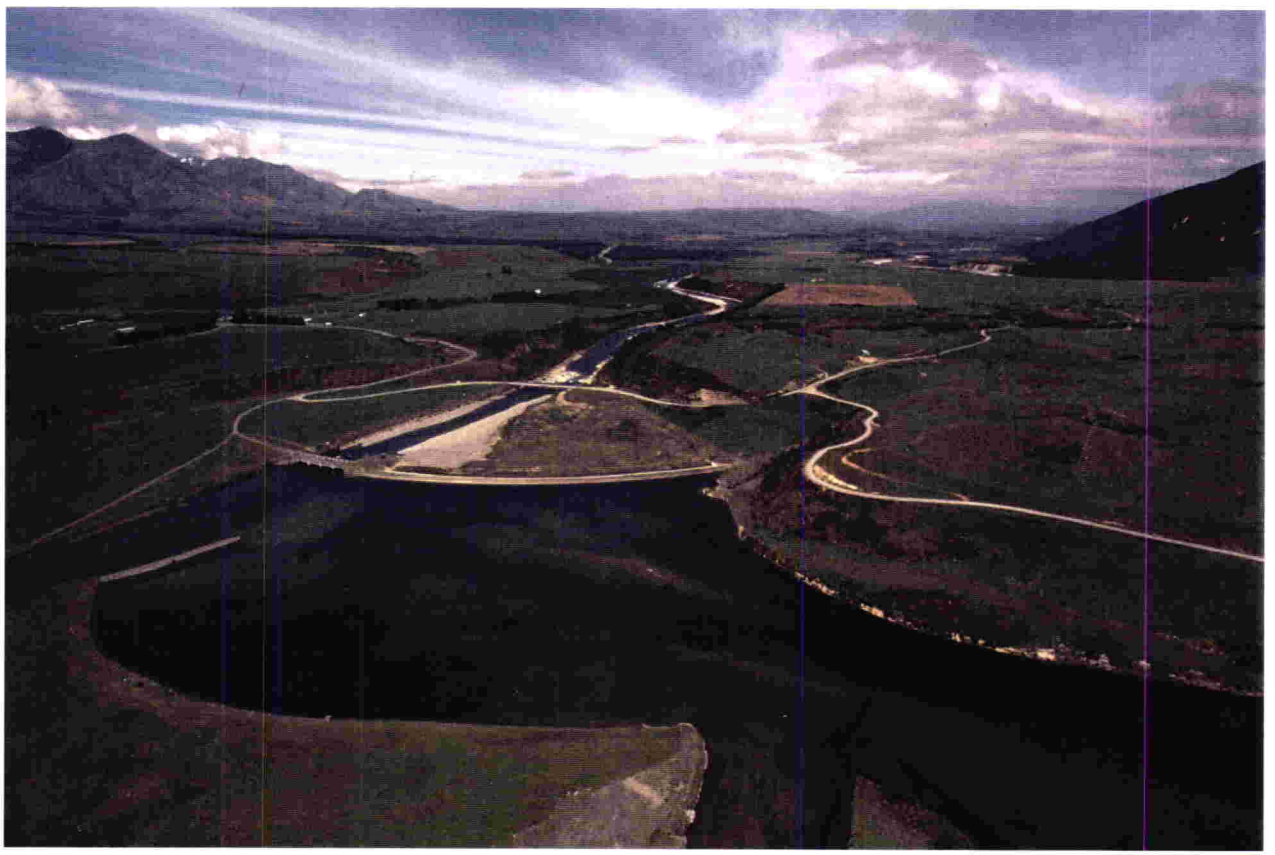


Figure 18 – Mararoa Weir (Manapouri Lake Control – MLC)

Table 7 – Mararoa Weir (MLC) Outflow Summary

Outflow	Post Control (1969 - 1991)
Maximum (1 day)	1470.3 cumecs (1988)
Mean	99 cumecs
Median	close to zero cumecs
Minimum (1 Day)	0 cumecs (various)

The median outflow of close to zero results from there being no flow from the Mararoa Weir 61% of the time. The lowest natural outflow on record was 99.5 cumecs (daily mean) in February 1953. This event has a return period greater than 100 years.

To ensure that Lake Manapouri level guidelines are achieved when the lake level is in the flood range, it is sometimes necessary to spill lake water through the control structure. The Mararoa Gate Operating Procedures for "dirty water" spills were developed following the Guardians' concerns that this discoloured and silt-laden water is neither aesthetically nor environmentally appropriate within a national park. It was agreed with the Guardians that the Mararoa Weir gates will be opened, and Mararoa water released, when its flow exceeds certain parameters. Recently, this guideline has been refined so the Mararoa River is released through the weir whenever the turbidity of the river water (monitored continuously at Cliffs) exceeds 30 NTU.

At other times water is released from the Mararoa Weir as is necessary to comply with the guideline rules for operating Lake Manapouri in its upper ranges. This would normally include the discharge of major catchment-wide flood events.

The typical pattern of the Mararoa Weir releases is described by the summary data in Table 8.

Table 8 – Analysis of the components of water spilled at the Mararoa Weir (after Riddell 1993a)

YEAR	Mararoa weir spill (cumecs)	Amount as lake spill (mean cumecs)	Amount as Mararoa spill (mean cumecs)	% of time spill occurred	% of time due to lake level Guidelines	% of time due to Mararoa Guidelines
1978	19.8	11.3	8.5	13	4	9
1979	70.8	49.7	20.8	33	22	11
1980	126.3	94.4	31.9	51	21	30
1981	17.2	3.9	13.4	15	2	13
1982	120.3	111.1	9.2	41	28	13
1983	98.4	87.2	11.2	50	25	25
1984	81.4	57.0	24.4	41	15	16
1985	52.0	40.8	11.2	29	10	19
1986	32.5	9.1	23.4	31	3	28
1987	86.8	66.5	20.3	55	28	27
1988	183.1	168.3	14.8	54	23	31
1989	12.4	0	12.4	19	0	19
1990	40.8	33.1	7.7	27	15	12
1991	68.4	43.3	25.1	33	23	10
MEANS	72.2	55.4	16.7	35	16	19

3.5.6 Tuatapere Flows

The catchment area downstream of the Mararoa Weir is 2341km^2 or 29% of the total Waiau catchment of 8134km^2 above Tuatapere. The Lake Te Anau and Manapouri catchments above the Mararoa Weir contribute 72% (average 99cumecs) of the Waiau River's natural mean flow (137cumecs) at Tuatapere, post-control. The other 28% comes from the Mararoa, Monowai and other tributaries of the Lower Waiau. Pre-control, the mean flow at Tuatapere was 560 cumecs.

Table 9 – Flow Summary for Waiau River at Tuatapere

Outflow	Pre Control (1964 - 1969)	Post Control (1973 - 1991)
Maximum (1 day)	1868 cumecs (1967)	3320 cumecs (1984)
Mean	560 cumecs	137 cumecs
Median	520 cumecs	62 cumecs
Minimum (1 Day)	232.8 cumecs (1966)	8.4 cumecs (1972)

Rainfall events producing high inflows into Lakes Te Anau and Manapouri are common in the Waiau catchment. However, lake storage and the diversion of flows through the power station considerably reduce the outflow from above MLC into the Lower Waiau catchment. Although the uncontrolled tributaries of the Lower Waiau catchment from Sunnyside to Tuatapere have relatively small mean flows they make a significant contribution in flood events.

Diversion of up to 465 cumecs through the Manapouri Power Station to Deep Cove means that nearly all floods at Tuatapere since control have been lower than they were before control. While many of the flood peaks at Tuatapere since 1979 have been large, they would have been even larger without the Manapouri Power Station's discharge into Deep Cove.

One of the two most significant flood events in the Waiau catchment since control was that of January 1984. Rainfall was high in the lower Waiau and Manapouri catchments but less in the Te Anau catchment. The flood was of short duration (18 hours) and much of the Manapouri inflow was stored in Lake Manapouri. While the flood at Tuatapere was still large, it was of a much lower return period than would otherwise have occurred from the same inflow.

Lake storage cannot reduce floods of unusually long duration. The major flood of November 1988 was the largest since records began in 1926, and resulted from continuous storms over some two months. As a result, after both lakes were in their upper ranges, subsequent floodwaters could not be stored and had to be spilled. Consequently, there were sustained high flows at Tuatapere.



Figure 19 – Mararoa Weir under flood



Figure 20 – Tuatapere flood, January 1984

3.6 Water Quality

The waters of the Waiau catchment have been "classified" Class C under the Water and Soil Conservation Act 1967. Figure 14 shows that the waters of all of the upper catchment, and most of the lower catchment, are classified as Class C. Coastal waters are Class SB (Appendix II).

The water quality of the rivers and lakes in the Waiau catchment is relatively high compared with other major Southland and New Zealand rivers. This is primarily due to the high rainfall in the region and the underlying geology. Tributary catchments with lower water quality are generally agriculturally developed.[20]

Low flows in the Lower Waiau immediately downstream of the Mararoa Weir affect water quality because dilution ratios are reduced as a result of flow diversion. All lakes in the catchment have particularly high water quality, especially the larger Lakes Manapouri and Te Anau.

3.7 Erosion and Channel Morphology

The high rainfall and steep slopes of the Fiordland region lead to extreme erosion potential within the Waiau catchment.[21] Erosion caused by catchment modification has greatly increased the amount of riverbed sedimentary material and influenced river mouth characteristics, which have yet to reach an equilibrium.[22]

Much of the Lower Waiau River is constrained by bedrock or river terraces, while some reaches are essentially braided. As a reach widens, the ability of the flow to carry sediment is reduced as energy dissipates over a broader area and sediment is deposited. Large volumes of sediment are added to the river at many tributary confluences, further affecting the channel form and resulting in deposition of sediment into mid-channel bars.

Much of the sediment which enters the Lower Waiau comes from the first three true left-bank tributaries downstream of the Mararoa Weir: Excelsior, Whare and Redcliff Creeks. All three catchments carry vast quantities of eroded material from the shattered scree slopes of the Takitimu ranges.[23] Considerable amounts of sediment are also provided by the Mararoa and its tributaries. Establishing a total sediment yield for the Lower Waiau is difficult as there are many tributaries contributing to the total volume of sediment inputs.

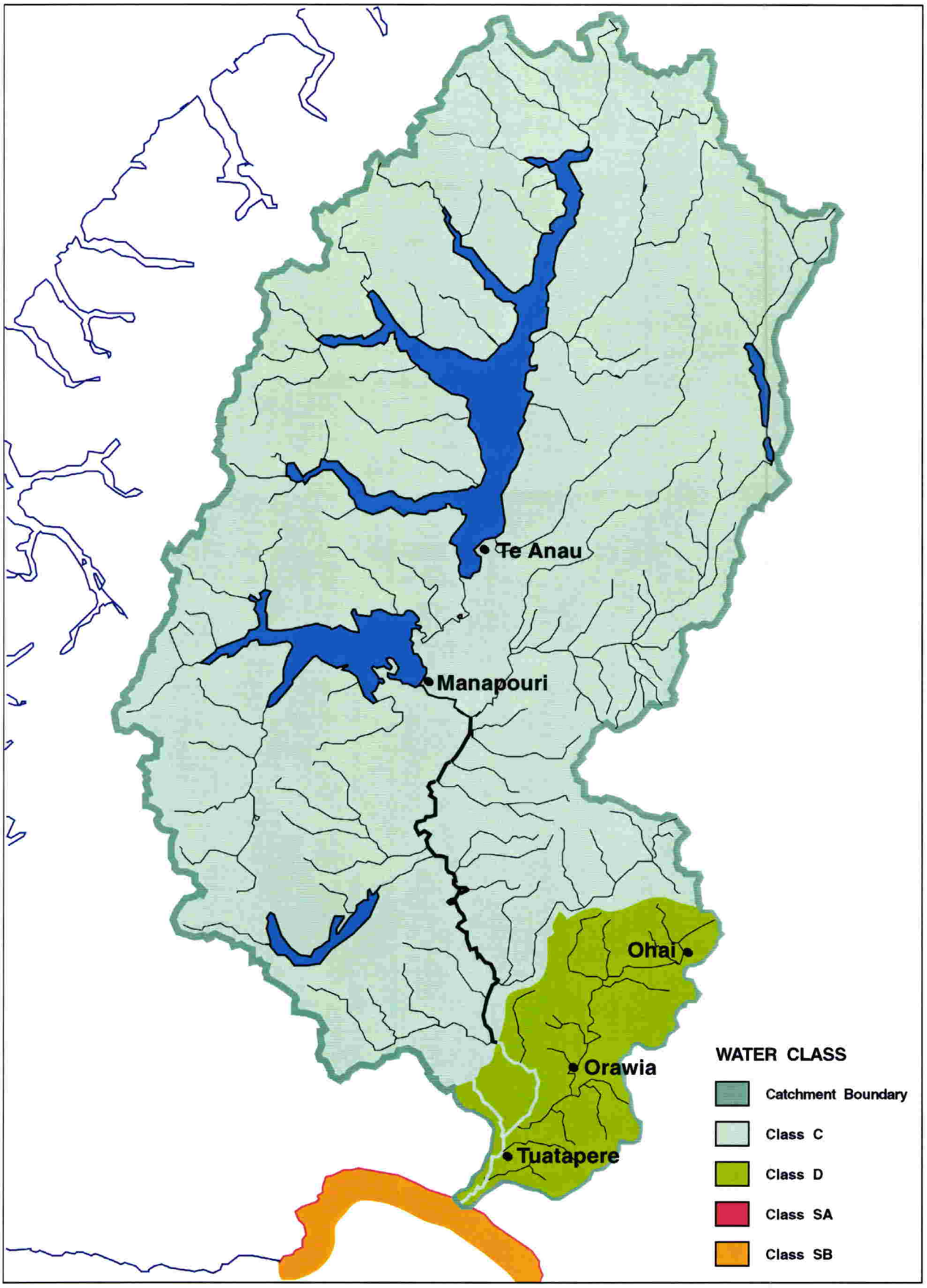


Figure 21 – Waiau Catchment – Water Quality Classification

3.8 Freshwater Ecosystems

3.8.1 The Lake Ecosystems

Lakes Te Anau and Manapouri provide a significant contribution to the ecosystem diversity of Fiordland National Park and the Southwest New Zealand World Heritage Area. Formed by glaciation, the lakes are deep with steep sides. Inflows are generally clear and nutrient-poor, keeping lake productivity low. The oligotrophic (low nutrient) status of the lakes means that there is very little mid-water (pelagic) plankton production. Most productivity comes from aquatic plants and periphyton which can exist in the shallow lake margins (the littoral zone), to the depths where light can penetrate.



Figure 22 – Nitella, an aquatic plant

The aquatic plants of Lakes Te Anau and Manapouri, together with Lake Monowai and (unregulated) Lake Hauroko, have been described for species diversity, depth range and abundance of submerged vegetation, and underwater erosion.[24] The submerged vegetation of these lakes is predominantly comprised of native species. *Elodea canadensis*, the most abundant tall vascular species, is the only introduced "oxygen weed". The most common group of plants is the Charophytes which grow at lower depths. Bryophytes (mosses and liverworts) are also widespread in the lakes, but not as abundant or as deep as in the ultra-clear, nearby Lakes Wakatipu and Wanaka.

In comparing the aquatic macrophytes of three regulated lakes (Manapouri, Te Anau and Monowai) with the unregulated Lake Hauroko, Wells et al (1993) found species diversity and abundance similar in all four lakes. Nationally endangered plants known only from these lake ecosystems include the small annual herb *Iti lacustris.*

Up to thirteen plant zones (communities) have been recognised as characterising the shoreline terrestrial vegetation of Lake Manapouri. Vegetation patterns along the Te Anau shoreline are similar. The communities range from aquatic vegetation and lake edge turf through to climax podocarp forest. Figure 22 shows a typical shoreline vegetation zonation pattern.

The lakeshore vegetation of both lakes shows a relationship to the natural fluctuations in lake levels.

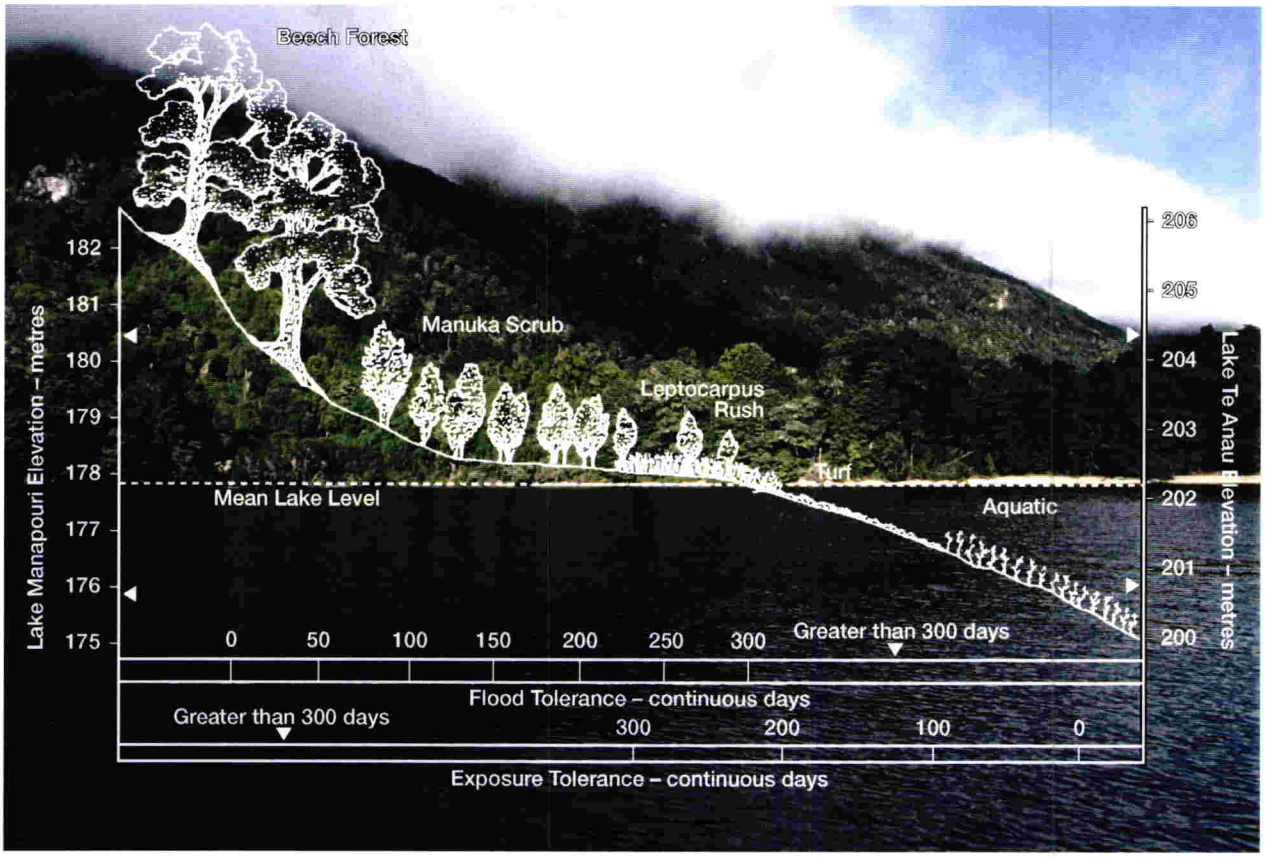


Figure 23 – Typical Manapouri/Te Anau shoreline vegetation pattern

Each community reflects the tolerances of the various species to either inundation (or periodic development of high water tables) or dissection through exposure. Therefore, lake levels determine the lakeshore vegetation plant communities, including their upper and lower limits.[25]

Macroinvertebrates in the lakes have not been studied in the same detail as those in the rivers and streams. Records of littoral macroinvertebrates from one transect in Lakes Te Anau and Manapouri are presented in Appendix III. The species present are typical of most other South Island glacial lakes. In these deep oligotrophic lakes, macroinvertebrate densities would be largely dependent on the distribution and density of the aquatic macrophytes upon which they feed.

Recent studies on the native and introduced fish in the Waiau catchment have greatly increased the database on fisheries. The Waiau catchment has fish species typical of the rivers and lakes of southern New Zealand. Twentyone native fish species and four exotic species have been reported from the Waiau catchment (Table 10). One native species, the New Zealand grayling (upukeroro) is probably extinct,[26] while another, Stokell's smelt, has possibly disappeared from the Waiau.[27] Many of these species, mostly native, migrate from the lakes to the sea during part of their life cycle. Some native fish species (eg. koaro, giant kokopu, bullies, smelt) can establish landlocked populations and remain present in the natural and artificial lakes of the Waiau catchment.



Figure 24 – Giant Kokopu (Galaxies argenteus)

Brown trout and rainbow trout have established in both lakes and provide a regionally important sports fishery. Both species are able to spawn in the Lower Waiau mainstem and tributaries. Atlantic salmon were liberated into the lakes by the New Zealand Wildlife Service and became a significant fishery in the 1930's. Since 1950 this fishery has declined, possibly due to negative interaction with rainbow trout.

Table 10–Fish Species Known to Occur in the Waiau Catchment[28]

Species	Occurrence
Yellow-bellied Flounder (Rhombosolea leporina)	Present in lower river. Largely marine but inhabit estuarine areas to feed.
Black Flounder (Rhombosolea retiaria)	Commonly called "river flounder". Range extends from lower to middle river. Freshwater/estuarine.
Long-finned Eel (Anguilla dieffenbachii)	Abundant and widely distributed in all accessible inland waters. Migratory, spawning great distances out to sea and returning as a small shoaling fish.
Short-finned Eel (Anguilla australis)	Primarily coastal. Preference for sluggish, muddy waters and coastal swamps and lagoons. Similar migratory habits to long-finned eels.
Lamprey (Geotria australis)	Not a true fish. Wide distribution. Spawns in freshwater streams during winter and spring. Migrates to sea for adult life.
Yellow-eyed Mullet (Aldrichetta forsteri)	Recorded in lower river. Largely marine but feeds in estuarine water.
Kahawai (Arripis trutta)	Found in lower reaches.
Torrentfish (Cheimarrichthys fosteri)	Found in Monowai River, Lill Burn and the Mararoa fish pass. Sea-going species mainly found near the coast but also well inland. Lives in swift flowing water among boulders and cobbles. Highly migratory.
Smelt (Retropinna retropinna)	Present in rivers and lakes. Spawns in fresh water near the sea. Fry return to sea for a time before returning as adults.
Stokell's Smelt (Stokellia anisodon)	Possibly disappeared from Waiau catchment.
Inanga (Galaxias maculatus)	Adults spawn in late summer at the base of estuarine marginal vegetation during high spring tides. Most common in lower reaches of Waiau River and in Te Waewae lagoon. Comprise bulk of whitebait catch.
Koaro (Galaxias brevipinnis)	Sea-running and landlocked populations. Juveniles form second largest component of whitebait catch. Can penetrate well upstream.
Banded Kokopu (Galaxias fasciatus)	Uncommon. Found in Lake Te Anau. Adept climbers.
Giant Kokopu (Galaxias argenteus)	Recorded in Lakes Monowai and Mistletoe. Largest of whitebait species. Rare, require abundant cover and slow flowing waters.

Table 10 – Fish Species Known to Occur in the Waiau Catchment[28] *(continued)*

Species	Occurrence
Common river galaxias (Galaxias vulgaris)	Adults present in Lower Waiau River. Juveniles likely component of whitebait catch in Lower Waiau.
Alpine galaxias (Galaxias paucispondylus)	Rare, found in headwaters of Mararoa River in swift, cold water in rapids with gravelly/boulder beds. Spawning occurs around river margins.
Common Bully (Gobiomorphus cotidianus)	Widespread in catchment. Huge numbers reported from Waiau River mouth. Sea-going and lake-dwelling populations. Spawning occurs on rocks and logs during spring and summer.
Upland Bully (Gobiomorphus breviceps)	Common in upland and lowland waters.
Bluegilled Bully (Gobiomorphus hubbsi)	Most likely found in the Lower Waiau. Sea-going.
Redfinned Bully (Gobiomorphus huttoni)	Sea-going species. Found in Te Waewae lagoon.
Giant Bully (Gobiomorphus gobioidies)	The largest of the bullies, sea-going. Recorded in Lower Waiau.
Brown Trout (Salmo trutta)	Widely distributed throughout catchment. Spawns in freshwater gravels. Sea-going migratory brown trout pass through estuarine zones to similar spawning grounds as do smolts returning to the sea.
Atlantic Salmon (Salmo salar)	Successfully established in the Waiau catchment, their only location in NZ. Once abundant in lakes and rivers, but despite recent releases of stock, remains rare in the Upper Waiau and very rare in the Lower Waiau.
Rainbow Trout (Oncorhynchus mykiss)	Widespread in catchment. More numerous in upper tributaries. Common in lower reaches of Waiau River. Increase in numbers since installation of Manapouri lake control structure. Spawns in late winter and spring throughout catchment.
Brook Char (Salvelinus fontinalis)	Found widely in NZ but little known in the Waiau. Present in Lake Misteltoe. Often form stunted populations.
Perch (Perca fluviatilus)	Present but uncommon in the catchment. Common in Lake Luxmore.
Quinnat Salmon (Onchorhynehus tsehawtha)	Occasional adults migrate into Lower Waiau River.

The lakes also provide a large, diverse habitat for many species of native and introduced birds in Fiordland (Table 11). Birds are particularly common in areas where river deltas feed into the lakes, as these provide resting and feeding areas. The lakes are also important as low elevation overwintering habitat for those aquatic birds which normally reside in the isolated alpine Fiordland lakes, but which must escape freezing conditions in winter.

3.8.2 River Ecosystems

The Waiau River provides a geographical boundary between largely developed catchments to the east, and largely unmodified catchments to the west. Therefore, the river exhibits characteristics of both a typical lowland Southland river, and a pristine natural waterway.



Figure 25 – Lower Waiau River, a natural boundary between developed and undeveloped catchments

Aquatic plants are present in the slower flowing areas of rivers and streams in the catchment. These are described by Chisholm (1992b). The riparian vegetation is dominated by native forest in the upper and western catchment while exotic species are more prevalent in the eastern and lower catchment. The riparian vegetation of the Lower Waiau River is described by Bennett (1993).

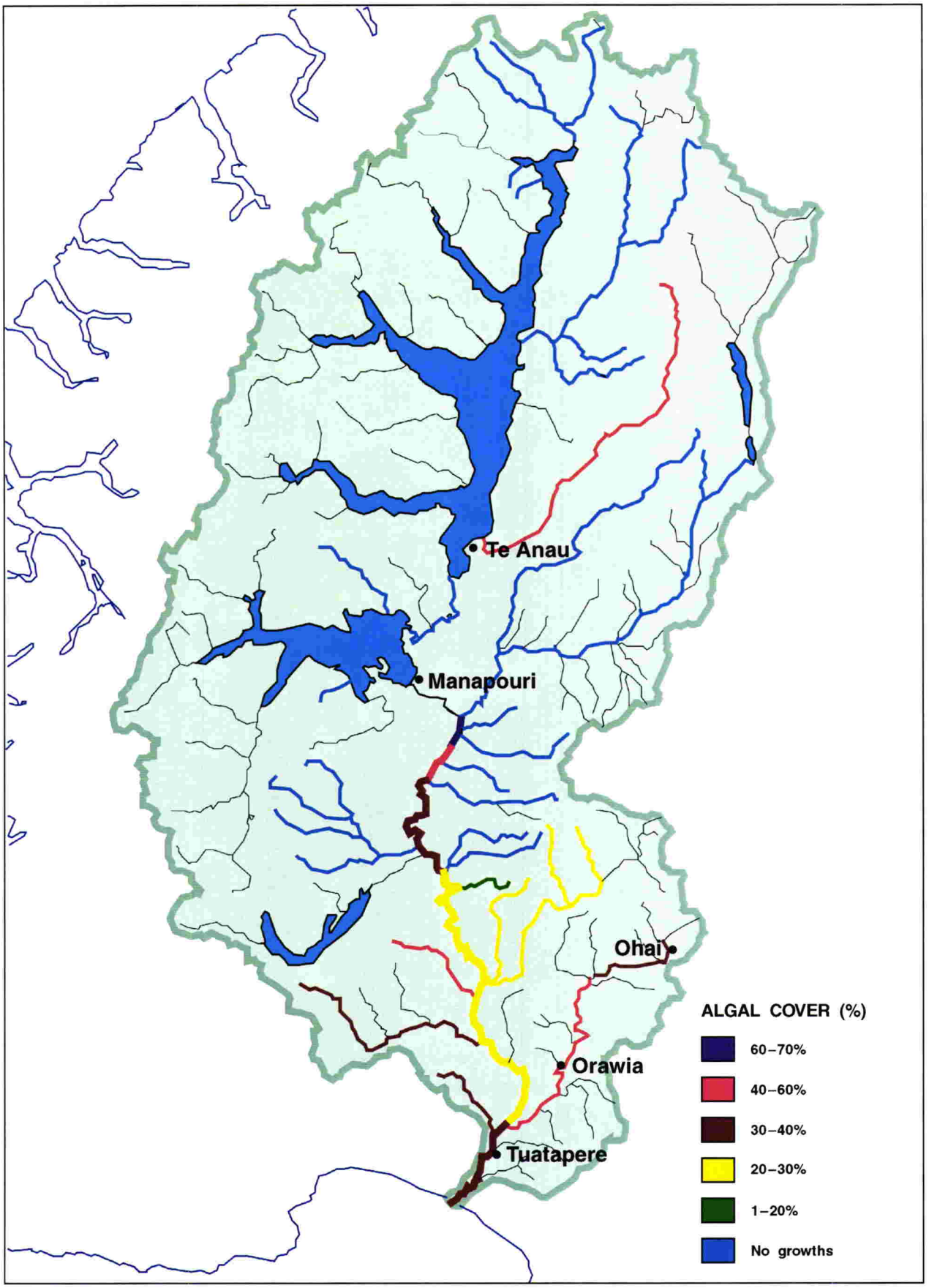


Figure 26 – Waiau Catchment – Relative abundance of benthic algal growths in rivers and streams during low February flows (Robertson, 1993).

A diverse assemblage of aquatic macroinvertebrate species is normally present in the Waiau catchment, generally reflecting a clean, unmodified environment.[29] Macroinvertebrates in the Upper Waiau are dominated in numbers by sandfly larvae (*Austrosimulum* sp.), and in biomass by net spinning caddis larvae (*Aoteapsyche* sp.).[30] Other common macroinvertebrates include freshwater snail (*Potamopyrgus* sp.) and the stonefly *Zealandobius decorata*.

Macroinvertebrate taxa found in the rivers and streams of the Lower Waiau catchment include flatworms, worms, snails, bivalves and aquatic insects. Aquatic insects include larval stoneflies, mayflies, caddisflies, midges, beetles, damselflies, dobsonflies and craneflies. "Clean water" fauna dominate in most areas. In more nutrient enriched rivers (such as the Dean Burn, Orauea and Morley Rivers) and the low flows area immediately below the Mararoa Weir, more pollution-tolerant forms (eg. worms) become abundant.[31] Algal abundance is also correlated with the nutrient status of rivers in the catchment, as well as the presence or absence of riparian shading.[32]



Figure 27 – Adult Stonefly (Stenoperla prasina)

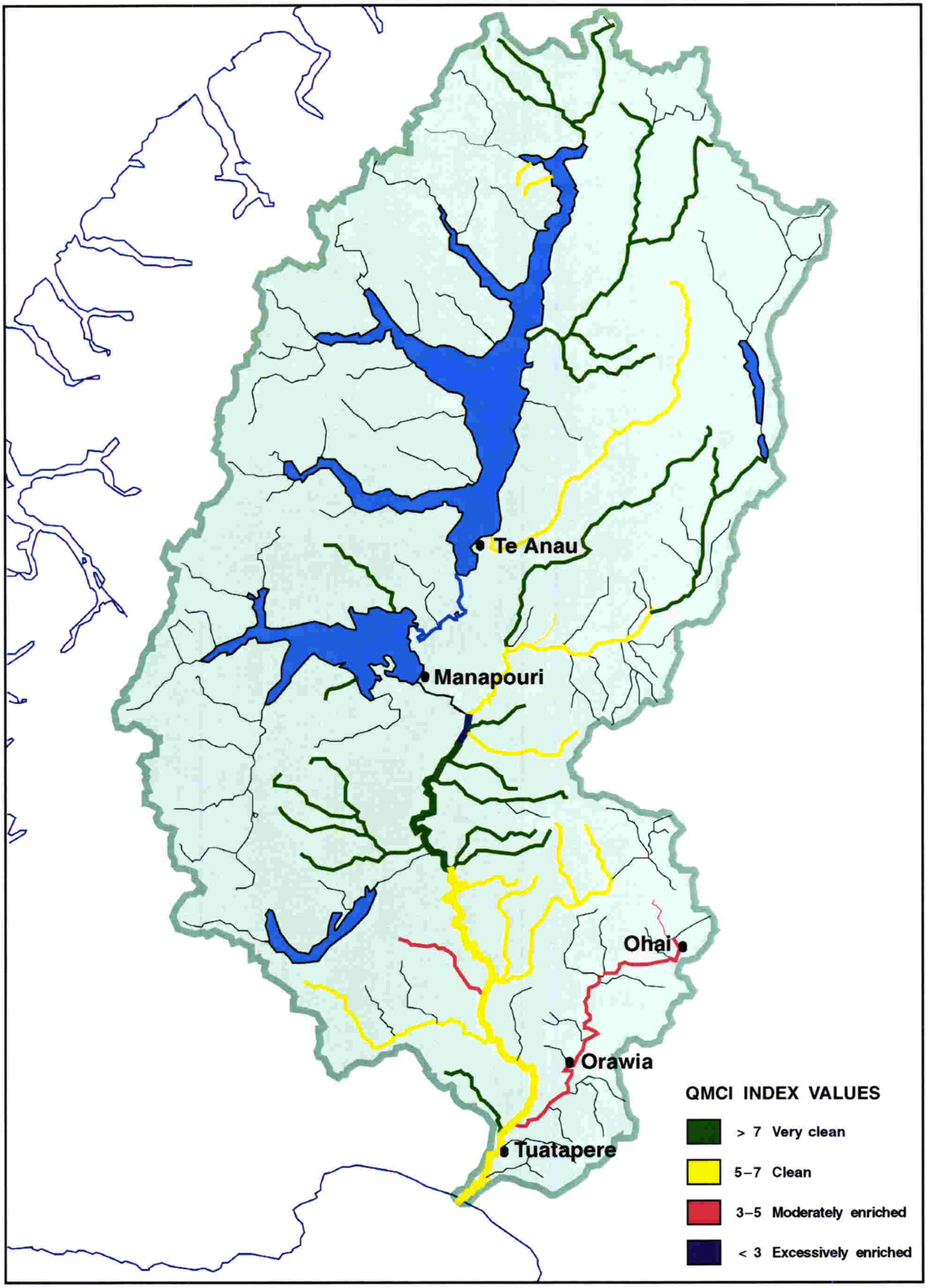


Figure 28 – Waiau Catchment – Quantitative Macroinvertibrate Community Index (QMCI) of rivers and streams during low flows (Robertson, 1993).

Rivers in the upper catchment sustain world class backcountry trout fisheries. The Lower Waiau River and tributaries sustain a more accessible, but regionally significant, trout fishery. Whitebait and eels are caught by recreational fishermen, although some commercial fishing for these species may occur. McDowall (1994b) provides a calendar of the seasonal timing of fish migrations into and out of the Waiau River (Figure 29).

Calendar of Seasonal Fish Migrations – Waiau River

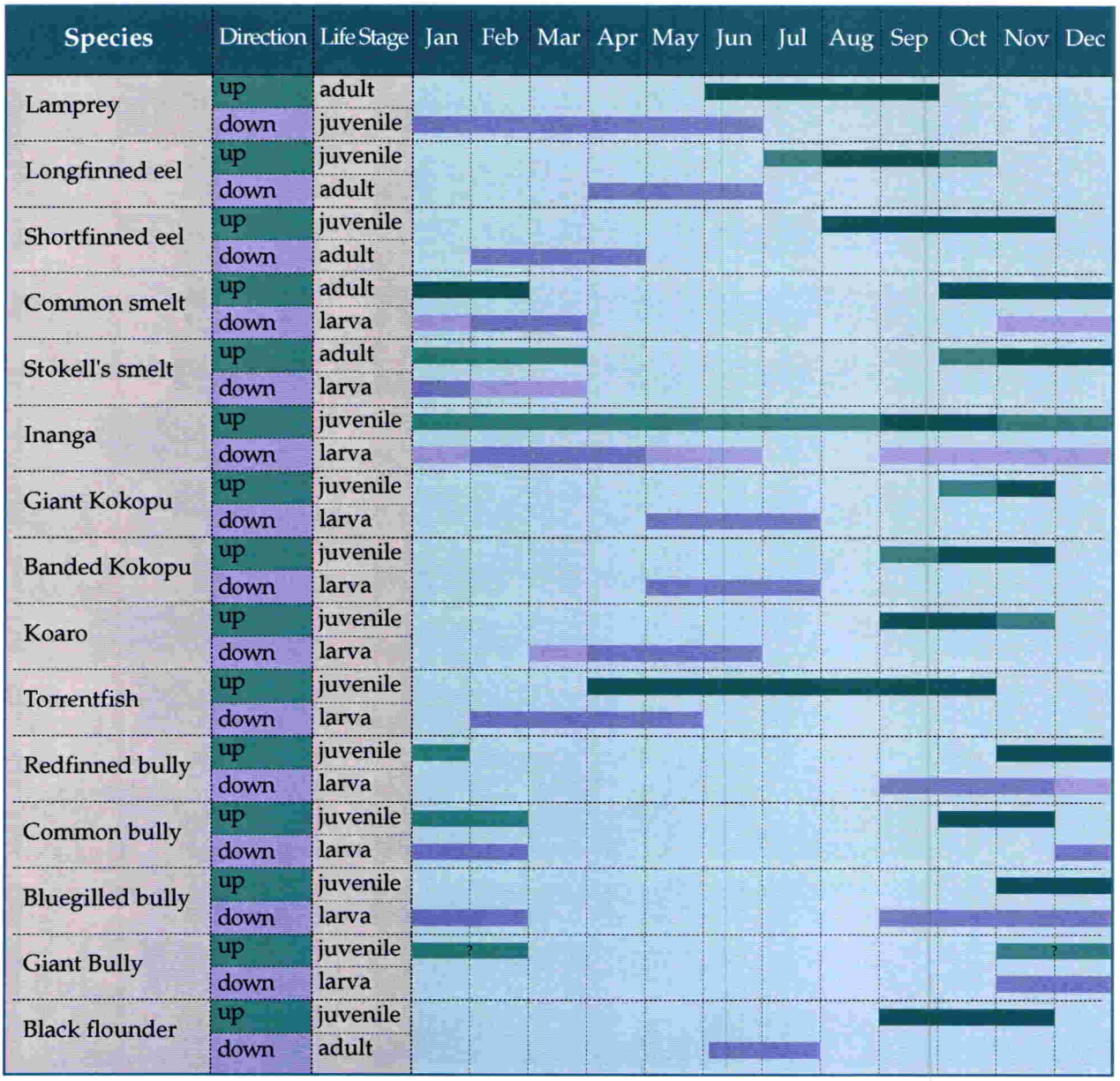


Figure 29 – Calendar of seasonal fish migrations in the Waiau River (McDowall 1994b)

Braided areas of the Lower Waiau River, particularly from the mouth up to the bridge at Tuatapere, provide significant breeding and feeding habitat for river bird species (Table 11). Black-backed gulls, black-billed gulls, banded dotterels, black-fronted terns, white-fronted terns, caspian terns, shags (black, little, spotted) pied stilt, white-faced heron and the occasional white heron all inhabit these areas. Wetlands associated with the Waiau River are also inhabited by many of these bird species, as well as pukeko, spur-winged plover and marsh crake. Wetlands, notably the restored Redcliff lagoons, also provide valuable habitat for gamebird species including shoveller, mallard, paradise duck, grey duck and Canada goose. A complete description of the birds of the Waiau catchment is provided in Chisholm (1992a).



Figure 30 – Spur-winged Plover

Table 11 – Birds of the Waiau Catchment

Wading Birds	Occurrence
S.I. Pied Oystercatcher (Haematopus finschi)	Semi-migratory - present August-March breeding.
Banded Dotterel (Charadrius bicinctus)	Semi-migratory - present August-March breeding.
Pied Stilt (Himantopus leucocephalus)	Resident and breeding - a few pairs.
Spur-winged Plover (Lobibyx novaehollandiae)	Resident and breeding. Moderate numbers - increasing.
Pukeko (Porphyrio melanotus)	Common in associated wetlands.



Figure 31 – Banded Dotterel

Wading Birds	Occurrence
Other species (including those on the DOC endangered list) which may use habitats in the Waiau catchment include:	
White heron (Egretta alba)	Occasional visitor to coastal area.
Blue heron (Egretta sacra)	Present in coastal areas.
Brown teal (Anas chlorotis)	Now only a remnant population in Southern Fiordland.
Blue duck (Hymenolaimus malacorhynchos)	Mainly found in western tributaries of Waiau catchment.
NZ scaup (Aythyo novaeseelandiae)	Found in both Lakes Te Anau and Manapouri (moderate numbers).
Black stilt (Himantopus novaezealandiae)	Rare at Lake Manapouri.
White-faced Heron (Ardea novaehollandiae)	A few birds present - possibly breeding.
Marsh Crake (Porzana pusilla)	Resident and breeding - small numbers in swampy vegetation.

Water Birds	Occurrence
White-fronted tern (Sterna striata)	Resident in small numbers.
Casian tern (Hydroprogne caspia)	Occasional migrant.
Grey Duck (Anas superciliosa)	Resident, breeding - common.
Mallard Duck (Anas platyrhynchos)	Resident and probably breeding. Common introduced species.
Black Swan (Cygnus atratus)	Resident and breeding - in small numbers. A few pairs breeding annually.
Canada Goose (Branta canadensis)	A few birds usually present.
Paradise Duck (Tadorna variegata)	Resident and breeding - abundant. Lakes important as moulting area.
NZ Shoveler (Anas rhynchotis)	Present in small numbers.
NZ Scaup (Aythya novaeseelandiae)	Resident and breeding - abundant.
Kingfisher (Halcyon sancta)	Present in small numbers - no recorded breeding, but possible.
Spotted Shag (Stictocarbo punctatus)	Coastal areas only.
Black Shag (Phalacrocorax carbo)	Resident and breeding in two small colonies.
Little Shag (P. melanoleucos brevirostris)	Resident and probably breeding.
Crested Grebe (Podicepscristatus australis)	Occasional visitor.
Black-backed Gull (Larus dominicanus)	Resident in small numbers.
Black-billed Gull (Larus bulleri)	Resident in moderate numbers.
Black-fronted Tern (Chlidonias albostriatus)	Resident in small numbers.

3.9 Coastal Ecosystems

3.9.1 Te Waewae Lagoon

Te Waewae lagoon, Matatarawae, lies between the mouth of the Waiau River and Te Waewae Bay, behind a 4 km gravel barrier. Along the edge of the lagoon is a mixture of native flax and *Olearia* bushes, intermixed with unimproved pasture. The lagoon provides habitat for many fish and bird species and is an important provider of fish (eels, yelloweye mullet, inanga, flounder and stargazer), and birds.[33,34]



Figure 32 – Te Waewae Lagoon and Waiau River Mouth

3.9.2 Te Waewae Bay

The Waiau River discharges through Te Waewae Lagoon into Te Waewae Bay which lies toward the Western end of Foveaux Strait between the Fiordland-Waitutu coast and Orepuki beach. The Te Waewae coastal ecosystem has developed over the last 6000 years. Initiated by tectonic uplift, the ecosystem has more recently been influenced by forest clearance and conversion to pasture. Increased erosion rates have increased the supply of coarse gravel to the coast, thus augmenting the gravel bar which forms a barrier between Te Waewae Lagoon and the Bay. To the east, the gravels blend into a more sand-shingle-cobble beach at Orepuki.

The dominant species in the upper intertidal zone is the sandhopper (*Talorchestia* sp.). The lower intertidal zone has mainly seaweed and bivalve mollusc species.

3.9.3 Doubtful Sound

Prior to the construction of the Manapouri Power Scheme, Batham (1965) carried out a brief preliminary survey of the intertidal fauna of Doubtful Sound. This was followed by a more comprehensive survey of the area's biology by the Otago University Department of Marine Sciences as reported in Mladenov (1995).

The dominant ecological factor in Doubtful Sound is the presence of a layer of fresh water (the "low salinity layer" or LSL) overlying the salt water. The low salinity layer is characterised by a brown-stained surface layer which flows rapidly seaward, and an underlying clear layer of seawater that flows much more slowly in the opposite direction. This feature is present throughout Fiordland and is created by the significant discharge of fresh water into the Sound from extremely high catchment rainfall (4,000-7,000 mm per year). The discharge from the Deep Cove tailrace augments the LSL in Doubtful Sound. Mean input of freshwater into Doubtful Sound is 209 cumecs from natural sources and 343 cumecs from the tailrace.

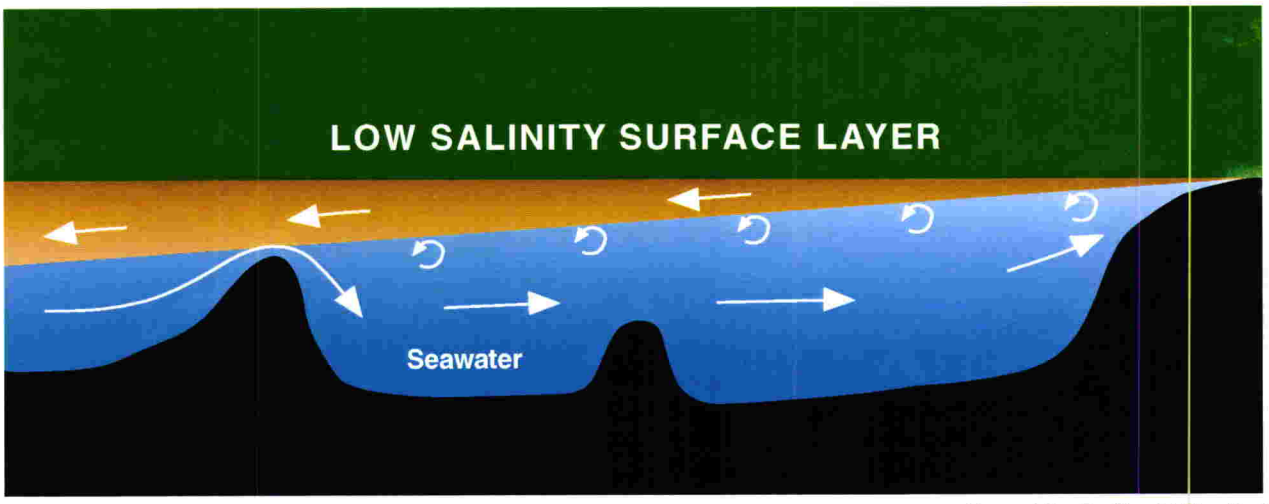


Figure 33 – Profile of LSL effect

The presence of this LSL, called an estuarine circulation, can affect the biota of the Sound by:

- diminishing the depth to which sunlight can penetrate
- causing opposing water currents at different depths
- causing zonation of intertidal communities and rock-wall biota dependent on their saline tolerances.

Plankton in the Fiordland Sounds have been briefly studied. Mladenov (1995) mentions that a normal complement of bacteria, phytoplankton and zooplankton can be expected to occur in the Sounds, with the possibility of an occasional natural plankton bloom. The intertidal fauna can be divided into inner-Sound and outer-Sound communities. Species present in the inner-Sound community, such as the freshwater snail *Potamopyrgus antipodarum*, and a shallow zone of black lichens, are tolerant of low salinities. The outer-Sound community, exposed to normal salinities, has more typical intertidal fauna of a southern New Zealand shore. Here, the fresh water snail and black lichen zones are absent.

The subtidal rock wall biota also show distinct zonation as a result of fluctuating salinities caused by the low-salinity layer. The shallow (0-4m) zone is relatively bare with only a few brackish-water species such as mussels, tubeworms and some algae. From about 4-40m the rock walls are covered with a diverse community of species including black coral, sponges, brachiopods, bryozoans, marine worms (polychaetes) and starfish. The darker environment created by the tannin-stained low salinity water is likely to be responsible for the interesting phenomenon of "emergence" of these normally deep water species into shallow areas of the Sound. Black coral, normally found below 40m, is common at depths of 10m. Colonies can be found at densities of up to 5 per square metre.

Other marine fauna include deepwater invertebrate and fish species, and a resident population of about 60 bottlenosed dolphins. There is an important rock lobster fishery in Fiordland, as well as new fisheries being established for species such as paua, sea urchins and sea cucumbers. Deep Cove is popular for recreational fishing for fish, crayfish and other shellfish.



Figure 34 – Black Coral with Snake Starfish

Chapter 4 – The Cultural Environment

It is not possible to overstate the splendour of the Fiordland region, as J. Herries Beattie wrote after a visit to Lake Manapouri in 1948:

> *"Not only do the islands exude loveliness, for it is all around us in the elegance of the whole design, in the symmetry and outline and in that harmony produced by conformity of each to their whole. There is not a discordant note in all this wonderful representation of nature".*

This outstanding natural heritage has been preserved in perpetuity for the people of New Zealand by the creation of the 1.2 million hectare Fiordland National Park, and more recently, the Te Wahipounamu (Southwest New Zealand) World Heritage Area. Preservation of the resources that have been appreciated in the past will continue to offer benefits to future generations.

It is within this setting that Maori and European settlement established both the knowledge and value of the environment which now influences decisions on resource management.

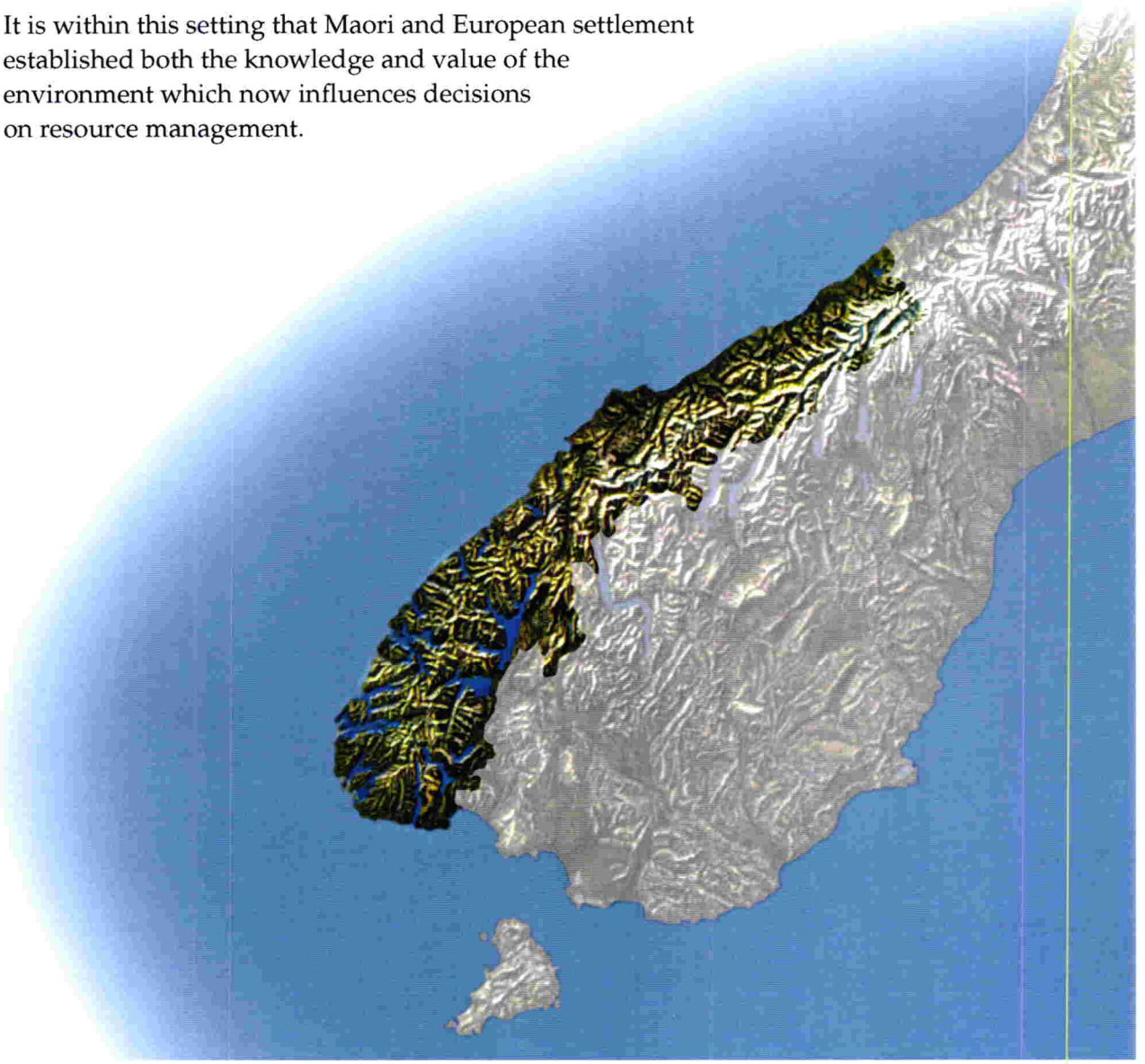


Figure 35 – Southwest New Zealand World Heritage Area

4.1 Historical Resources

4.1.1 Maori History

Whakapapa (Maori genealogical table) and many of the place names of the region record the history and earliest known visitors to the rivers, lakes and fiords of the Waiau catchment.

> *"The events in our histories can only be understood by reference to whakapapa because that explains the relationships between people: the 'what' of Maori tradition cannot be comprehended without a grasp of the 'who'. Thus our histories are structured and expressed in the form of whakapapa. It provides an acceptable chronology for Maori, and it sets the people of the past and their activities in a comprehensive order".*[35,36]

Over time, various tribal migrations brought Waitaha, Kati Mamoe and finally Kai Tahu to the region where widespread use was made of the resources of the Waiau catchment and Fiordland. At the time of Waitaha occupation of the region, Takitimu, the most sacred and most tapu of the great canoes that came to Aotearoa was wrecked in Te Waewae Bay. The canoe's crew came ashore at the river which they named Waiau, meaning swirling waters. This event is important to the mana whenua and is marked by many of the place names remaining to tell the story. For example, Te Puka-o-Tamatea (Monkey Island) is the anchor of Takitimu. Other place names, such as Wai Harakeke (Dean Burn) which contained a large harakeke (flax) resource, reveal the Maori use of the area's natural resources.

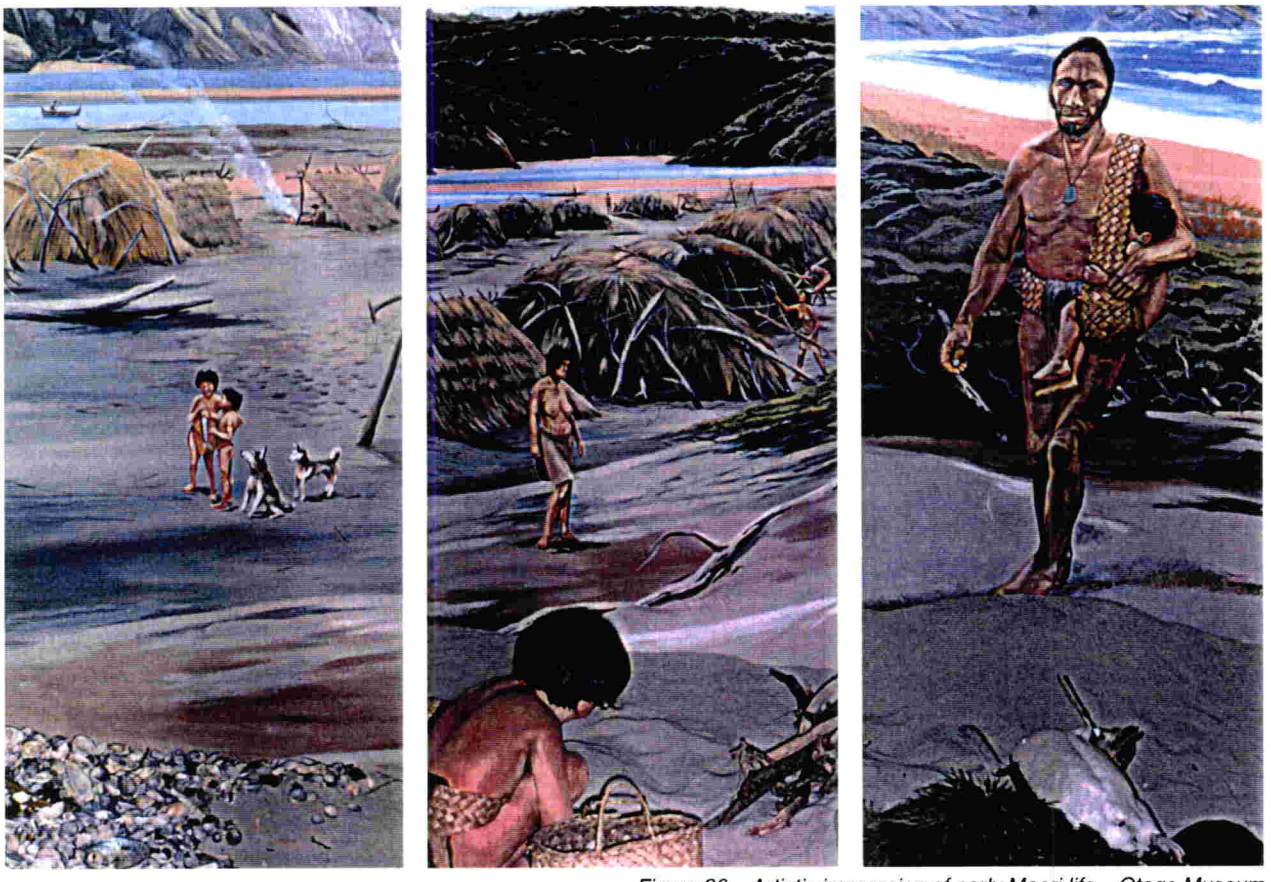


Figure 36 – Artistic impression of early Maori life – Otago Museum

"Because Kai Tahu moved throughout Te Waipounamu, their knowledge of the land was intimate and detailed. This knowledge was preserved in the naming of places. Indeed, the stories of the ancestors' journeys of exploration and the creation and shaping of the land also acted as "oral maps", with place names and meanings woven carefully into them. So the places and their names were part of a memory system in which religious belief, history and geography were combined".[37,38]

The journeys of the Maori, primarily in search of mahika kai, discovered most of the routes presently used for movement in Fiordland. For example, Wilmot Pass was a relatively direct route from the lakes over to Doubtful Sound.

Little is known of the true extent of occupation of Doubtful Sound, although one archaeological site has been identified. Skeletal remains of a middle aged man together with a midden containing shellfish remains, fish and bird bones were found in a cave at Murrel's Cove. Flax remains, possibly of food carrying bags or a cloak were also found so the cave may have been used as a casual shelter and not as a place of permanent habitation.[39]

Maori history is a highly regarded resource and has been recognised throughout the Manapouri Power Scheme programme. Maori interests are represented in the Guardians and on the Waiau Working Party.

4.1.2 European History

Captain Cook was the first recorded European visitor to the entrance of Doubtful Sound in 1770, although he did not venture inland. Subsequent European visits to Doubtful Sound came from the Spanish corvettes "Descubierta" and "Altriveda" in 1793. These ships were soon followed by others in their pursuit of sealing and whaling opportunities in the fiords. In 1852, William Stephen and Charles Nairn were the first Europeans to glimpse Lake Te Anau from terraces at the western end of the Takitimu mountains.[40] Three days later they arrived at the shores of Lake Te Anau. In 1854, farmers arrived in the Te Anau basin and large sheep stations were established on the eastern border of the catchment. Thirty years later, the service towns of Manapouri and Te Anau were established.

The tourist potential of the region was recognised from the outset. The first tourist vessel, "Titiroa", was launched in 1893. Sightseeing and duckshooting trips on the lake were popular, but it was the opening of the Milford Track in 1890 that marked the first major tourism venture in the area, initiating a growing industry which continues today.

4.2 Cultural and Economic Resources

Cultural and economic resources in the Southland Region vary with the diverse landscape. With European settlement, development spread from the waterways and the Waiau Valley continued, as it had in pre-European times, to be a main access route.

4.2.1 Land Uses

A large portion of the Southland Region lies within Fiordland National Park. Recreational activities within the National Park coincide with wilderness preservation.

Forestry activities are widespread throughout the region, with small holdings operating throughout the area and increased planting of exotic forests in the upper catchment. Timber milling has historically occurred, and continues, around Tuatapere.

Of the agricultural land in the Waiau catchment, much is devoted to sheep and beef farming, with deer farming found in the Te Anau basin and near the southern reaches of the catchment. There has been a recent increase in conversion of sheep farming areas to dairy farming in lowland areas.

The Fiordland coasts support some commercial fisheries, with dredge oysters and crayfish being the species of most value.

Although minerals may be found within Fiordland, its designation as a national park generally precludes mining. Elsewhere in the Waiau catchment, surface mining for sand and gravel has value for roading and building aggregate, and there has recently been some gold prospecting along the Lower Waiau River.

Hydro power generation is an important and valuable industry in the Region, with the ECNZ and Southland Electric Power supplies contributing to both Southland and the national grid.

4.2.2 Infrastructure

The main townships in the Waiau catchment are Te Anau, Manapouri and Tuatapere. Te Anau is the main service centre for the upper catchment, providing for both local residents and tourists. Manapouri serves as a centre for visitors to the Manapouri Power Station and the Doubtful Sound tourist resource. Tuatapere serves the rural area of the Lower Waiau catchment. Both Te Anau and Manapouri have water and sewerage systems. Tuatapere utilises river and bore water systems with private sewage systems.

Road access is available to Te Anau, Manapouri and Milford Sound. Access to West Arm and Doubtful Sound is by boat across Lake Manapouri, and road over Wilmot Pass. The Lower Waiau River and Tuatapere are well served by roads. Te Anau township is served by an airport. There are no railways in the area.



Figure 37 – Tourist boats at the Deep Cove wharf

4.2.3 Recreation and Tourism

With such a valuable natural resource as Fiordland National Park, various ventures have developed throughout the catchment, with a particular emphasis on recreational and remote area pursuits focusing on eco-tourism. Fiordland receives over 250,000 visitors annually.[41] Boat tours, fishing and wilderness travel are all catered for, with Te Anau providing the largest range of accommodation and activity options in the area. A full description of tourist activities in the Waiau catchment is provided by Anderson (1992).

Part 3

Public Consultation and Issues Identification

Chapter 5 – The Public Consultation Programme

The application for renewal of water permits for Manapouri Power Station and the matters covered in this Assessment of Effects on the Environment are largely the result of a programme of consultation which has extended over more than six years. ECNZ has followed a consultative approach as a conscious policy because it is best suited to the particular nature of the development and the activities for which permits are sought.

Throughout the programme of preparing resource consent applications, ECNZ has been committed to consulting openly with all stakeholders so a successful consent application and associated outcomes are achieved to the satisfaction of all involved. This has been met by involving interested parties and ECNZ in a three-step process of education, consultation and negotiation. Education is achieved through the acquisition of information on the actual processes involved with the scheme under investigation. Consultation is essentially (to paraphrase a legal definition):

> *" the communication of a genuine invitation to give advice and a genuine consideration of that advice ... to achieve consultation sufficient information must be supplied by the consulting to the consulted party to enable it to tender helpful advice. Sufficient time must be given by the consulting to the consulted party to enable it to do that..."*

ECNZ views consultation as, first and foremost, a process of sharing information. To consult effectively, the applicant must: genuinely seek the advice of those being consulted; provide those people with sufficient information to allow them to understand the issue(s) and to respond in an informed way; take such responses into consideration to the extent that the applicant is prepared to alter its plans if that is appropriate; then, make a decision. Consultation is not synonymous with consensus, although it may facilitate such an outcome. In this case, the consultation process has played a very large part in the scoping of the assessment of the effects of the Manapouri Power Scheme.

Following the acquisition of knowledge and effective consideration of that information, the negotiation phase began. Options acceptable to all parties have been discussed. Through this process, an environmental balance has been achieved which provides acceptable outcomes for all involved.

5.1 Waiau Working Party

On 27th April 1990, ECNZ invited various regulatory agencies, statutory authorities, special interest groups and other parties interested in or affected by the renewal of consents for the operation of the Manapouri Power Scheme, and its effects on the environment, to participate in a consultative "Waiau Catchment User Forum". Prior to that forum, people were invited to present written submissions, covering both perceived undesirable effects of the operation of the station and opportunities for improvement or enhancement which they thought should be explored. At the forum, held at Manapouri, all attendees were encouraged to present their views

and all issues raised were recorded. Following the forum, it was agreed to convene a Waiau Working Party (WWP) to investigate the issues raised and maintain on-going consultation between community representatives and ECNZ.

Subsequent meetings of the WWP were held on the Murihiku Marae and at Tuatapere. Again, these initial meetings were opportunities for discussion of concerns and feelings, which previously had no means of being heard.

The WWP then proceeded to build a body of scientific knowledge about the catchment, its basic nature and dynamics, and the effects on these of the hydraulic management regime resulting from hydro-generation. This was essentially a three stage process:

(i) Research and collation of the large body of literature already available about the catchment.

(ii) Identification of gaps in the available knowledge and initiation of studies to fill those gaps.

(iii) Commissioning of more detailed studies aimed at identification of options to address identified adverse effects.

Liaison between ECNZ and the WWP is ongoing. At the time of writing, the Waiau Working Party (including the initial Manapouri Forum) has met 27 times since April 1990. During their investigative phase, technical subgroups (taskgroups) were formed to oversee the requirements for scientific studies and other investigations into the effects of the power scheme on the environment, and the possible mitigation and enhancement options available.

Normally, taskgroups met between main working party meetings, enabling the taskgroups to report their progress to the WWP. Taskgroups focused on issues under the following headings:

- National/Legal
- Iwi
- Hydrology
- Coastal
- Aquatic Ecosystems
- Erosion/Sedimentation
- Recreation

Technical specialists were engaged by the taskgroups to provide reports on various issues, listed in Section 6.1.1.

The funding for this work was provided annually by ECNZ. The WWP decided by consensus on the brief for the studies and the preferred experts to study the issue. All reports were tabled and made available to participants. The outcome of the process has been a body of data which is accepted as common. While there may be differences of opinion as to which option is best for resolution of an issue, all parties to the group have a common understanding of the processes which are taking place.

Since its inception, the WWP has built up a considerable body of knowledge on the Manapouri Scheme and other issues related to the Waiau catchment in general. In some cases, the effects of the scheme cannot be assessed until the results from detailed long-term environmental monitoring are available (eg. the effects of freshwater discharges into Doubtful Sound). The challenge for the WWP has been to explore options for enhancing physical, ecological and social aspects of the new Waiau River catchment while it continues to provide an important source of New Zealand's electricity provision.

The following organisations are currently represented on the Waiau Working Party:

Department of Conservation
ECNZ
Federated Farmers
Lower Waiau Farmers
Mararoa Federated Farmers
Fiordland Promotion Association
Guardians of Lakes Manapouri, Te Anau and Monowai
Kai Tahu Runakanui O Murihiku
Ministry for the Environment
Royal Forest and Bird Protection Society
Southland Conservation Board
Southland District Council
Southland Electric Power Supply
Southland Fish and Game Council
Southland Jet Boating Association
Southland Regional Council
Southland Resource Monitor Group
Te Anau Community Board
Te Anau Rod and Gun Club
Tuatapere and Districts Promotions Group
Tuatapere Community Board
Waiau River Action Group

Over the period of consultation, the WWP has given particular attention to the interests of the community of the Waiau catchment. The human perspective, in conjunction with ecological studies, has been considered necessary and appropriate as perceptions are a vital yardstick of "natural character", "amenity values" and "quality of the environment".

The community is represented by the agencies and special interest groups on the WWP, through consultation with Kai Tahu and on-going contact with statutory authorities.



Figure 38 – Iwi visit to Deep Cove

5.2 Tangata Whenua

ECNZ acknowledges that the Waiau Catchment, its lakes and rivers are of special spiritual and cultural significance to Kai Tahu. It recognises Kai Tahu as the tangata whenua of the land. These traditional relationships with the river provide Kai Tahu with special standing as the kaitiaki of their taonga and as partners with statutory and regulatory agencies in the process of resource management.

The Waiau Working Party has accepted the importance of this special relationship. One of the task groups established to oversee the first phase of studies was an Iwi Task Group through which issues relevant to iwi interest were identified and priorities put forward for further assessment. The report of this group on the historical and cultural significance of the catchment to the tangata whenua, "Tikanga Maori Cultural, Spiritual and Historical Values of the Waiau River", has assisted greatly in an enhanced understanding of this aspect of the resource. The ongoing participation of members of local runaka has considerably enriched the consultation process.

ECNZ has consulted separately with the local runaka, particularly through the assistance of the Murihiku representative on the Ngai Tahu Maori Trust Board. A significant catchment-wide inventory was made of mahika kai, by the local runaka. Understanding of this resource has grown from discussions with representatives of all local runaka. This reciprocal information gathering has increased the knowledge base of both the iwi and the Working Party.

Independent of iwi involvement in the WWP, Kai Tahu have been fully informed of the process and its progress. The Murihiku representative on the Ngai Tahu Maori Trust Board has received all the information and reports from the Working Party. Also, ECNZ's project manager has met with representatives of the Aparima Runaka and briefed them on progress with the consultation process. On each of these occasions, iwi representatives were asked to voice any issues they felt still needed to be addressed.

5.3 Other Statutory Authorities

Consultation with the Minister of Conservation occurs through The Guardians of Lakes Manapouri, Te Anau and Monowai, and Department of Conservation (DOC) representation on the WWP. ECNZ representatives and Southland Regional Council's (SRC) project manager have attended twice-yearly meetings of the Guardians to report on progress and ensure that their knowledge and experience were utilised. ECNZ regularly briefs the DOC staff in Southland and at Head Office.

ECNZ has, from time to time during the process, consulted separately with the Southland Fish and Game Council (SFGC) to ascertain that the matters relevant to their particular statutory responsibilities were being appropriately addressed.

5.4 Information Dissemination

During 1994, a series of three public meetings was held in Te Anau, Invercargill and Tuatapere to ensure that all interested parties had an opportunity to be briefed on progress and to raise any issues that may not have been addressed. Initially, there was a perception that only big organisations could afford to get involved in a consultative process although any individual could attend and contribute to the working party process. The series of public meetings ensured that all who wished to, could participate and their concerns would be addressed within the WWP process. All issues and concerns brought up at these public meetings had previously been raised within the WWP and attendees were satisfied that their concerns were being addressed appropriately.

Ongoing liaison with the Te Anau Rod and Gun Club and the Waiau River Action Group has served to keep more specific interest groups informed and involved. Meetings were also held with the Te Anau and Tuatapere Community Boards.

In addition to media features and reports on the WWP, ECNZ has funded a working party newsletter called "Waiau Watch", produced by the Southland Regional Council and distributed free to all households in the Waiau River catchment and to all working party members. "Waiau Watch" includes information on WWP meetings, profiles of members and progress on environmental issues and technical reports.

5.5 Conclusion

Consultation on the Manapouri resource permits has been extensive. As a result of the enthusiastic and persevering involvement of a widely representative group, the outcome has been all that could be hoped for—a well informed basis for decision making on a nationally significant part of New Zealand's natural environment and developed infrastructure.

Chapter 6 – Issues Identification



Figure 39 – Early airing of concerns and identification of issues

The intensive consultation programme raised and addressed issues covering all aspects of the Manapouri scheme. Drawing on the collective interest and knowledge of the members of the WWP, SRC, expert advisers, special interest groups and the public, ECNZ developed a broad approach to issues identification and management.

For the preparation of this AEE, issues were identified for further investigation in the context of the Manapouri Power Scheme being an existing operation rather than a new development. Therefore, scoping of environmental effects has occurred over a longer time frame than would normally be the case with a new development.

6.1 Scoping

For an appropriate scoping of issues at an early stage, an inclusive approach was taken by ECNZ, beginning with the public consultation process via the WWP. From the initiation of this process, all available information was distributed to the WWP as a starting point for future discussions. Throughout the process, members were invited to submit those issues relevant to their concerns. When information on an issue was not available, the WWP was empowered, through their ECNZ funding, to commission studies to assist in their deliberations. The studies commissioned have utilised the best available scientific expertise (nationally and internationally) to investigate issues. Expertise from within the WWP has allowed for appropriate management and peer review of all scientific studies. Additional technical and scientific input has also been available through consultation reviews and presentations to WWP meetings.

6.1.1 Waiau Working Party

Scoping through public consultation assisted in forming study requirements. The WWP identified gaps in the information base and commissioned the reports detailed in Table 12.

Table 12 – Waiau Working Party Reports Commissioned

Information Requirements	Reports Commissioned
Aquatic Ecosystems Task Group	
Present and historical avian species and habitat distributions within the Waiau catchment to identify gaps in knowledge and determine where further study required.	A1: Avian Information from the Waiau Catchment. W.P. Chisholm 1992.
Present and historic fish species and habitat distributions within the Waiau catchment to identify gaps in knowledge and determine where further study required.	A2: Review of Fish Distribution in the Waiau Catchment, Southland. J.W. Hayes, S.F. Davis, D.J. Jellyman, I.G. Jowett 1992.
Present and historic aquatic macrophyte distributions within the Waiau catchment to identify gaps in knowledge and determine where further study required.	A3: A Review of the Aquatic Macrophytes of the Waiau Catchment. W.P. Chisholm 1992.
The impact on the Waiau River whitebait fishery of the construction of the dam at Mararoa, and the reduction in flows down the Waiau River and at its mouth.	A4: The Waiau River (Southland) Whitebait Fishery: A Consideration of the Impacts of the Mararoa Dam and Flow Diversion from the River. R.M. McDowall 1993.



Figure 40 – Whitebaiting near the Waiau River Mouth

Table 12 – Waiau Working Party Reports Commissioned *(continued)*

Information Requirements	Reports Commissioned
Flow required in the Waiau River between Mararoa weir and Borland Burn to provide for migrating trout, maintain instream habitat for adult brown trout and benthic invertebrates. Assess quality of habitat maintained by an increased residual flow.	A5: Minimum Flow Requirements for Instream Habitat in the Waiau River, Southland, from the Mararoa Weir to the Borland Burn. I.G. Jowett 1993.
Initial resource assessment of the benthic communities in the Waiau River, suggesting effects of current low-flow regulation on benthic communities and identifying more detailed studies which may be necessary for assessment of alternative flow regimes.	A6: Report on Periphyton and Invertebrate Communities in the Waiau River, February 1993. B.J.F. Biggs 1993.
Determine the native fish fauna of the estuary, mainstream and lower tributaries of the Waiau River and the impacts on populations of the reduced flows. Recommend optimum flows for native fish, especially in the upper part of the Lower Waiau River and optimise habitats in the Waiau River lagoon for all life stages of fish species present.	A7: Native Fish Populations of the Waiau River (Southland) and the Impacts of the Lake Manapouri Control Structure (the Mararoa Weir). R.M. McDowall 1994.
To assess habitat requirements of target species and how distribution and abundance may have been affected by hydro-electric power development. To determine flow requirements necessary to maintain habitats.	A8: Aquatic Birds of the Waiau River November 1993 and March 1994. P.M. Sagar. 1994.
Whitebait habitat in the Lower Waiau River, impact of river flows on habitat and options for suitable habitat protection/enhancement.	A9: The Waiau River (Southland) Inanga Spawning Survey 1994. P.J. McClelland 1994.
The passage of fish past the Mararoa weir.	A10: Fish Passage Problems and Options for Fish Passage at Mararoa Weir. C. Mitchell 1994.
Passage of migrating native fish through the Waiau River mouth.	A11: A Calendar of Fish Migrations Through New Zealand River Mouths. R.M. McDowall 1994.
The effects of Upper Waiau River flow control on aquatic macroinvertebrates.	A12: Upper Waiau Benthic Invertebrates. J. Richardson, I.G. Jowett. 1995.
Coastal Task Group	
Interactive processes between the river and coastal system, particularly in terms of mouth opening, closing and movement.	C1: Geomorphic Processes and Coastal Change in the Lagoon System, Lower Waiau River, Southland. R.M. Kirk, J. Shulmeister 1994.

Table 12 – Waiau Working Party Reports Commissioned *(continued)*

Information Requirements	Reports Commissioned
Erosion/Sedimentation Task Group	
Character and evolution of the Lower Waiau River, particularly changes to the erosion and sedimentation regime induced by flow regulation.	E1: River Reach Analysis of the Waiau River, Southland, from Mararoa Weir to Te Waewae Bay. G.J. Brierley May 1992
Literature review on shorelines of the Waiau River and catchment lakes. Identify gaps in knowledge and recommend future research.	E2: An Annotated Bibliography of the Shorelines of Lakes Manapouri, Te Anau, Monowai, Hauroko, North Mavora and South Mavora. M.B. Single 1993.
Flood history and channel adjustments relationship. Evaluate the role of flow regulation associated with hydro-electric power development on channel adjustments along the Waiau River between Lake Te Anau and Te Waewae Bay.	E3: Channel Adjustments along the Waiau River, 1946-1992: Assessment of the Impacts of Flow Regulation. G.J. Brierley, K. Fitchett 1994.
Nature and character of Lower Waiau tributaries from Pearl Harbour to Tuatapere.	E4: Reach Analysis of Waiau River Tributaries Immediately Downstream of Mararoa Weir (Lake Manapouri Control Structure). G.J. Brierley 1994.
Whitestone River characteristics and general regional setting of tributaries of the Lower Waiau.	E5: Waiau River Regional Setting and Whitestone River Reach Analysis. G.J. Brierley, A. Beveridge, A Hajnal 1994.
Primary physical characteristics of tributaries of the Lower Waiau River.	E6: Tributary Characterisation and Assessment of Tributary Impacts on Geomorphic Behaviour of Waiau River, Southland, New Zealand. G.J. Brierley, A. Beveridge 1994.
Tributary impacts of flow regulation along the Lower Waiau.	E7: Tributary Reach Analysis of Waiau River Catchment, Southland. G.J. Brierley 1994.
Hydrology Task Group	
Hydrological data currently available for the Waiau catchment.	H1: Hydrological Database Index. D.C. Riddell 1991.
Hydrological system of the Waiau catchment.	H2: Waiau River Hydrology. D.C. Riddell, H. Freestone, S. Nutting 1993.
Sourcing of Tuatapere water from the Waiau River and bore supply.	H3: Cursory Analysis of Tuatapere Water Supply data. D.C. Riddell 1993.

Table 12 – Waiau Working Party Reports Commissioned *(continued)*

Information Requirements	Reports Commissioned
Spilled water from the Mararoa weir from high lake levels (Lake Manapouri) and Mararoa River spills (turbid water).	H4: Separation of Manapouri Lake Control Spill into Mararoa River and Lake Manapouri Components. D.C. Riddell 1993.
Rising flow profile, flow attenuation and times of travel of water released from the Mararoa weir. Determine flow profile as outflow from the Mararoa weir is progressively reduced.	H5: Lower Waiau River Flow Attenuation and Times of Travel (Part A) and Flow Recession Profile and Times of Travel (Part B). D.C. Riddell 1994.
Iwi Task Group	
Tikanga Maori values of the Waiau River catchment.	I1: Tikanga Maori Cultural, Spiritual and Historical Values of the Waiau River. S. Corry, R. Puentener 1993.
National/Legal Task Group	
Integrated nature of the ECNZ generation network, unique characteristics of the Manapouri Power Station and its importance in the national network, and links to issues such as future supply, energy efficiency and electricity pricing.	N1: The Role of Manapouri Within the ECNZ Generation System. R. Howie, R. Brasell, S. Powell 1993.
Inter-relationship of various legislation which covers the water resource of the Waiau catchment.	N2: Legislation Hierarchy Report; Part A - Summary; Part B - Report. H. Talbot, R. Sommerville, A. Callaghan 1994.
Recreation Task Group	
Existing information on the recreational and tourism values/uses of the Waiau catchment.	R1: Report on Tourism and Recreation in the Waiau Catchment. M. Anderson 1992.
History of the Waiau catchment with an emphasis on post-European history.	R2: Historical Review of the Waiau River and Coastal Area. D. Day 1993
Impact of hydro-electric development on recreation in the Waiau catchment.	R3: The Waiau River Recreation Survey. G.K. Kearsley 1994.

6.1.2 Guardians of Lakes Manapouri, Te Anau and Monowai (the Guardians)

Since their inception in 1973, the Guardians have monitored aspects of Lakes Manapouri and Te Anau and the Upper and Lower Waiau Rivers. Over this time a considerable environmental database has been formed, allowing issues to be readily identified and leading to the publications described in Table 13.

Table 13 – Publications Relating to Guardians Issues

Publications
Information Requirements – Preservation of the shoreline vegetation of Lakes Manapouri and Te Anau Johnson, P.N. 1972a. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 1: Vegetation of Lake Manapouri shoreline. Proceedings of the New Zealand Ecological Society 19: 120-142. Johnson, P.N. 1972b. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 2: The lake edge flora - Habitats and relations to lake levels. Proceedings of the New Zealand Ecological Society 19: 120-142. Johnson, P.N. 1988. Lakes Manapouri and Te Anau: Vegetation resurveys. DSIR Botany Division report. Mark, A.F. 1972. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. General introduction. Proceedings of the New Zealand Ecological Society 19: 100-101. Mark, A.F.; Johnson, P.N. 1972. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 4: Recommendations. Proceedings of the New Zealand Ecological Society 19: 100-101. Mark, A.F.; Crush, J.R.; Meurk, C.D. 1972. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 3: Vegetation of the Lake Te Anau shoreline. Proceedings of the New Zealand Ecological Society 19: 143-154. Mark, A.F.; Johnson, P.N.; Wilson, J.B. 1977. Factors involved in the recent mortality of plants from forest and scrub along the Lake Te Anau shoreline./ Proceedings of the New Zealand Ecological Society 24: 34-42.
Information Requirements – Beach erosion on Lakes Manapouri and Te Anau Andrews, P.B.; McKellar, I.C. 1973. Lake Manapouri shoreline stability and the effects of lowered lake levels. Report of Geological Survey, New Zealand Department of Scientific and Industrial Research. McKellar, I.C. 1974. Te Anau lakeshore beach sediments. Report of Geological Survey, New Zealand Department of Scientific and Industrial Research.

Table 13–Publications Relating to Guardians Issues *(continued)*

Publications
Information Requirements – Beach erosion on Lakes Manapouri and Te Anau
Pickrill, R.A. 1976. Lacustrine geomorphology of Lakes Manapouri and Te Anau, New Zealand. Unpublished PhD thesis, University of Canterbury. 402pp.
Pickrill, R.A. 1978. Beach and nearshore morphology of Lakes Manapouri and Te Anau, New Zealand; natural models of the continental shelf. New Zealand Journal of geology and geophysics 21: 229-242.
Pickrill, R.A. 1978. Effects of boat wakes on the shoreline of Lake Manapouri. New Zealand Engineering 33: 194-198.
Irwin, J. 1974. Shoreline profiles of selected sites on Lakes Manapouri and Te Anau. Oceanographic Field Report No. 1. February 1974. NZ Oceanographic Institute, Wellington. 22p.
Irwin, J. 1975. Shoreline profiles of selected sites on Lake Te Anau. Oceanographic Field Report No.5. September 1975. NZ Oceanographic Institute, Wellington. 43p.
Kirk, R.M. 1985. Foreshore erosion and shoreline management: Te Anau township. Report to Electricity Division, Ministry of Energy: The Guardians of Lakes Manapouri and Te Anau: The Te Anau Community Council and the Wallace County Council. June 1985.
Kirk, R.M. 1989. Catamaran wake from the "Fiordland Flyer", on the shoreline of Lake Manapouri. Report to Guardians of Lakes Manapouri and Te Anau, March 1989.
Kirk, R.M.; Single, M.B. 1988. Beach changes on Lakes Manapouri and Te Anau 1973-1988. Report to ECNZ and Guardians of Lakes Manapouri and Te Anau 1988.
Kirk, R.M.; Single, M.B.; Guernsey, P.F. 1988. Lakes Manapouri and Te Anau: - Beach changes February to August, 1988 with special reference to earthquake-related effects on and after June 4th. Report to ECNZ and Guardians of Lakes Manapouri and Te Anau 1988.
Kirk, R.M.; Single, M.B.; Harrowfield, D.L.; McGowan, A.C. 1989. Beach changes on Lakes Manapouri and Te Anau, August 1988 to February 1989. Report to Guardians of Lakes Manapouri and Te Anau, March1989.
Kirk, R.M. 1989. Shoreline erosion, lower Waiau River (Pearl harbour to Home creek), Manapouri. Report to ECNZ.
Kirk, R.M.; McGowan, A.C. 1989. Beach Changes at Stockyard Cove, Lake Manapouri, February to December 1989. Report to ECNZ.
Information Requirements – Submerged vegetation in Lakes Manapouri, Te Anau and Monowai, in relation to an unregulated lake (Lake Hauroko)
Wells, R.D.S.; Clayton, J.S.; de Winton, M.D. 1993. The submerged vegetation of Lakes Hauroko, Te Anau, Manapouri and Monowai, Fiordland, New Zealand and effects of water level fluctuations. NIWA Hamilton report to ECNZ. No. ELE121.

Table 13 – Publications Relating to Guardians Issues *(continued)*

Publications
Information Requirements – Promulgation and refinement of the Guidelines for operating the levels of Lakes Manapouri and Te Anau Mark, A.F.; Johnson, P.N. 1985. Ecologically derived guidelines for managing two New Zealand lakes. Environmental Management 9: (4): 355-363. Mark, A.F.; Kirk, 1987. Lake levels and lakeshore erosion. In: W.N. Vant (ed.). "Lake managers handbook". Ministry of Works and Development Water and Soil Miscellaneous Publication No. 103: 215-222. Mark, A.F. 1988. Manapouri-Te Anau: Case study of its hydro-electric development from conflict to resolution. Proceedings of "Ecopolitics III" conference, University of Waikato, Hamilton, September 1988.
Information Requirements – Diversion of turbid Mararoa River floodwaters from Lake Manapouri Freestone, H.J.; Carter, B.J.; Rogers, N.C. 1991. Mararoa flood - 8/9 August 1991. Works Consultancy Services Report to ECNZ. Mills, G.W.; Freestone, H.J. 1992. Manapouri Lake Control, April 1992 Cross Section Survey. Works Consultancy Services report to ECNZ. Wellington NZ. Greer, M.L.; Freestone, H.J.; Maslin, D.C. 1993. Manapouri lake control audit, flood event and dirty water spill 5-26 October 1993. Works Consultancy Services Report to ECNZ .
Information Requirements – Refinement of operating procedures for the Lake Te Anau Control Structure ECNZ Production Control, Wellington. 1991. Proposed operating procedures for the Lake Te Anau Control Structure. Discussion document. Report to ECNZ.

6.1.3 ECNZ

Although ECNZ has input into both the Guardians and the Waiau Working Party, studies commissioned by these two organisations reflected their particular environmental concerns. Other studies relating to statutory and operational aspects of this resource consent application were therefore commissioned by ECNZ independently of these two organisations. Nevertheless, all studies commissioned by ECNZ which have been used in this AEE were promptly submitted to the Waiau Working Party and Guardians for their appraisal and further action (if necessary).

ECNZ has subsequently collated the existing body of knowledge on the catchment as part of the preparation of this AEE. This includes reports from the Waiau Working Party and Guardians and research by private organisations and ECNZ itself. In addition, ECNZ has monitored aspects of their own use of the water resource, such as lake levels, flows and discharges. Studies commissioned by ECNZ are listed in Table 14.

Table 14 – Publications Relating to Additional Issues Identified by ECNZ

Publications
Information Requirements – The effects of flow control on erosion in the Lower Waiau River channel
Duffill Watts and King Ltd 1993. ECNZ Sediment transport monitoring programme baseline survey Te Waewae reach - Way River Southland data record. Report to ECNZ.
Duffill Watts and King Ltd 1991. ECNZ Ltd Sediment transport monitoring Waiau River - Southland. Report to ECNZ.
Duffill Watts and Davis Ltd 1991. Lower Waiau River. River erosion management - Sanderson property. Report to ECNZ.
Duffill Watts and Davis Ltd. 1990. ECNZ Ltd River erosion management options C.J. Carr property Waiau River, Southland. Report to ECNZ.
Duffill Watts and Davis Ltd 1990. ECNZ River erosion management options D.B. & P.R. Stalker property Waiau River, Southland. Report to ECNZ.
Duffill Watts and Davis Ltd 1990. Waiau River. Possible erosion control options for W.K. and F.L. Allen property. Report to ECNZ.
Duffill Watts and Davis Ltd 1990. ECNZ River erosion management options R.G. Pearce estate property. Report to ECNZ.
Electricorp Production, South Island Hydro Group 1988. Lower Waiau River. Interim report. Investigations into cause and remedies for: Flood damage October/November 1988. Report to ECNZ.
Information Requirements – The effects of freshwater discharge on the marine environment of Deep Cove
Bowman, M.J.; Dietrich, D.E. 1995 The influence of the Manapouri Power Station on the circulation of Doubtful Sound, numerical model simulations. Otago University Department of Marine Science report to ECNZ.
Mladenov, P.V. 1995. Overview of research on the Doubtful Sound fiord system with an assessment of possible marine impacts resulting from increased freshwater discharge, final report. Report to ECNZ, Dunedin.
Smith, A.M.; Mladenov, P.V. 1995. Suspended sediment discharge study, Manapouri duplicate tailrace proposal. Report to ECNZ, Dunedin.
Smith, F. 1995. Structure of subtidal rock wall invertebrate communities of three reference sites in Doubtful Sound. Report to ECNZ, Dunedin.
Davies-Colley, R.J. 1995. Manapouri tunnelling project. Optical effects of construction discharges to Deep Cove, Doubtful Sound. Report on Phase I investigations. NIWA Consultancy report ELE 60208/1.
Waugh, J.R.; Devgun, M.S. 1995. Sediment input into Doubtful Sound - Natural inputs from the Lyvia River. Works Consultancy Services report to ECNZ, Dunedin.

Table 14 – Publications Relating to Additional Issues Identified by ECNZ *(continued)*

Publications
Information Requirements – The effects of flow control on groundwater resources in the Lower Waiau valley Works Consultancy Services 1994. Waiau River valley groundwater monitoring. Works Consultancy Services report to ECNZ, Dunedin.
Information Requirements – Fish passage through the Mararoa weir Rogers, N.C.; Currie, B.; Stapp, C. 1995. Manapouri Lake Control. Supplementary report on residual flows and fishpass improvements. Works Consultancy Services report to ECNZ. Rogers, N.C.; Ritchie, P.D.; Wild, M.; Webby, M.G.; Freestone, H.J. 1995. Manapouri Lake Control. Report on residual flows and fishpass improvement. Works Consultancy Services report to ECNZ.
Information Requirements – The effects of flows control on landscape resources in the Lower Waiau valley Rackham, A. 1995. Manapouri power scheme Waiau River landscape assessment. Boffa Miskell Ltd, Report to Waiau Working Party for ECNZ, Dunedin.
Information Requirements – Options for improving whitebait habitat in the Lower Waiau River Mitchell, C.P. 1994. Enhancement of whitebait habitat in the Lower Waiau River. Report to Waiau Working Party for ECNZ, Dunedin.
Information Requirements – Options for reducing the turbidity of the Mararoa Mackay, G.H. 1994. Possible origins of turbidity and suspended sediment in the Mararoa -Whitestone catchment. Report to ECNZ, Dunedin.
Information Requirements – Mahika kai values of the Waiau catchment Mitchell, C.P.; Davis-Te Maire, K.T.A. 1994. Mahika kai values of the Waiau River. Report to ECNZ, Dunedin.

Over the last 6 years, the WWP, Guardians and ECNZ have organised all the available information. The working party has then made recommendations for addressing and resolving each issue. Some of the early concerns were resolved during the consultative process. All parties now consider that there is enough information available to formulate a resolution to all the environmental effects of this resource consent renewal.

The following sections outline those issues which have been considered most important by the WWP, Guardians and ECNZ. These issues are analysed individually in Part 4.

6.2 National Issues

The National Issues Task Group of the Waiau Working Party, including members from the Southland Fish and Game Council, Department of Conservation, Tuatapere Community Board and Kai Tahu Runakanui O Murihiku, identified the following issues connected to the generation of power at Manapouri.

1. Storage of water in the lakes. More storage in the system allowed for more hydro power to be saved for use during peak load periods, thereby reducing the need to rely on thermal power generation (see Section 7).
2. Carbon dioxide emission reduction. Hydro-electric power generation was seen as "cleaner" than thermal power generation, as the emission of the greenhouse gas, carbon dioxide, did not occur (see Section 7.2).
3. The effect of the Manapouri Power Scheme and aluminium smelter on the Southland economy (see Section 7.4.2).

6.3 Issues Associated with the Damming and Discharge of Water at the Te Anau Control Structure

1. Flow manipulation of the Upper Waiau may have led to accelerated erosion of the unstable gravel riverbanks of the Upper Waiau River (see Section 9.2).
2. Reductions in the density of freshwater macroinvertebrates in the Upper Waiau River could be linked to rapid flow fluctuations in the Upper Waiau River (see Section 9.3).
3. The Te Anau control structure impedes the passage of trout and native fish into and out of Lake Te Anau (see Section 9.4.1).
4. Flow changes in the Upper Waiau River affects fish spawning. Lower flows after the spawning season could lead to dewatering of trout redds in the Upper Waiau River (see Section 9.4.3).

6.4 Issues Associated with the Damming, Diversion and Discharge of Water at the Mararoa Weir

6.4.1 Reduced Flow in the Lower Waiau River

The reduced flow in the Lower Waiau River may have:

1. Exacerbated the changes of an extended river mouth closure event. The river mouth of the Waiau River was fully closed in 1974 during completion of the Manapouri Power Scheme. The other documented river mouth closure was in April 1994. Rivermouth closure brings with it problems of flooding surrounding farmland, and preventing the migration of native fish to and from the sea (see Section 10.3.5).

2. Affected the quantity and quality of trout habitat, particularly between the Mararoa Weir and Borland Burn (see Section 10.4.3).
3. Reduced the habitat available for native fish (see Section 10.4.5).
4. Affected the habitat of aquatic birds associated with the Lower Waiau River (see Section 10.4.8).
5. Affected actual and potential recreation and tourism opportunities for the region (see Section 12.3).

6.4.2 Altered Flow Regime of Lower Waiau River

Aspects of the artificial flow regime which replaced the natural flow regime and the rate of change of flows in the Lower Waiau River were of particular concern to local residents. Artificial river flow variations were thought to affect erosion, create a safety hazard, and possibly create a flood hazard during extreme events. Specific issues related to the modified flow regime included:

1. The effect of flow reversal on fish migration and the movement of lower quality water into Lake Manapouri in an area of high tourism values (see Section 10.3.1). Flow reversal now occurs in the river reach between Lake Manapouri at Pearl Harbour, and the Mararoa Weir. Originally, Pearl Harbour was a large lake outlet for the Lower Waiau River, but it is now principally an inlet for the Mararoa River to flow into. Exceptions to this flow regime occur when the Mararoa Weir releases Lake Manapouri spill water down the Lower Waiau River, or when the Mararoa River water is released down the Lower Waiau River, in accordance with the spill rules for discoloured water, whenever turbidity exceeds 30 NTU.
2. The ability of ECNZ's water management regime to prevent flooding of the lower catchment. Two events in particular had raised concern—the flood of 1984, and the extended high flows of spring 1988 (see Section 10.3.2).
3. The implications of discharge of turbid Mararoa water from the Mararoa Weir for fisheries habitat. The "flushing" (of fine sediment and periphyton) effects of minimum flows and spill flows was considered worth investigation (see Section 10.3.3).
4. Deposition of gravel and fine sediment in the Lower Waiau riverbed, and therefore the competence of the modified river channel to pass floods. Deposition of coarse and fine sediment was observed in some river reaches, possibly causing natural diversions of the river to erosion points further downstream (see Section 10.3.6).
5. The establishment of an equilibrium where sediment (mainly gravels) had accreted at the "Mararoa delta" immediately above the Mararoa Weir and where a delta had formed at Home Creek (see Section 10.3.7).
6. Very occasional discharge of turbid Mararoa River water into Lake Manapouri when the river is in flood and Manapouri's lake level is close to its minimum.

6.4.3 Fish Habitats

Reversal and reduction of flows, the barrier created by the Mararoa Weir and the provision of a fishpass had raised the following issues:

1. Rivermouth closure caused by reduced flows created a barrier to native fish passage between the sea and the river (see Section 10.3.5).
2. Trout had been regularly seen congregating below the Mararoa Weir, mainly after a flow release from the Mararoa Weir. Releases were thought to provide an attracting flow to trout, and when the releases ended, the trout became stranded below the weir, requiring salvage. Downstream trout passage was not seen as a particular concern as these fish would be able to pass through the Mararoa Weir during a flow release (trout tend to migrate during freshes). The particular concern was the maintenance of free passage for all life stages in both upstream and downstream directions to optimise trout habitat utilisation within the catchment (see Section 10.4.4).
3. The installation of a fishpass into the Mararoa Weir in 1975 was seen as the answer to the fish passage problem. Monitoring of the fishpass between 1978 and 1981 showed that fish were using this structure to gain access to the upper catchment. The present low effectiveness of the fishpass may be a result of gravel clogging the structure and inappropriate design (see Section 10.4.4).
4. Some native fish species are obligate migrants, ie. they must migrate to or from the sea to complete their life cycle. These species include short and longfinned eels, lamprey and giant bully. The Mararoa Weir was seen as a barrier to these migrations, ultimately making habitats upstream of this structure unavailable to them. Migrating elvers had been seen congregating below the weir. Elver migrations were also thought to be affected by the diversion of the Mararoa River flow into Lake Manapouri. This reversal of flows could cause those elvers which passed through the Mararoa Weir fish pass to continue their upstream migration to the headwaters of the Mararoa catchment; to the exclusion of the Manapouri - Te Anau lakes (see Section 10.4.7).

6.4.4 Recreation

The reduction in flows through damming Lake Manapouri may have an effect on the following recreational values of the Lower Waiau River:

1. Landscapes: reduced flows, particularly in the area between the Mararoa Weir and Borland Burn, affect landscape values of the river (see Section 12.2.2).
2. Access: although reduced flows make physical access along the river somewhat easier, recreational access by boat may have suffered because of reduced flows (see Section 12.3.1).
3. Jetboating: the Waiau is the only river in Southland which has no speed restrictions for jetboating. However, reduced flows have made the river virtually unusable for jetboating except during freshes. Lower flows have also made physical access to boat launching areas more difficult (see Section 12.3.2).
4. Fishing: the effects of reduced flows on trout habitat may have adversely affected the fishing in the river (see Section 12.3.3).

6.4.5 Riparian Management

Reduced flows and flow fluctuations affect riparian management in the Lower Waiau River, specifically:

1. Wildlife habitat: weed encroachment affects wildlife habitat, particularly waterfowl species (see Section 10.4.8).
2. Weed and pest control: the exposed riverbed became a habitat for rabbits and weeds. Increased weed control (especially of willows) was required to clear growth from the exposed riverbed (see Section 12.2.1).
3. Riparian fencing and stock control: the exposed riverbed hampers stock control. Previously, the Lower Waiau River was used as a natural barrier to stock movement. Now, most of the riverbed needs to be fenced. However, large flow fluctuations make fencing the riverbed untenable (see Section 12.2.1).
4. Erosion control: the encroachment of willows and other weed species on the exposed riverbed has implications for erosion and flood control (see Section 12.2.1).



Figure 41 – Waiau Working Party inspecting riverbank erosion

6.4.6 Iwi Issues

Kai Tahu Runakanui O Murihiku representatives raised a number of issues, many of which are related to the alteration of the Lower Waiau River environment. Iwi concerns about the utilisation of the Waiau River for power generation include:



Figure 42 – Syd Cormack on the bank of the Lower Waiau River

1. The "mauri" (life force) of the river has, to a large extent, been lost. Where a river's flow has been truncated in the manner to which the Lower Waiau has, there is a corresponding loss of mauri (see Section 12.1.1).
2. Native fish and other mahika kai, the traditional foods which were gathered from the Waiau catchment, have now disappeared, partly because of agricultural development and other European modifications to the natural environment. Flow reduction and associated habitat changes adversely affect the native fish of the river, particularly eels and whitebait. Eel passage throughout the catchment is a major issue (see Section 12.1.2).

6.4.7 Tuatapere Amenities

The diversion of the Lower Waiau River at Mararoa has created changes and raised issues at Tuatapere:

1. Formerly, the town water supply was pumped from the river. After hydro development, much of the town supply needed to be gained from bore water pumps because the increased turbidity of the river water affected the town supply's water quality (see Section 12.2.3).
2. Some of the groundwater bores serving some household and stock water systems dried up immediately after hydro development (see Section 12.2.4).
3. There was a loss of the general amenity value with the change from a "big river" to a "smaller river" in the Lower Waiau River. Future opportunities for river-related industrial and tourism development at Tuatapere were reduced as a result of reduced flows. Fishing safaris and other river-based tourism developments, eg. scenic jetboat tours, were now unable to proceed. These represented potential economic loss to Tuatapere, which was exacerbated by the loss of nearby forestry development (see Section 12.2.5).

6.5 Lake Level and River Management Issues Identified by The Guardians of Lakes Manapouri and Te Anau

1. The Guardians have monitored the effects of lake level management since 1974 and found that the environmental effects of artificial lake level management centred mainly on shoreline erosion and changes to shoreline vegetation and littoral macrophyte density and diversity (see Section 8).
2. The Guardians have also been active in agreements on the setting of operating procedures for the Te Anau control gates (see Section 9.1).
3. Concerns about diverted turbid water flowing from the Mararoa River into Lake Manapouri prompted the Guardians to recommend that it be prevented (see Section 10.3.3).

6.6 Issues Concerning West Arm Powerhouse and Deep Cove Discharge

1. Most concerns relating to lake level management of Lakes Manapouri and Te Anau were considered by the WWP to have been adequately handled by the Guardians of Lakes Manapouri, Monowai and Te Anau (see Section 8).
2. Some of the eels migrating to the sea to spawn are attracted to the outlet flow at the West Arm powerhouse. Reports of dead eels in the intake screens at the powerhouse raised concerns that there could be considerable mortality of migrating spawning eels (see Section 12.1.3).
3. The additional discharge of fresh water into Deep Cove has possible effects on the overall scale of freshwater influence in the Sound (Section 11.1.1), surface flow velocities (Section 11.1.2), and subsequent effects on the biota of the Sound (Section 11.1.3).
4. A possible effect of an increase in freshwater discharge from a second tailrace is an increase in sediment inputs into the Sound (Section 11.2).

Part 4

Impact Assessment

Chapter 7 – National and Regional Importance of the Manapouri Power Scheme

The Manapouri Power Scheme is significant in terms of both its regional contribution of power to Southland and its position as the largest single contributor to the national electricity system. The considerations of local effects must be balanced with economic and environmental costs to the nation as a whole.

Total power generation from ECNZ's systems throughout New Zealand is approximately 30,000 GWh. Between 1992 and 1994 the Manapouri scheme generated on average 4,271GWh/yr, approximately 14% of the national figure. ECNZ operators base generation on both availability of water supply and demand for power, at least cost and to a secure supply standard. Full electricity supply is maintained, even during periods of low water inflow.

The Manapouri Power Station is an extremely efficient converter of water "head" to electricity. Most hydroelectric power stations operate at 60% of their maximum generation capacity (Waitaki average). Manapouri operates at 91% of its generation capacity. The other 9% is made up during periods of high inflows, indicating that there is not much storage in the system and it is largely a "run of the river" system. The total water stored within Lakes Te Anau and Manapouri has a generation potential of less than 10% of Manapouri's total annual generation.

Nationally, as the Manapouri Power Station operates on availability of water inflows, with no reliance on non-renewable energy sources, maximum use of the available water keeps financial and environmental costs well below those of thermal power generation. Any reduction in generation from the Manapouri scheme increases the requirement from other stations, with potential for an increase in the environmental costs, as well as the average cost of electricity. In the longer term, if the potential generation available from existing installed capacity is reduced by the imposition of further restrictions upon the use of water for hydro generation, then the security of supply from the existing network is reduced. This will bring forward the date when additional capacity like Taranaki combined cycle, or Tuapeka hydro projects would be required to maintain security of supply.

The proposed second tailrace tunnel will increase Manapouri's mean annual generation by 552 GWh pa to approximately 4850GWh pa and will allow Manapouri water to be used more efficiently. This will increase hydro electric generation by 3.6 percent per annum and add a potential 2.3 percent per annum to the total amount of electricity generated in New Zealand.

In summary, the Manapouri Power Scheme is an efficient use of existing structures throughout the system and of the sustainable, physical resource in terms of the amount of power generated from the volume of water used. The contribution of this resource use to the long-term benefit of New Zealand is discussed in the following sections.

7.1 National Contribution of the Manapouri Power Scheme

Manapouri is of key importance to New Zealand's electricity system, being the largest single contributor to hydro-electric generation in the country. The guidelines for operating this station are more detailed than those for any other power station in New Zealand due to the need for environmental protection in this geographically unique area. These points, coupled with the periodic high inflows of rain water into the catchment, have led ECNZ to rank the storage in Lakes Manapouri and Te Anau above all other hydro storage to minimise the risk of spilling valuable water.

The production of electricity requires that supply constantly match demand. The sizes of power stations are carefully optimised, with combinations assessed to maximise benefits and reduce risks, while allowing for planned and unexpected power station outages. A margin is also required to meet expected and unexpected variations in electricity demand. The generation system is operated to minimise costs and, if valuable hydro generation is lost from Manapouri, more expensive thermal generation must be used to replace it.

In the years 1992 to 1994, Manapouri produced on average 4271GWh/yr or 14% of New Zealand's total annual electricity demand of 29,964GWh/yr.[42] As an illustration, 0.75 cumecs of water passing through the powerhouse produces 1MW or 8.76 Gigawatt hours of electricity (continuous). Manapouri's output is equivalent to that required to supply about 512,000 households or the personal needs of about 1.28 million people on an ongoing basis, based on 1 GWh being the amount of power required to supply the needs of 120 households, assuming an average of 2.5 people per household.

The total energy gain of 552gwh/yr[43] that would be due to the second tailrace tunnel is approximately equivalent to the average annual output of the North Island hydro stations of Karapiro or Rangipo. In comparison, for the 1994 financial year, the North Island thermal station of Stratford was required to produce 490GWh of electricity.[44] ECNZ's largest station, Huntly, with an installed generating capacity of 1000MW, produced almost 19% of the total demand over the same period, or sufficient to meet the personal needs of 1.7 million people.

7.2 National Cumulative Benefits

The Manapouri Power Station contributes to an electricity generation system which is predominantly based on hydro electric power. Because of the extensive contribution that hydro stations like Manapouri make towards national electricity supply, it has the effect of making New Zealand's per capita emissions of carbon dioxide lower than would otherwise be the case. Manapouri's contribution to electricity requirements has the effect of an overall reduction of carbon dioxide discharge from that of meeting demand for electricity by fossil fuelled power stations. If the average generation were to be reduced by any agreement, replacement generation would have to come from stations further down the merit order in terms of economic and environmental efficiency. Since the marginal station is usually a fossil fuel plant, then any reduction in hydro generation results in increased emissions of CO_2. The effect of having renewable and non carbon dioxide (CO_2) - emitting generation at Manapouri is to avoid the discharge of about 2.5 Megatons of carbon dioxide per year, along with other gases such as oxides of nitrogen and sulphur, if the equivalent of Manapouri's power generation were to be provided by fossil fuel generation.

The electricity generation sector currently produces about 16 per cent, and the transport sector about 34 per cent, of New Zealand's total CO_2 emissions. New Zealand was a signatory to the Framework Convention on Climate Change (FCCC) signed at the Earth Summit held in Rio de Janeiro in June 1992. The Government continued development of its climate change policy to ensure that New Zealand met its obligations under the FCCC. Current Government policy (21 July 1994) is to return net carbon dioxide emissions to their 1990 levels by the year 2000, and hold them there, based on a joint reliance upon emission reductions and expansion of carbon storage, to enable New Zealand to stabilise net emissions. Emission reductions are expected to be achieved by a mix of additional energy efficiency actions, support for non-traditional renewable energy like wind and solar power, co-ordinated by the Energy Efficiency and Conservation Authority (EECA), and a voluntary industrial emissions reductions scheme. To reach ECNZ's target, emissions need to be reduced by a further 370,000 tonnes per year by the year 2000. The proposed second tailrace tunnel would make a significant contribution to limiting New Zealand's CO_2 emissions.

The future control of CO_2 emissions from the electricity generating sector will be significantly influenced by whether major renewable energy supply developments like the proposed Manapouri second tailrace tunnel project proceed. The second tunnel is estimated to mean an additional 552GWh of generation and a potential avoidance of 324KtCO_2/yr emissions based on the current rate of emissions from equivalent thermal power generation.

7.3 Other National Economic Benefits

The profit ECNZ makes from the generation of electrical power is paid in the form of a dividend to the shareholders, the Ministers of Finance and State-Owned Enterprises. The total profit paid to the government by ECNZ for the previous financial year of fifteen months ending 30 June 1994 was $725 million, of which about 20% is derived from the Manapouri scheme.[45] That money is used for the national benefit as a contribution to Government services and gross domestic product.

7.4 Regional Benefits

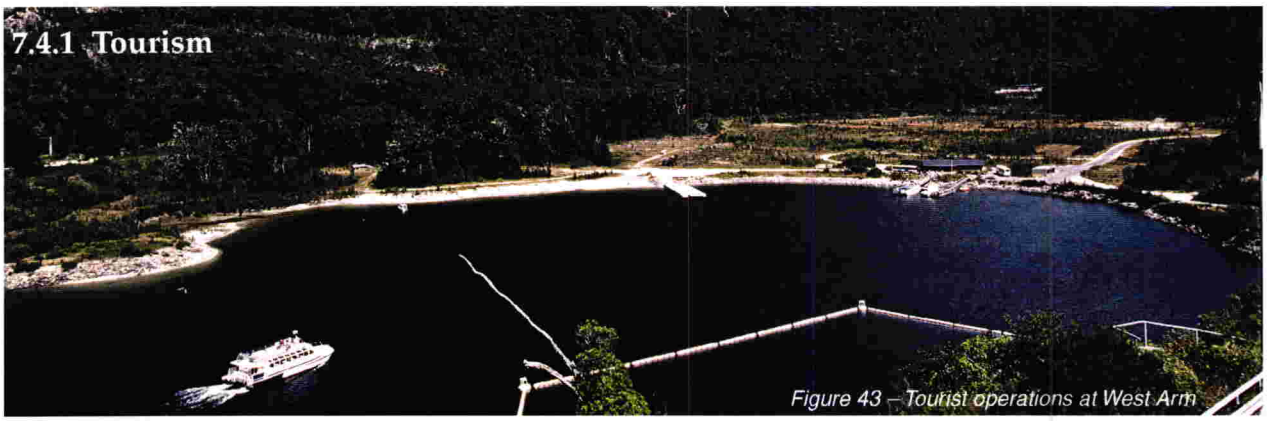


Figure 43 – Tourist operations at West Arm

The Manapouri Power Scheme, along with regional conservation strategies, has provided the Western Southland region with a significant boost in tourism opportunities and direct benefits to regional and national economies. The development of the Manapouri Power Scheme has opened Fiordland National Park to the tourism and recreational potential of West Arm, Deep Cove, Doubtful Sound and the Grebe Valley. Two major tourist operators carry up to 35,000 visitors per year on day-trips to West Arm.[46] Tourist boat operators use the boat launching facilities on Lake Manapouri at Pearl Harbour and West Arm and the power station itself is a tourist attraction. Throughout the Manapouri - Te Anau district, benefits accrue through tourist accommodation, services and transportation businesses. In general, the effects of the Manapouri Power scheme on tourism in the Manapouri - Te Anau district have been positive.

Tourism opportunities available to the Lower Waiau community before the construction of the Manapouri Power Scheme included guided fishing, white-water rafting, jet boat safaris and nature tours (particularly bird-watching near the Waiau mouth). With the proposed 12-16 cumec minimum flow into the Lower Waiau, it is expected that guided fishing opportunities on the Lower Waiau may be restored and that proposed recreational flow releases will increase the certainty of flows at specific times, allowing for better forward planning for jet boat tours and other tourist operators. Other effects on local tourism opportunities are discussed in Section 12.2.5.

7.4.2 Industry and Employment

Electricity produced at the Manapouri Power Station is supplied to the Tiwai Point Aluminium Smelter at Bluff. The smelter has the capacity to produce 260,000 tonnes of aluminium annually, with an expectation of increased production of 313,000Tpa by 1996. ECNZ guarantees provision of a total of 543MW to the smelter until 2012. The smelter dominates manufacturing in Southland, directly employing 1,100 local residents and providing further indirect economic benefits on the economy of Southland.

Electricity is also used to supply other Southland industries. New and proposed developments in dairy farming and wood processing are dependent on a continuous, cost effective source of electricity. These manufacturing industries provide further employment and maintain the region's existing infrastructure. The Manapouri Power Station employs 30 people.

Chapter 8 – Environmental Effects of Lake Control

8.1 Lake Levels

As currently managed, the levels of Lakes Manapouri and Te Anau are operated within gazetted operating guidelines (Table 15). These guidelines are based on the three most extreme high and low lake levels measured within the 32 year recorded period for natural conditions, (pre-control). The Guardians of Lakes Manapouri, Te Anau and Monowai, and ECNZ recommend to the Minister of Conservation the lake level guidelines after monitoring the lakes' shoreline erosion and vegetation condition. Such monitoring has enabled detailed assessment of changes in the lakeshore and shoreline vegetation since the inception of the Manapouri Power Scheme.

More than 60 years of reliable data on levels of the two lakes show some differences between the natural and controlled lake level regimes. Since lake control, levels have been both higher and lower than previously recorded (Figures 20, 21). The longest periods of low levels occurred during the early 1950's and early 1970's. Higher levels, resulting from the combined influence of lake control and higher than normal inflows, were recorded during the late 1970's and 1980's.[47] Extreme high levels were a result of the October-November 1988 flood of the catchment, an event too extreme for the power station operation to suppress. Low levels recorded in 1972-74, before and during the establishment of the guidelines, were a result of power station operations and are now avoided through operation of lake levels within the guidelines.

8.2 Gazetted Lake Level Guidelines

The Waiau Working Party has agreed to adopt the gazetted guidelines for the operation of Lakes Manapouri and Te Anau without alteration. This decision is based on the close monitoring of the guidelines for more than a decade by the Guardians, based on ecological principles used to protect the shoreline ecosystem. Moreover, to prevent or minimise any significant unforeseen adverse effects, the Guidelines will continue to be reviewed as provided for under the existing legislation.

8.2.1 Ecological Basis for Guidelines

Initial studies concentrated on the shoreline plant ecology of both lakes, aimed particularly at understanding the patterns of lakeshore vegetation in relation to natural lake level variation and assessing the environmental consequences of the proposed lake level changes for each lake. The vegetation zonation pattern was found to be generally similar for both lakes, with such factors as elevation, substrate, and exposure to prevailing westerly winds being significant, suggesting a dominant control by natural lake level variation. For example, analysis of hydraulic records indicated that the beech trees would probably not tolerate more than 55 days of continual submergence of their root systems, while for the shrub zone the period was up to 256 days.

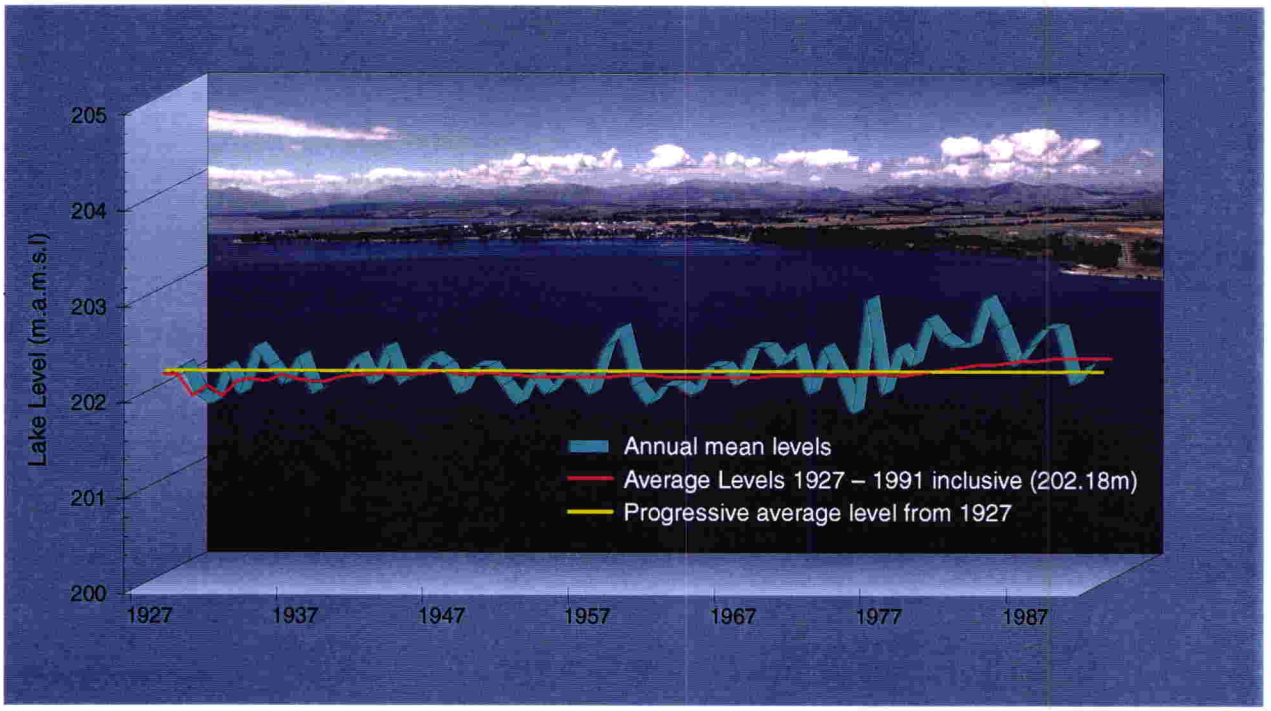


Figure 44 – Lake Te Anau Annual Mean Levels

Additional scientific studies were carried out following the decision in 1972 to operate both lakes within their natural ranges. The need to obtain a better understanding of lakeshore erosion and sediment transport processes was apparent after the collapse and slumping of localised sections of Manapouri's shoreline when that lake was lowered some 56cm below its natural minimum for the first time in August 1972. A study of the beach geomorphology of both lakes in 1976 confirmed the apparent vulnerability of the beaches, related to their glacial origin ("incompetent" sediments), combined with narrow shelves that generally graded into very steep slopes.

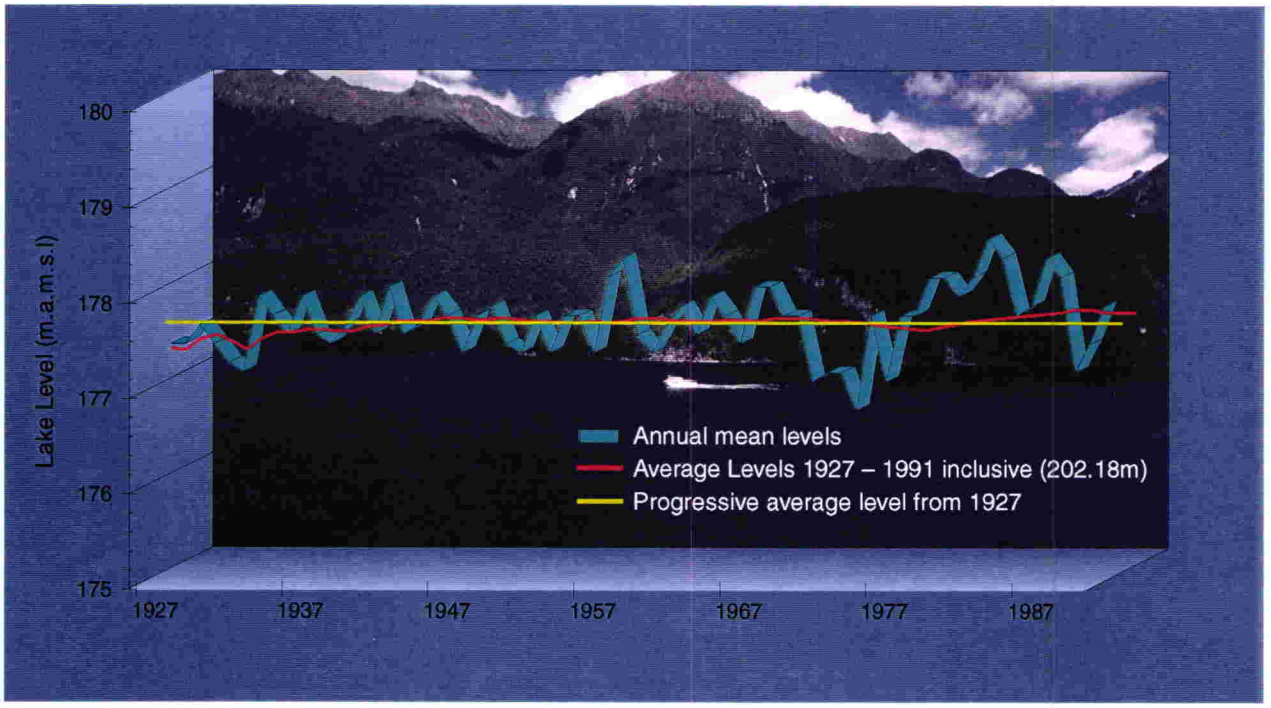


Figure 45 – Lake Manapouri Annual Mean Levels

Table 15 – Operating Guidelines for the Levels of Lakes Manapouri and Te Anau

Lake Manapouri

Main Operating Range[a] 176.8-178.6 m

High Operating Range[b] Above 178.6 m

Elevation (m)	Max duration[c]	Minimum interval between floods to this level[c]	Guideline ratio standards[d]
At 180.5	1	100	100.0
Above 180.4 & below 180.5	3	100	33.0
Above 180.1 & below 180.4	9	100	11.0
Above 179.8 & below 180.1	22	80	3.6
Above 179.5 & below 179.8	35	40	1.1
Above 197.2 & below 179.5	44	40	0.9
Above 178.9 & below 179.2	99	20	0.2

Low Operating Range[e] 175.86-176.70 m

Elevation (m)	Max duration[c]	Annual frequency
Below 176.8 & above 176.5	105	4
Below 176.5 & above 176.2	65	2
Below 176.2 & above 175.9	52	2
At 175.86	25	<1[f]

Lake Te Anau

Main Operating Range[a] 176.8-178.6 m

High Operating Range[b] Above 178.6 m

Elevation (m)	Max duration[c]	Minimum interval between floods to this level[c]	Guideline ratio standards[d]
At 180.5At 204.3	1	100	100.0
Above 204.2 & below 204.3	3	100	33.0
Above 203.9 & below 204.2	10	60	6.0
Above 203.6 & below 203.9	22	30	1.4
Above 203.3 & below 203.6	39	30	0.8
Above 203.0 & below 203.3	65	30	0.5
Above 202.7 & below 203.0	125	20	0.2

Low Operating Range[e] 200.86-201.50m[e]

Elevation (m)	Max duration[c]	Annual frequency
Below 201.5 & above 201.2	80	2
Below 201.2 & above 200.9	55	2
At 200.86	1	<1[f]

a Continuous variation in level required in this range. Long-term mean values of 177.7m (Manapouri) and 202.1m (Te Anau) to be achieved as five-year running means (but +0.4m for Manapouri and +0.1m to -0.3m for Te Anau) and also within -0.5m on an annual basis for both lakes.

b Periodic operation up to 179.8m (Manapouri) and 203.6m (Te Anau) is required to retain stable attractive shorelines. Operations above these levels if not required for this purpose.

c Continuous days.

d The guideline ratio standard is obtained as the value for minimum interval/maximum duration and is based on the historical record of natural lake levels. It application to lake level management is described in the text.

e Only in exceptional circumstances should Lake Te Anau be drawn down to 200.86m. Operation within the low range must not exceed natural rates of drawdown, that is, 0.05m/day for Lake Manapouri or 0.03m/day for Lake Te Anau (both averaged over four days).

f Exceptional circumstances only with the best endeavours to avoid equinoctial periods (March, April, October and November), when storms are common.

8.2.2 Basic Elements of Operating Guidelines

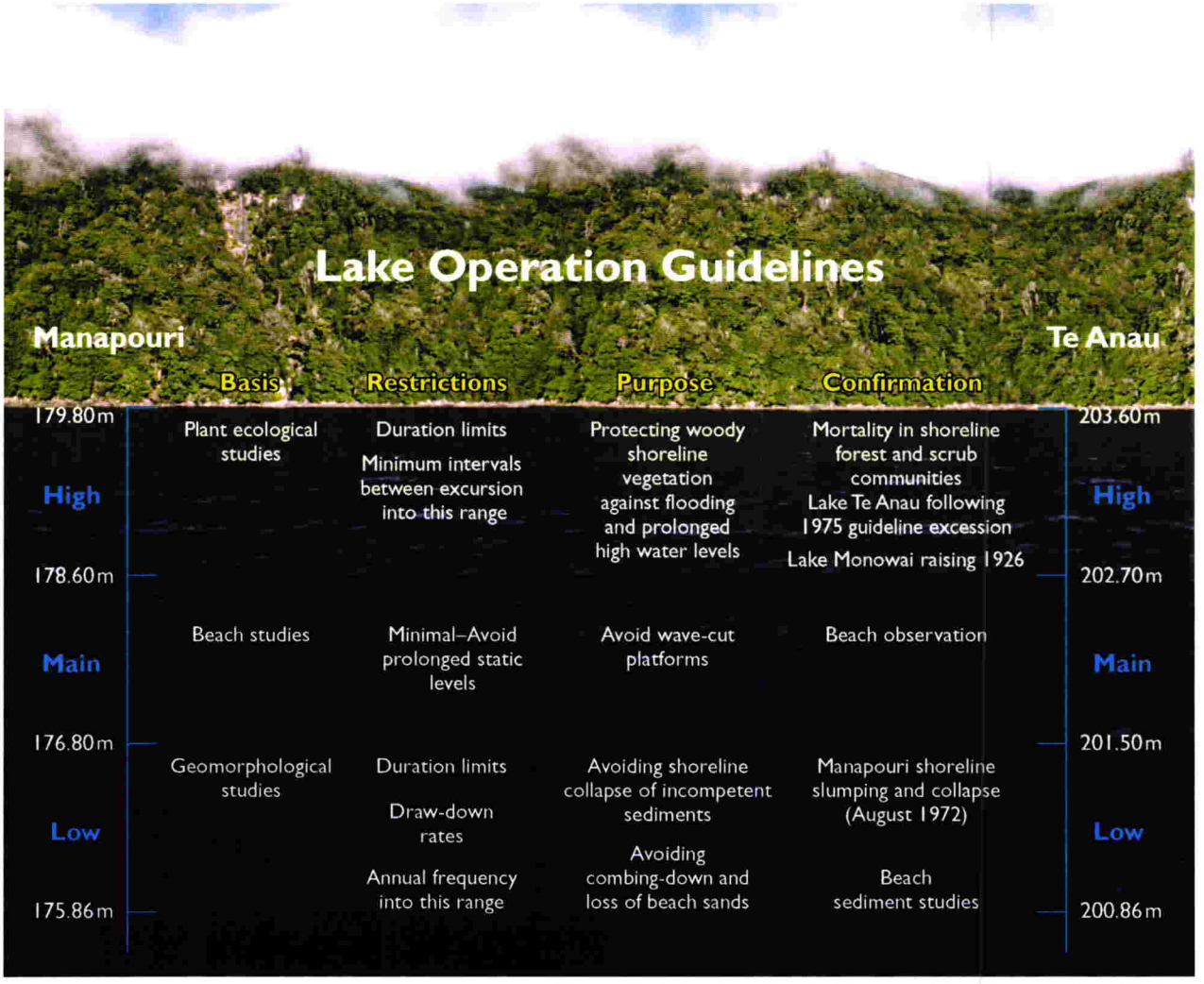


Figure 46 – Lake Operating Guidelines – Lakes Manapouri and Te Anau

The separate problems of high and low lake levels within the lake's natural ranges clarified the Guardians' need to recognise three categories of lake level operation in order to retain ecological stability of the shorelines. These categories have been termed the "high", "main" and "low" operating ranges.

In the "high" operating range, problems were associated with the death of woody vegetation when the root immersion tolerance limits of its species are exceeded by either direct flooding or prolonged high water tables. Two significant factors were identified.

(a) the maximum period at any particular level

(b) the minimum interval between periods at any particular level that would allow adequate drainage of water tables.

Values for both of these factors were derived from what had been experienced naturally during the three wettest of the 32 years for which detailed records were available.

Verification of these high range guidelines came as a result of exceptionally high inflows in March 1975. At the time of the initial storm, there was some delay in opening the gates controlling Lake Te Anau outlet in an attempt to protect vulnerable earthworks at the Mararoa Weir site, then under construction. Subsequently, guidelines for the high operating range were exceeded for both lakes when high levels occurred for unnaturally long periods. The resulting damage to shoreline vegetation was only locally conspicuous and could not be considered serious, but it was significant in confirming the reliability of the guidelines for the high operating range.

The "main" operating range is that range between the high and low ranges where there are no operating limitations apart from recommended fluctuations to prevent development of wave-cut platforms on gravel beaches.

In the "low" operating range, the stability of shoreline sediments and possible impairment of recreational and amenity values are the important considerations. The guidelines provide maximum rates of drawdown and durations at particular levels as well as absolute minimum levels. The guidelines originally also provided for annual frequencies for incursions to each level, although this provision has been modified subsequently.

The important trout fishery of the lakes and the invertebrate fauna of the lakeshores were thought not to require special consideration since the lakes were to be operated within their natural range. The trout feeding beds of submerged aquatic plants, being below the natural minimum levels of the lakes, were also expected to be unaffected (see Section 8.5).

8.2.3 Monitoring by Guardians

The Guardians have implemented a programme of periodic monitoring of the representative areas identified as being significant in development of the guidelines. Initial shoreline surveys conducted by Johnson in 1972 were repeated in 1988. The shoreline surveys carried out by Pickrill in 1976 and 1978 were repeated by Kirk in 1985 and 1989, with the establishment of permanent survey transects. Further refinements include a survey of littoral macrophytes by Wells et al in 1993 and the extension of all three programmes to include comparative surveys of Lake Hauroko as an unmodified "control".

It is concluded to date that there are no discernible significant adverse effects of the operating regime on the beach morphology, vegetation or macrophytes of the two lakes since the introduction of the guidelines.

Monitoring of these important environmental factors will provide the necessary information for ongoing management of lake levels to optimise ecological sustainability and power generation. Reviews of the gazetted guidelines will take place under the provisions of the relevant existing legislation.

The following sections discuss, in more detail, the issues, studies and management action taken by the Guardians to protect the fragile lakeshore ecosystems and the recommended future management to ensure their sustainability.

8.3 Lakeshore Erosion

Issue: Lake level management has the potential to cause lake shore erosion with damage to the fragile shoreline ecosystem and disruption of recreational use of the lake.

Discussion: Studies indicate that shoreline stability is a complex mix of wind, wave and lake level events. Low lake levels have the greatest effect on shoreline stability by exposing the shoreline to excessive erosion and movement of beach sediments. This can result in the loss of beach sediments to deeper waters by transport over the narrow submerged shelf edges that border the beaches.[48,49,50]

Some shoreline changes were reported on Lake Manapouri during the early stages of operation when water levels were lowered somewhat below their natural range. Sections of the shore in Surprise Bay and Lookout Beach slumped and collapsed in August 1972 when the lake was lowered 54cm below its natural minimum.[51]



Figure 47 – Beach slumping caused by low lake levels

There appears to be a positive link between the lake level range and the volume of beach sediment involved in active reworking, with fluctuations in lake levels having a greater influence on erosion around Lake Manapouri than on Lake Te Anau. As there is no information about trends of shoreline behaviour on either lake under natural conditions, it is not possible to assess changes in beach behaviour. The gazetted guidelines stipulated by the Guardians have taken this into account, but it is expected that ongoing erosion/accretion will not be greater than that caused under natural conditions. Kirk and Single (1988) concluded that the gazetted guidelines, as implemented by the Guardians, have adequately achieved their management aim.

One-off events may play a much larger part in shaping the character of the lakeshore than ongoing small variations in lake levels. An earthquake centred on North Fiord, Lake Te Anau on 4th June 1988 registered a Richter magnitude of 6.5. The effects of this earthquake included a loss of beach by mass-movement to deeper water, changes to the elevation of beaches, and rilling and erosion resulting from water movements during the earthquake. It is apparent that some accelerated beach erosion is caused by tectonic events occurring regardless of, and probably not exacerbated by, the gazetted guidelines selected.[52]

The effects of large floods on shoreline erosion have also been assessed.[53] Sustained high rainfall and flooding during November 1988 resulted in appreciable shoreline erosion at higher than usual elevations. Damage to services and infrastructure occurred at both Manapouri and Te Anau townships. However, while there was evidence of shoreline erosion on both lakes after this event, beaches had sustained little long-term damage except on those most exposed to westerly winds.[54] Indeed, many beaches had gained sediment as high lake levels eroded the higher level backshore deposits back onto the beaches. While every attempt is made to maintain the lake within the guidelines, exceedences cannot always be prevented when large storms and floods occur. This is accepted within the principles of lake level management.

Monitoring of shoreline erosion transects around the Te Anau township has shown that foreshore erosion is part of an ongoing natural process.[55] Change in the pattern of lake levels is by no means the only or largest contributor to erosion along the Te Anau shoreline. Recommendations for preventing excessive erosion of the Te Anau shoreline do not involve varying the current lake level guidelines.

Conclusion: Shoreline erosion can occur through extreme high or low lake levels, and as a result of tectonic activity. Ongoing monitoring has determined that, excepting the period 1972 - 1974, erosion has not been exacerbated by lake level control.

Future Management: Lake levels will continue to be maintained within the gazetted guidelines promulgated by the Guardians. Monitoring of shoreline vegetation and sediment erosion transects will continue, to ensure that lake level guidelines can be accurately specified to avoid any significant effects on shoreline environments. A monitoring programme is proposed to take measurements every five years, and after specific high or low lake level events (see Appendix IV).



Figure 48 – Inspection of Lake Manapouri shoreline

8.4 Shoreline Vegetation

Issue: Natural lake shore vegetation develops over a long time period in relation to the natural variation in lake level. Excessive immersion, exposure and desiccation of root systems, caused by artificial lake level changes, can be detrimental to the shoreline vegetation and alter the natural pattern of plant zonation.

Discussion: Ongoing shoreline vegetation surveys since 1972 have provided an understanding of the patterns and processes of lakeshore vegetation and its zonation. Survey results, along with beach morphology studies and over 37 years of daily lake level records, have been used to set ecologically-derived guidelines for the operation of lake levels to protect the shoreline vegetation. For each lake, high, main and low operating ranges were recognised, each amounting to about one third of the natural variation in the level of each lake (3.5m for Lake Te Anau, 4.8m for Lake Manapouri).

In the high operating range, problems are associated with the death of plants through flooding or prolonged high water tables. The high operating ranges therefore define the maximum duration at a particular level and the minimum interval between periods of high levels (to achieve drainage and root aeration) to satisfy the ecological requirements of the shoreline's forest vegetation. The Guardians also recommended periodic operation of the lakes up to levels close to their natural maxima to prevent encroachment of woody vegetation and thereby retain stable and attractive shorelines.

In the low operating ranges the stability of shoreline sediments and possible impairment of recreational and amenity values were the important considerations. Guidelines were set for:

- Rates of drawdown—to prevent slumping of fine glacial till underlying the limited areas of natural beaches.
- Maximum durations at particular levels—to prevent combing down of beach sediments to levels where they could be irretrievably lost.

The main operating range is defined as the range between the high and low ranges where there are no operating limitations. This range has few restrictions. However, fluctuations in levels are required to prevent development of wave-cut platforms and associated "mini-cliffing" (see Figure 49).

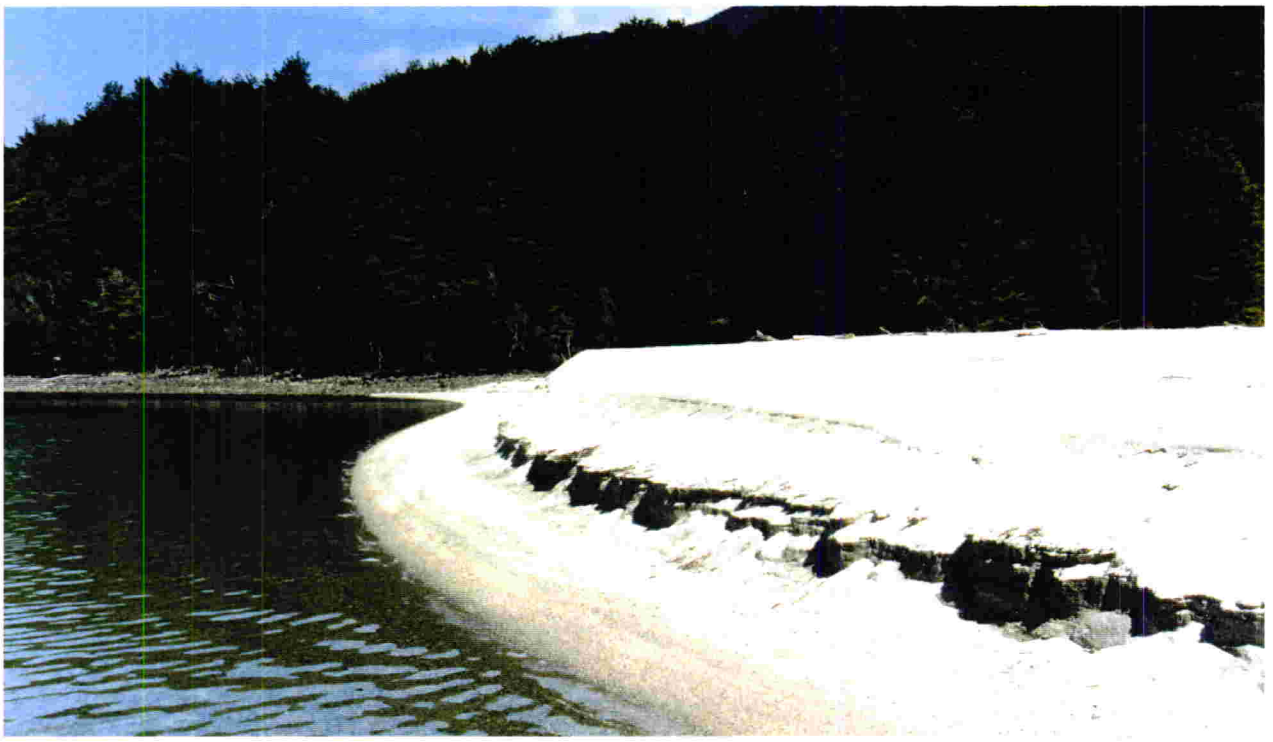


Figure 49 – Wave-cut platforms and mini-cliffing caused by steady lake levels

The guidelines have been substantially verified in practice and through observations and detailed scientific assessment.[56] Monitoring of shoreline vegetation at both lakes since 1973 has generally confirmed achievement of the lake management objectives, although some minor refinements of the guidelines were adopted in 1990.

Conclusion: Monitoring lakeshore vegetation has allowed the Guardians to develop lake level management guidelines to avoid the adverse effects of lake level control on the lakeshore vegetation.

Future Management: Lakeshore vegetation is protected by continued operation of lake levels within the gazetted guidelines promulgated by the Guardians. Monitoring of the vegetation and shoreline stability of Lake Te Anau, as prescribed by the Guardians, will continue. It is proposed that this monitoring will be done every five years, and after specific high or low lake level events (see Appendix IV).

8.5 Aquatic Macrophytes

Issue: Littoral macrophytes (aquatic plants along lake margins) can be susceptible to dewatering during prolonged periods of low lake levels. They are also damaged as a result of habitat loss or smothering through excessive shoreline erosion. These plants provide an important habitat for macroinvertebrates, native fish and juvenile trout.

Discussion: The species diversity, depth range and abundance of submerged vegetation, as well as signs of underwater erosion in Lakes Manapouri and Te Anau, have been examined and compared with Lake Monowai and (unregulated) Lake Hauroko. Species diversity and abundance were similar in all four lakes, with any differences attributable to factors other than water level fluctuations.[57] The depth ranges and abundance of plants in the shallows of each lake were commensurate with natural water level fluctuations of approximately 2.5-4.5 metres.

Conclusion: The lake level guidelines set to avoid the effects on shoreline vegetation and erosion have similarly avoided adverse effects on the submerged vegetation. It is expected that native fish and macroinvertebrates will correspondingly remain unaffected. Aquatic macrophytes are protected by continued operation of lake levels within the gazetted guidelines promulgated by the Guardians.

Future Management: Monitoring of the existing submerged vegetation transects will continue under a proposed five yearly programme, and after specific high or low lake level events (see Appendix IV).



Figure 50 – Isoetes with Milfoils



Figure 51 – Southern Crested Grebe (Podiceps cristatus australis)

8.6 Aquatic Birdlife

Issue: Lake level management may have an impact on bird habitats.

Discussion: Scant information is available on the distribution of birds on Lakes Manapouri and Te Anau.[58] (see Table 11). However, the lakes are known to be particularly important as overwintering habitat for aquatic birds forced out from the Fiordland's hinterland by the winter's cold.

Steady declines have been noted in once numerous populations of native birds in the fiord district, but these declines began long before the advent of the Manapouri Power Scheme. Some birds show a decline throughout New Zealand, which may be due to factors such as predation by introduced mammals, loss of riparian vegetation and disturbance by humans. There is little evidence to suggest that lake level management is a factor in the decline of aquatic birdlife, as lake levels are not managed outside their natural range. Indeed, it would be difficult to assess whether lake level management within the natural range, and within the constraints of the gazetted guidelines, could have an adverse effect on birdlife.

Conclusion: While the lakes provide important overwintering habitat for birds, it is most unlikely that lake level management within the current gazetted guidelines has any adverse effects.

Chapter 9 – Environmental Effects of Flow Control on the Upper Waiau River

9.1 Te Anau Control Gate Operating Procedures

Gate operating procedures at the Te Anau control gate have been set by ECNZ in agreement with the Guardians and the Southland Fish and Game Council (SFGC)[59] to control the effects of flow control in the Upper Waiau River on instream fauna and on river users, and to keep changes as close as feasible to those which happen naturally. The procedures were designed to avoid dewatering of spawning redds and minimise rapid fluctuations in flows while maintaining the lake level regime specified in the gazetted guidelines.

To achieve these objectives, the Te Anau gates are operated to meet the following criteria:

- Rate of change
  - for flows below 180 cumecs, the total reduction in flow during any calendar day shall not exceed 20% of the mean flow for the previous calendar day
  - for flows between 400 and 180 cumecs, the reduction, on the same basis as above, shall not exceed 30%
  - subject to the above, hourly rates of change are restricted to a maximum of 20 cumecs
- Flows may not be both increased and decreased during the same calendar day, unless required to meet the gazetted guidelines.
- If lake inflows are low, flows below 115 cumecs are only released with the prior agreement of the Guardians and in consultation with SFGC and iwi.
- Flows below 80 cumecs will only be released when requested in writing by the SRC.
- Spring flows are held at the same level or greater than the flows in late winter.

This revised flow regime offers an enhancement from the natural situation, in that extreme low flows that have occurred naturally (down to 53 cumecs) are avoided whenever possible by augmentation from lake storage. However, flow management in the Upper Waiau River is contingent upon there being sufficient water in Lake Te Anau to provide a specific flow without breaching the gazetted guidelines set by the Guardians to preserve the lake ecosystems.

To prevent or minimise any significant unforseen adverse effects, the rates of change and fluctuations of flow will be made conditional to a review. It is proposed that the SRC be empowered in terms of the RMA to review the rates of change and fluctuations of flow within 6 months of receiving a report from the Waiau Working Party recommending review.

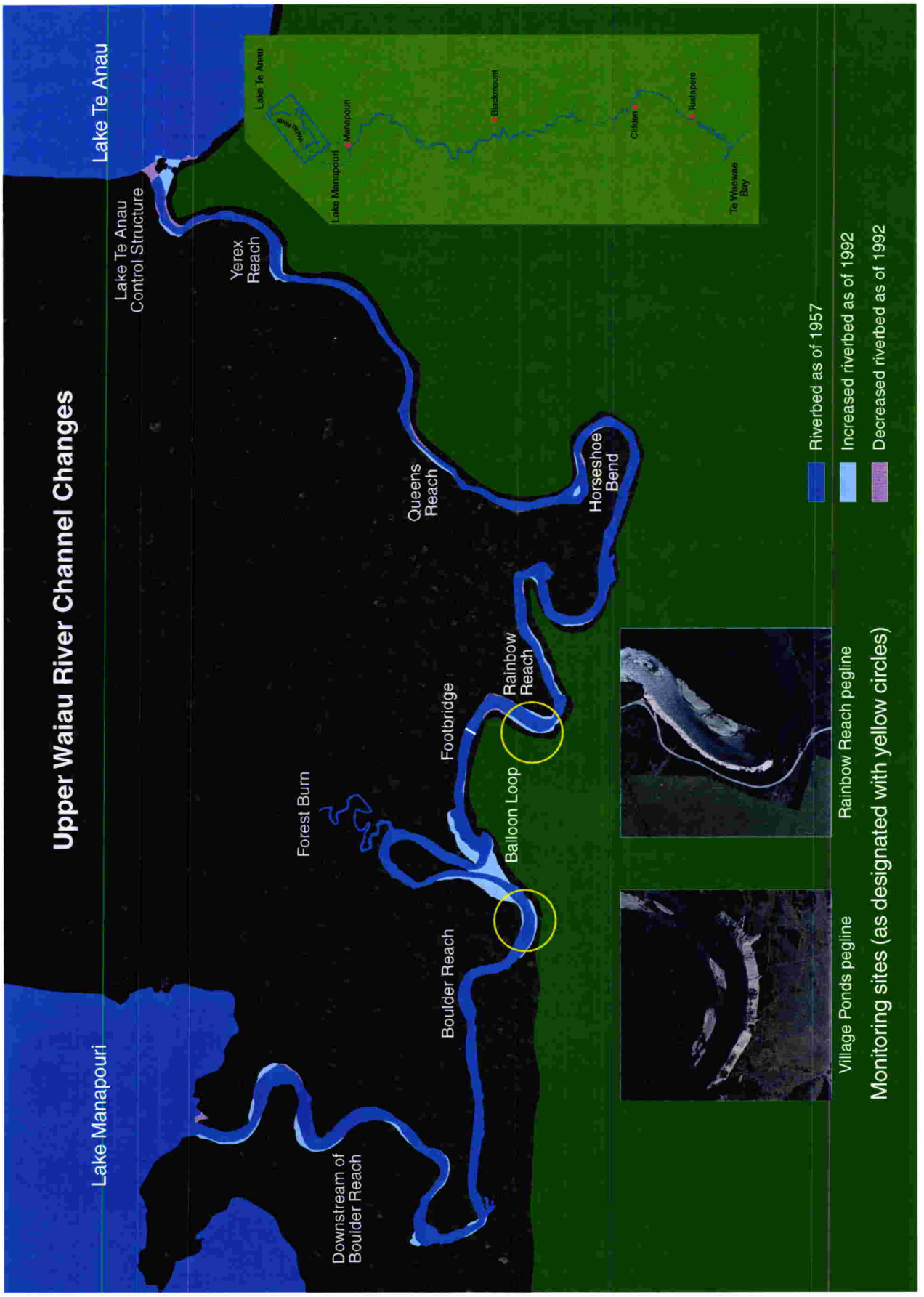


Figure 52 – Upper Waiau River channel changes (from Brierley 1994)

9.2 Erosion and Sedimentation

Issue: The river reach containing the Lake Te Anau outlet is deeply incised into loosely formed, easily eroded glacial outwash gravels. Possible effects of artificial control on erosion rates in the Upper Waiau River have been considered.

Discussion: Channel changes on the Upper Waiau evident between 1957 and 1992 are shown in Figure 52[60] and indicate that:

- Construction of the Lake Te Anau control structure moved the lake outlet 100m to the east. Some sediment deposition has occurred on the lakeshore adjacent to the structure.
- Significant trimming of the bend upstream of the Kepler Track footbridge has occurred.
- A tight gooseneck meander (Balloon Loop) at the confluence with the Forest Burn has been closed off.
- Three bends immediately upstream of Lake Manapouri have expanded laterally (up to 50m).
- The Lake Manapouri delta has extended.

Erosion in the Upper Waiau is mainly caused by the high velocity and duration of floodwaters and the rate of recession. It is only the latter which can be avoided through flow control by the gate operating procedures.

Erosion between 1977-1992 was most prominent in the Yerex reach, Balloon loop and "downstream of Boulder" reaches. Such erosion almost certainly reflected the floods during the 1980's, especially the October/November 1988 flood which exceeded 1000 cumecs for several days.[61] The high terrace gravel banks significantly increased the volumes of eroded material and influenced accumulation on the river bed and delta development in Lake Manapouri. Gravel extraction and blasting at the Balloon loop gooseneck in 1965 were identified by Brierley (1994a) as possibly having some impacts on erosion.

Conclusion: Erosion is caused by floods, and possibly gravel extraction and blasting. Brierley (1994a) concluded that riverbank erosion and flow management in the Upper Waiau would require further study before any links could be determined. Ongoing monitoring correlated to flow releases from the Lake Te Anau control structure, was recommended. The gate operating procedures in place control erosion by ensuring rates of change closer to the natural hydrograph.

Future Management: ECNZ will continue to monitor the extent of bank erosion at Rainbow Reach and "Village pond" using photographic transects (see Appendix IV). Monitoring will be linked with the flow regime to identify conditions that may exacerbate erosion.

9.3 Macroinvertebrates

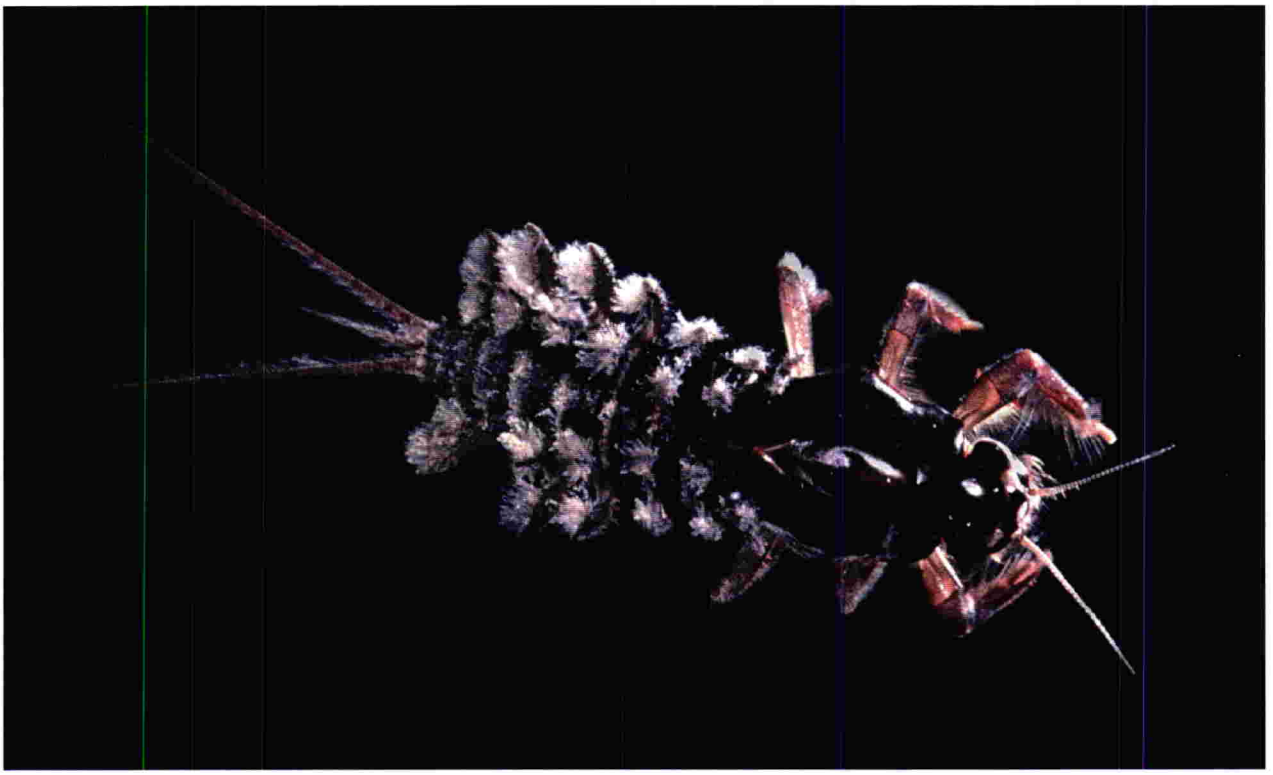


Figure 53 – Mayfly nymph (Coloburiscus humeralis)

Issue: Lake outlet streams typically have large numbers of filter feeding macroinvertebrates which construct nets to catch drifting plankton. These may be adversely affected by rapid flow fluctuations.

Discussion: Extreme flow fluctuations can reduce macroinvertebrate abundance to low levels (less than 200/m^2) However, the existing Te Anau gate operating procedures are designed to prevent rapid changes in flow. The Upper Waiau River had macroinvertebrate densities of 1200-400/m^2 in 1995, comparable to those commonly found in other large rivers and at lake outlets.[62]

Conclusion: Current evidence suggests that the present Te Anau gate operating procedures prevent rapid flow fluctuations and there is no adverse effect on macroinvertebrates.

9.4 Native and Introduced Fisheries

9.4.1 Native and Introduced Fish Passage

Issue: Prior to the construction of the Lake Te Anau control, the lake's outlet had been identified by the Southland Fish and Game Council as a significant spawning area for brown and rainbow trout. Currently, the upper 5kms of the Waiau provide a significant spawning area for these fish. Concern has been expressed that trout and native fish access to this area from Lake Te Anau may be affected by the operation of the control gates.

Discussion: The effects of the Te Anau control gates on fish passage have been investigated by the SFGC. Calculations of flow velocities at the gates were made, along with known fish swimming speed and endurance (Table 16). These data reveal that native fish without climbing ability and trout up to about one year old may not be able to swim upstream through the gates. Conversely, trout over one year old (100mm), and native fish with climbing ability are less affected. Recruitment of fingerling trout into Lake Te Anau from the spawning areas of the Upper Waiau will probably not be reduced, as emerging trout fry tend to migrate downstream to juvenile rearing areas.[63] Those native fish which may not be able to pass upstream through the control gates include bullies, smelt and koaro. These species should not be adversely affected as they can successfully establish landlocked populations in Lake Te Anau.[64]

Table 16 – Fish Maximum Swimming Speed and Endurance

					Temperature
Fish length (mm)	100	150	350	500	
Endurance (secs)	3.0	3.0	30	60	10 °C
Endurance (secs)	0.5	1.5	20	35	15 °C
Max. speed (m/sec)	1.3	1.6	2.5	3.4	10 °C
Max. speed (m/sec)	1.7	2.1	3.2	4.3	15 °C
Note: Velocities at the Te Anau Control Gates range from 1.6 to 4.5m/sec. Each of the 3 gates is 12.2 metres wide.					

The Te Anau Control Structure does not appear to affect the upstream or downstream passage of eels. Equal densities of long and short-finned eels have been found above and below the control structure. Although most eels were older than the control structures, it has been concluded that the Mararoa Weir would present more of a barrier to upstream migration than the Te Anau Control Structure. For downstream-migrating eels (heke), the risks of passage through the control gates are considered small.[65]

Conclusion: The Te Anau control gates may restrict the passage of juvenile trout and some smaller native fish. Although this is not expected to adversely affect these fisheries as a whole, a native fishpass would ensure their sustainability in Lake Te Anau.

Future Management: A native fish pass will be installed on the Te Anau control structure to assist the passage of elvers and smaller native fish (smelt, koaro and bullies) (see also Section 10.4.7).

9.4.2 Trout Fisheries

Issue: Creel census data from the Southland Fish and Game Council indicate that the size and numbers of trout in Lakes Te Anau and Manapouri have diminished over the period 1972-1994.



Figure 54 – Brown Trout

Discussion: The reason for the decline in the lake fisheries is unknown. Limited drift diving and creel census data and anecdotal evidence from the Southland Fish and Game Council, suggest the Manapouri Power Scheme probably enhances the Mararoa River, Lake Manapouri and Lower Waiau River rainbow trout fishery, as flow reversal of the Mararoa River provides a lake suitable for rearing juvenile rainbow trout.

The lakes are typical low-productivity, backcountry trout fisheries. Their sports fisheries are dependent on both maintenance of suitable habitats and control of harvest.[66] To date, no comprehensive fish population surveys or studies have been done on these two lakes or the Waiau River. Therefore, a baseline is required for monitoring the response of native and introduced fish in the lakes to any fisheries enhancement measures and variation in habitat.

Conclusion: Detailed information on the status of the lake trout fisheries is lacking. There is no evidence that the Manapouri Power Scheme adversely affects the fishery. The operation of the lakes in the natural range and no discernible change in macrophyte beds support the premise that there is no adverse effect on trout fishery. There is some anecdotal evidence that the power scheme enhances the rainbow trout fishery of Lake Manapouri, the Mararoa River and the Lower Waiau River.

9.4.3 Trout Spawning

Issue: The Te Anau Control Structure may impede the natural patterns of lake outlet spawning by trout, and flow control has the potential to expose trout spawning redds. The latter is of primary concern during the spawning season of May to November, especially when higher river levels in the early spawning months may influence the number of redds dewatered during lower levels late in the year.

Discussion: In the North and South Mavora Lakes, trout regularly spawn immediately downstream of the lake outlets. The Southland Fish and Game Council reports that the same occurs in the Te Anau outlet, with very large fish regularly seen spawning downstream of the Te Anau Control Gate during the spawning season.[67] This spawning habitat at the lake outlet, with large gravels and clear water is used exclusively by larger trout and is considered to be valuable to the lake fishery. It is most important to a fishery that the larger trout spawn successfully. There is evidence that eggs from larger fish produce larger fry and hence larger fish at maturity.[68] During the spawning season (May - June), the river is held low to restrict the area where redds can be laid, ensuring that dewatering of redds after spawning is unlikely.



Figure 55 – Dewatered trout redd, as occured prior to modifications of the control gate operating procedures

Conclusion: The control gates do not impede the passage of large trout to the important lake outlet spawning grounds. During the trout fry emergence period, flows need to be equivalent to or greater than those during the spawning period.

Future Management: The current control gate operating procedures, designed to avoid dewatering trout spawning redds, particularly during the trout fry emergence period, will remain in place. The gate operating procedures will be further optimised if dictated by the results of monitoring by the Waiau Fisheries Trust.

Chapter 10 – Environmental Effects of Flow Control on the Lower Waiau River

10.1 Introduction

The Lower Waiau River was once a "big river", but, diversion of water for the Manapouri Power Scheme has resulted in a significant reduction of flow. Therefore, ECNZ proposes to instigate a new flow regime designed to adequately avoid, remedy and/or mitigate these effects while allowing the Manapouri Power Scheme to continue to provide electricity in an environmentally sustainable manner.

10.2 New Flow Regime

The results from reports on the environmental effects of the lower mean flow in the river below the Mararoa Weir indicate that the identified environmental effects of the present flow regime need to be remedied and/or mitigated. The challenge has been to design a flow regime which provides for a sustainable river ecosystem and addresses the community values of the Lower Waiau River; and then instigate a monitoring program which ensures the new regime is achieving those results.

After extensive community consultation and careful assessment of scientific studies, a new flow regime is proposed:

- A continuous flow immediately downstream of the Mararoa Weir of at least 12 cumecs.
- Variations in flow with a minimum flow of 12 cumecs from 1 May to 30 September, 14 cumecs in April and October, and 16 cumecs at all other times.

  The basis for setting these minimum flows includes the significant enhancement of fisheries habitat, reduction of nuisance algal growths, improvement of water quality and the restoration of aspects of the river landscape.
- Recreational flows released on the fourth Sunday in each month between October and April (7 flows per summer) of 35 cumecs for 24 hours to allow the flow to continue through daylight hours.
- A "flushing" flow of at least 35 cumecs for 24 hours on one occasion in each of the months of June and August.
- One "River mouth opening flow" per year of at least 150 cumecs for 24 hours, if required, during autumn (March, April, May) and spring (September, October, November), the provision of which will be subject to compliance with the guidelines.

To prevent or minimise any significant unforseen adverse effects, the minimum flow regime of 12 to 16 cumecs will be made conditional to a review. It is proposed that SRC be empowered in terms of the RMA to review the minimum flow regime within 6 months of receiving a report from the Waiau Working Party recommending review.

Section 12.4 sets out and describes agreements entered into between ECNZ and the WWP to further mitigate the effects of flow control.

10.3 Physical Effects

10.3.1 Flow Reversal at the Mararoa Weir

Issues: Diversion of the Mararoa River into Lake Manapouri was thought to affect:

(i) water quality of Lake Manapouri, particularly around Pearl Harbour, a significant tourist area

(ii) elver recruitment into Lake Manapouri as elvers passing over the Mararoa Weir may only follow the positive flow up the Mararoa River, thereby avoiding the Lake Manapouri catchment

Discussion: The diversion of the Mararoa River into Lake Manapouri reverses the flow in the river reach between Lake Manapouri (at Pearl Harbour) and the Mararoa Weir. Originally, Pearl Harbour was the outlet from Lake Manapouri to the Lower Waiau River, but is now principally an arm of the lake. Exceptions to this flow reversal occur:

(i) when high lake levels require the release of water from Lake Manapouri into the Lower Waiau River

(ii) when the Mararoa River is released down the Lower Waiau River because of turbidity exceeding 30 NTU.

Flow releases through the MLC have not always prevented turbid water from entering Lake Manapouri when its level is low. In large floods the Mararoa River flow can completely suppress outflow from Lake Manapouri, in addition to flowing down the Lower Waiau. This recently occurred on the 8-9th August 1991 when Mararoa flood water still flowed into Lake Manapouri (which was within 44cm of its minimum operating level) even though the spillway gates at the Mararoa Weir were fully open.[69]

As part of a catchment-wide mahika kai study, Mitchell and Davis-Te Maire (1994) compared the distribution of eels in the Mararoa catchment with the Upper Waiau catchment. They found similar densities of younger age-class eels in both catchments and concluded that the reversal of flows at the Mararoa Weir had not excluded migrating elvers from the Upper Waiau catchment. Native fish monitoring proposals outlined in Appendix IV will confirm this over time.

Conclusion: The water quality of the Mararoa River at normal flows is considered to be "generally high",[70] therefore, diverting the Mararoa at normal flow is not expected to adversely affect the water quality of Lake Manapouri nor elver recruitment into the lake.

Future Management: Native fish monitoring outlined in Appendix IV will be able to confirm whether elver recruitment into Lakes Manapouri and Te Anau continues. Measures taken to prevent turbid water entering Lake Manapouri will continue through gate operating procedures which require water to be released when the turbidity of the Mararoa River exceeds 30NTU.

10.3.2 Flood Control

Issue: The water management regime may not prevent flooding in the lower catchment. Two events in particular are of note–the flood of 1984, and the extended high flows of spring 1988.

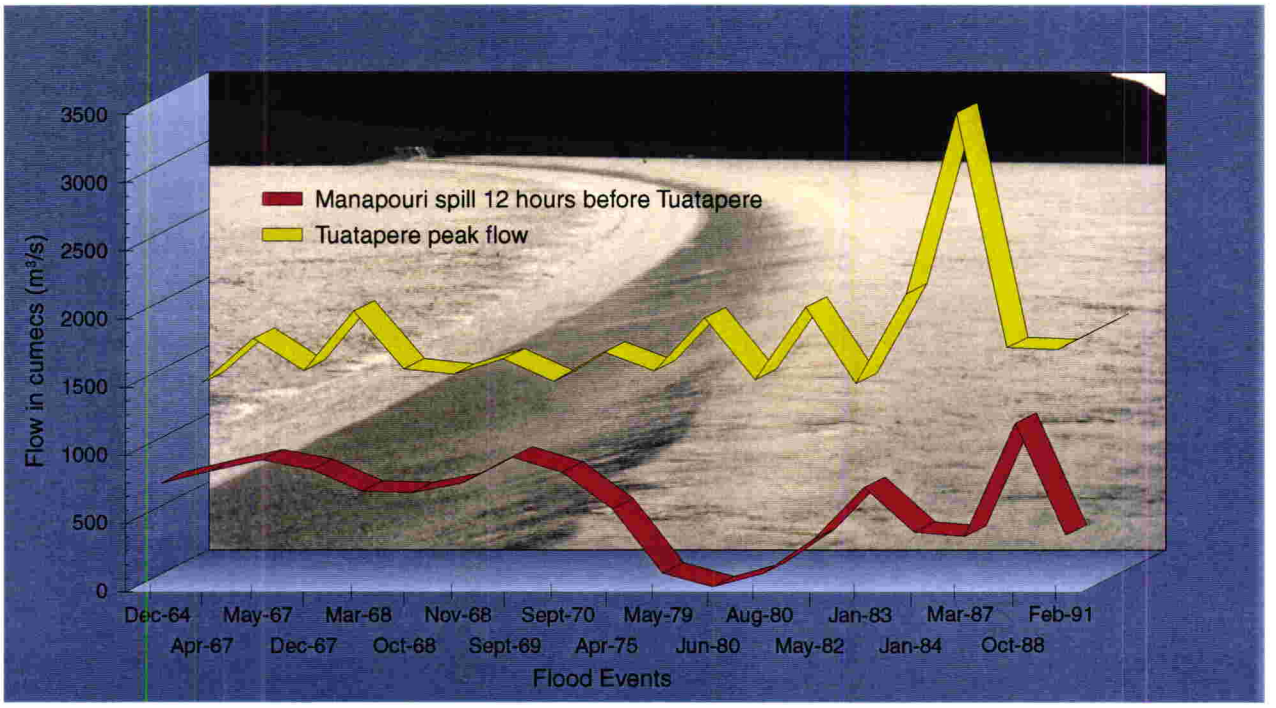


Figure 56 – Lower Waiau River flood peaks

Discussion: Proximity to Fiordland makes rapid flooding a common occurrence in the Waiau catchment, although floods are significantly dampened by Lakes Te Anau and Manapouri. This dampening effect does not apply to the uncontrolled tributaries of the Lower Waiau from Sunnyside to Tuatapere. Figure 30 shows that the development of the Manapouri Power Scheme has reduced Manapouri spills during floods to less than what they were before 1970. While many of the flood peaks at Tuatapere since 1979 have been very large, without the Manapouri Power Station discharging water into Deep Cove they would have been even larger.[71] The Manapouri Power Scheme thus provides considerable protection from flooding in the Lower Waiau valley.

The following points relate to flood control in the Waiau catchment.[72]

1. The highest flood inflows are those into Lake Te Anau, due to the larger catchment area (3,095km2) in a wet region with no significant intermediate storage lakes.
2. Lake outflows are significantly lower than lake inflows due to the dampening effect of lake storage.
3. Lake Manapouri flood discharges are now generally half of what they were before the Manapouri Power Scheme because of water discharged into Deep Cove, making floods at Tuatapere lower than they would be naturally.

Since the inception of the Manapouri Power Scheme, the most significant flood events in the Waiau catchment were those of January 1984 and November 1988. The 1984 flood was reduced at Tuatapere by storage of floodwaters in Lake Manapouri. While the flood was still large, inflows into Lake Manapouri at that time suggest it would have been considerably larger without control. The 1988 flood resulted in sustained high flows at Tuatapere, due to a sequence of large rainfalls which progressively brought both lakes up to their flood ranges. Subsequent floodwaters could therefore not be stored, and were spilled.

Conclusion: Power generation and lake storage can significantly reduce the frequency and magnitude of floods in the Lower Waiau. Despite this, the catchment is prone to major flooding which cannot always be prevented by operation of the Manapouri Power Scheme.

10.3.3. "Flushing" Flows

Issue: The resource consents applied for allow the flow of the Mararoa River to normally be diverted into Lake Manapouri, except when sediment-laden flood flows are passed through the MLC down the Lower Waiau River. These "flood flows" are defined as flows with a turbidity exceeding 30 NTU as measured at Cliffs monitoring station. Such flows are released to avoid the environmental and aesthetic problems caused by turbid waters at Manapouri township (a significant tourist area), and weeds such as crack willow, broom and gorse from colonising the national park.

Concerns with this flood release regime focus on the effects of allowing only turbid water to pass through the MLC, and then, as the flood recedes, reducing flows below the weir to 12-16 cumecs. It is not known if the new flow regime, especially the pattern of flow releases, will be sufficient to flush the fine sediment generated by flood releases from the Mararoa River. In addition, release of turbid Mararoa water into the Lower Waiau River may have implications for aquatic ecosystems if algal growths (periphyton) and fine sediment are not regularly flushed from the riverbed substrate (see Section 10.4.1).

Discussion: Sediment generated in the Upper Waiau catchment is deposited in Lake Manapouri, so most sediment passing through the Mararoa Weir and hence down the Lower Waiau River results from flood releases of the Mararoa River. However, many tributaries contribute to the total quantities of sediment which pass down the Lower Waiau. Therefore, the contribution of Mararoa river flood flow releases to fine sediment deposition is probably minor, particularly downstream of the Monowai River.[73]

The pattern of flow releases from the Mararoa Weir shows that not all releases consist of turbid Mararoa water. Riddell (1993a) investigated which "flood rule" contributes to the source of floodwaters in the Lower Waiau River, (ie. how much of the floodwater comes from spilling clear Lake Manapouri water, and how much from spilling turbid Mararoa River water). The study found that 77% of the spill volume resulted from Lake Manapouri spill and 23% from the Mararoa River. However, the duration of spill flows is roughly equal at 46% Lake Manapouri spill, and 54% Mararoa River.

Much of the sediment released into the Lower Waiau River from turbid Mararoa River water will be moved along the river channel by the proposed 12-16 cumec minimum flow.

Generally, flows of more than three times the base flow will cause considerable substrate movement (see Section 10.4.1), which will prevent sediment buildup in the main channel. Flows close to this magnitude will be provided at least nine times a year by the two 35 cumec flow releases during the winter months, in addition to flood flow releases (see Section 3.5.5), summer recreational flows, and mouth opening flows.

Conclusion: It is difficult to calculate the contribution of sediment from Mararoa River flood releases to the total amount of sediment carried by the Lower Waiau during a flood. Much of the present spill volume is water from Lake Manapouri, which is essentially sediment-free. Winter flow releases plus other flow releases should provide a sufficient sediment "flushing" effect throughout the year.

Future Management: The new flow regime, including "flushing" flows released during the winter months, will ensure regular pattern of substrate deposition and removal, independent of natural floods and the operation of the Manapouri Power Station. The flushing flows will each be of 35 cumecs over 24 hours.

10.3.4 Flow Fluctuations

Issue: Flow management of the Lower Waiau River may have induced a pattern of flow fluctuations which may increase river channel erosion and deposition, with consequent effects on riverine ecosystems.

Discussion: During a flood, the Mararoa Weir gates are opened progressively as the flows increase. As the flood progresses downstream, the full flow reaches the lower reaches of the river, unattenuated. In addition, tributary spates often augment spill flows from the Mararoa Weir.[74]

However, there is no evidence to suggest that major erosion or river channel formation is caused by rapid changes in flow, although there is no measurement of the extent of minor or localised erosion which may have been exacerbated by short-term flow fluctuations.[75]

Conclusion: Although the flow fluctuations occur as a result of flow control at the Mararoa Weir, there is no evidence of effects on riverbank erosion.

10.3.5 Rivermouth Closure

Issue: Reduced flows may have contributed to river mouth closure.

Discussion: The most significant post-control hydrological changes affecting the river mouth system have been the substantial reduction in minimum flows in the river and the reduction in flood flows, possibly contributing to river mouth closure. However, the principal agent of river mouth closure is the combination of low flows and coastal onshore storms. Closure is now most probable in the autumn and late winter, when these two events are most likely to coincide, although to date there have been only three substantiated mouth closure events: in 1972, 1973 and 1994.[76]

Long-term adjustments in rivermouth processes as a result of changes in the catchment, including hydro development, will continue. These adjustment processes may take *"...in the order of 50 years,"*[77] although most of the change has already occurred. Agricultural development in the catchment has affected rivermouth processes by introducing large quantities of sediment to the lower river. No management action can reasonably be taken which will prevent the process of rivermouth adjustment, or reverse the cycle of changes initiated by hydro-electric power development in 1969.[78]

Conclusion: Mouth closure and movement are principally controlled by onshore coastal storms and high-low river flow extremes. Changes in rivermouth processes have been influenced by both flow changes and agricultural development. The pattern of rivermouth changes cannot be reversed.

Future Management: To address any effects of flow regulation on rivermouth closure, a water level recorder will be placed in the Waiau Lagoon. Continuous water level readings will indicate times when the river mouth is blocked. If these times coincide with the native fish migration times (autumn and spring), river mouth opening flows will be provided. Such flows will constitute a 24 hour flow release at the Mararoa Weir of 150 cumecs. Provision of these flows will depend on whether there is sufficient water storage in Lake Manapouri to provide them so that gazetted lake level guidelines are not breached. These river mouth opening flows may also encourage native fish to migrate upstream from the sea. Information from the recorder will be relayed to Southland Regional Council.

10.3.6 Channel Erosion and Deposition

Issue: Deposition of sediment in the Lower Waiau riverbed may influence the competence of the modified river channel to pass floods. In addition, excessive deposition of coarse and fine sediment in some river reaches over the 20 year period 1974-1994 may cause natural diversions of the river to erosion points further downstream, causing erosion of productive land.
The ability of the modified river to pass floods without significant erosion of productive farmland or damage to property has been a regular concern. Past attempts to mitigate the potential effects of this erosion have led to purchases of affected properties by ECNZ and its predecessors. However, past attempts to correlate the effects of flow regulation on erosional forces have not been conclusive.

Discussion: A comprehensive study of the Lower Waiau channel form before and after the power scheme has been conducted for the WWP by Brierley (1994a). The study asked the question: "How have modifications to the flow regime of the Lower Waiau changed the river?"

Erosion rates were high before hydro development and lessened during the 1970's. Following the progressive flow modification and regulation between 1969 and 1974, the Lower Waiau River adjusted to a new erosion-deposition equilibrium. After 1974, deposition became dominant and the channel contracted. In the 1980's there was a period of high erosion-deposition in the lower catchment caused by significant floods in 1984 and 1988. Overall, since hydro development, there has been a shift from erosion to deposition, although this is at least partly due to measured deposition rates including those areas which had been abandoned by the river because of its reduced flow.

Hydro development has had the effect of reducing the river's mean flow, but not the extreme flows when much of the erosion and deposition occur. Therefore, there are only minor changes to erosion/deposition rates as a result of mean flow changes.

Channel changes are negligible along most of the river course, as large sections of the Waiau River are constrained by either bedrock or terraces. Channel changes mostly occur in the Redcliff, Wairaki, Lillburn downstream of Clifden, and Tuatapere river reaches, all unconfined braided reaches where the river has the space to shift laterally.

Conclusion: Brierley (1994a) concluded that many of the tendencies for river channel change in the Lower Waiau River were set prior to hydro development. However, hydro development may have caused them to happen more quickly. The tendency had been for a shift from erosion to deposition. Future channel changes are most likely to occur at tributary confluences or in the lowland braided river reaches, particularly at Redcliff and downstream of Wairaki, Lillburn and Tuatapere.

Future Management: Brierley (1994c) outlined a monitoring programme to assess the ongoing patterns of erosion and deposition in the Lower Waiau. Aspects of this monitoring programme recommended by the Waiau Working Party to ECNZ were to remeasure the following transects annually, or after flood events greater than 1,200 cumecs (measured at MLC) within certain reaches of the river. Monitoring after 1,200 cumec flows is based on the premise that these are 10-year return period floods and were identified by Brierley (1994a) as river bed shaping flows. A photographic record will be kept of each transect and will include:

- all 11 existing transects between Tuatapere and the river mouth.
- a new transect immediately downstream of the Lillburn confluence
- a new transect immediately downstream of the Wairaki confluence

10.3.7 Deposition Above and Below the Mararoa Weir

Issue: There has been noticeable sediment deposition immediately above and below the Mararoa Weir, and at the Home Creek delta as a result of flow reduction in the Lower Waiau. Deposition has the potential to affect the operation of the Mararoa Weir, particularly its ability to pass sediment-laden Mararoa River floodwaters into the Lower Waiau River. Delta formation at Home Creek may exacerbate erosion on the true right river bank opposite Pearl Harbour and limit boat passage.

Discussion: The build-up of gravel at the Mararoa Weir has been regularly monitored via cross-sectional analyses since 1976.[79] Sediment deposition was found to be prevalent in the Waiau River channel between Pearl Harbour and the Mararoa Weir. In 1987, the Mararoa River was diverted onto a more straight channel pathway to the Mararoa Weir control gates (the "Mararoa cut"). Riddell et al (1993) report that since the commissioning of the Mararoa cut the sediment build-up, particularly at the old Mararoa River confluence, has diminished and the outlet channel is performing well.



Figure 57 – Sediment build-up above and below Mararoa Weir

Most of the rest of the sediment build-up has been below the Mararoa Weir in the stilling basin. Despite the sediment build-up around the weir, it has not affected the ability of the structure and channel to pass flood waters. The Mararoa cut had reduced a backwater effect caused by gravel build-up above the weir. The cut itself had contributed some of this gravel which had to be removed by bulldozer. Amounts of sediment contributed by the cut now seem considerably less than before, and it is expected that the problem of gravel deposition above and below the weir should become progressively less.

Mills and Freestone (1992) also found sediment build-up occurring at the Home Creek delta. The formation of a delta at the Home Creek confluence did not appear to affect boat passage. Erosion on the riverbank opposite Pearl Harbour may also be caused by boat wakes.[80] The erosion is not opposite Home Creek and is thought to be natural and more likely to be due to wind events.[81]

Conclusion: Sediment deposition above and below the Mararoa Weir is now much less of a problem than before. The effects of delta formation at the Home Creek confluence on erosion are inconclusive.

Future Management: Monitoring of sediment deposition above and below the Mararoa Weir, and at the Home Creek delta, will continue using the programme instigated by Mills and Freestone (1992) (see Appendix IV). ECNZ will carry out any work necessary to maintain a navigable channel between Pearl Harbour and the Fiordland Travel boat slip.

10.4 Ecological Effects

10.4.1 Periphyton

Issue: Excessive algal (periphyton) growths in the riverbed can occur if there is not sufficient flow to shear it off the rocks. Although algae are necessary to the ecosystem as primary producers in the food chain, excessive growths can create problems for the instream ecosystem, and cause the presence of unsightly, slippery growths on rocks in the riverbed.

Discussion: An analysis of the periphyton and invertebrates in the Lower Waiau River (Mararoa Weir to Borland Burn) was carried out to complement an IFIM study of fisheries habitat (see Section 10.4.3), and recommend a suitable minimum flow which would prevent excessive algal growths in the riverbed.[82] The study found that periphyton was at nuisance levels mainly in the Excelsior reach immediately downstream of the Mararoa Weir. A minimum flow which gave a mean flow velocity greater than 0.3 m/s would be sufficient to reduce levels of periphyton, and thereby improve the instream ecological communities. This is provided by a continuous flow of 12 cumecs or greater. The shear stress associated with such flows should prevent periphyton buildup to nuisance levels.

The new flow regime includes monthly recreational flow releases of at least 35 cumecs during summer, and two extra "flushing flows" of at least 35 cumecs during winter. From work undertaken on the Lower Waitaki River,[83] it was concluded that flows of 3 times the mean flow are sufficient to remove periphyton through substrate movement and shear stress. Therefore, the winter "flushing flows" should be sufficient to remove any periphyton build-up in the Lower Waiau River. The summer recreational flows should also provide sufficient shear stress to remove nuisance algae at regular monthly intervals.

Although these flow releases may appear to cause some habitat disruption, rapid recovery of periphyton after major disturbance (flooding) occurs within 21 days (depending on the amount of substrate movement, water temperature and absence of further floods). Small freshes of this magnitude (35 cumecs) will have no major effects on macroinvertebrates.[84]

Conclusion: In the Lower Waiau River, the scouring effect of the 12-16 cumec flow, the monthly 35 cumec recreational flows during summer and the proposed flows during the winter months will ensure removal of excessive periphyton growths. The adverse effects of these small freshes on the overall instream ecology of the river will be minimal, and are outweighed by the beneficial effects of reducing periphyton growths.

Future Management: To ensure that the proposed flow regime achieves its objective, ECNZ will continue periphyton monitoring in the established locations on the Lower Waiau River.



Figure 58 – Adult Mayfly (Ameletopsis sp.)

10.4.2 Macroinvertebrates

Issue: The flushing flows and recreational flows, as well as other flow releases from the managed flow regime, could adversely affect macroinvertebrate communities and have a follow-on effect on trout habitat.

Discussion: There are differences in macroinvertebrate community composition between rivers which are regularly "flushed" and those which are not.[85] Flow regimes which include flushing and flood flows favour taxa such as mayflies (Figure 58) and caddis flies (both cased and free-living species). These are macroinvertebrate species which are highly favoured as trout food. Research in the Lower Waitaki River showed that macroinvertebrates which are not available as food for trout (such as *Oxyethira*, amphipods and chironomid larvae) tend to dominate in rivers which have stable, moderate flows without regular "flushing" events. Therefore, the flow regime proposed will ensure the best possible conditions for enhancing the trout habitat in the Lower Waiau River, within the constraints of flood releases.

Conclusion: The "flushing" (of fine sediment and periphyton) effects of minimum and spill flows should not adversely affect macroinvertebrate communities in the Lower Waiau River.

Future Management: To ensure that the proposed flow regime achieves its objective, macroinvertebrate communities in the Lower Waiau River will be monitored for the 5 years following grant of consent. This will include the area immediately below the Mararoa Weir, to assess whether the macroinvertebrates recover to form a typical "lake outlet" community.

10.4.3 Trout Habitat

Issue: Reductions in flow of the Lower Waiau were thought to affect the trout fishery through reductions in the quality and quantity of fish habitat. This effect was considered most significant in the river between the Mararoa Weir and the Borland Burn, where the median flow had changed from around 400 cumecs to around 0.3-2.0 cumecs. A further effect on the fishery may be a reduction in potential spawning habitat.

Discussion: Habitat modelling was used to assess actual and potential trout habitat available at various flows.[86] Habitat preference criteria were used to assess the impacts of altered stream flow regimes on a stream habitat. This relies principally on factors most closely related to stream hydraulics: depth, velocity and substrate. Preference criteria are developed, based on the assumption that fish and macroinvertebrates will tend to select areas within the stream having the most favourable hydraulic conditions. The analyses give an index of the amount of habitat available to different species, described as Weighted Usable Area (WUA). In other words the model predicts what fish habitat and "food producing" habitat will be created at various flows. It should be noted, however, that variability in species density can be large, especially where biological habitat tolerances are broad. Therefore, the WUA model is useful for predicting the occurrence of suitable habitat for freshwater species, but cannot accurately predict the final densities of those species. A five-year programme will monitor macroinvertebrate and fish densities in the Lower Waiau River, as outlined in Appendix IV.

The IFIM technique is generally recognised as the most appropriate and defensible technique for assessing minimum flow requirements. IFIM was successfully used for assessing the minimum flow for the restoration of the Ohau River on the Waitaki system by the Waitaki Working Party and Canterbury Regional Council.

Figures 59–61 show the available brown trout habitat (WUA) under various flow conditions. Jowett (1993) explains that flow recommendations can be based on the flow below which habitat begins to decline sharply, a so-called "point of inflection". These figures show that brown trout

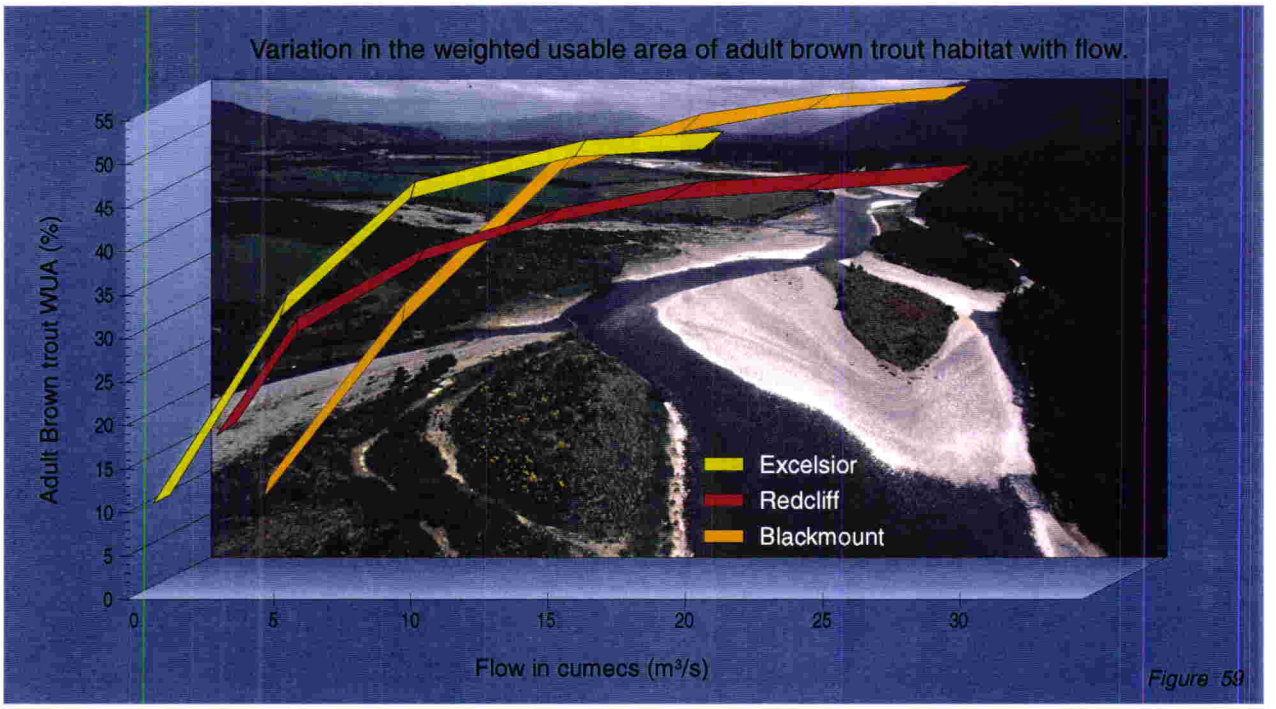


Figure 59

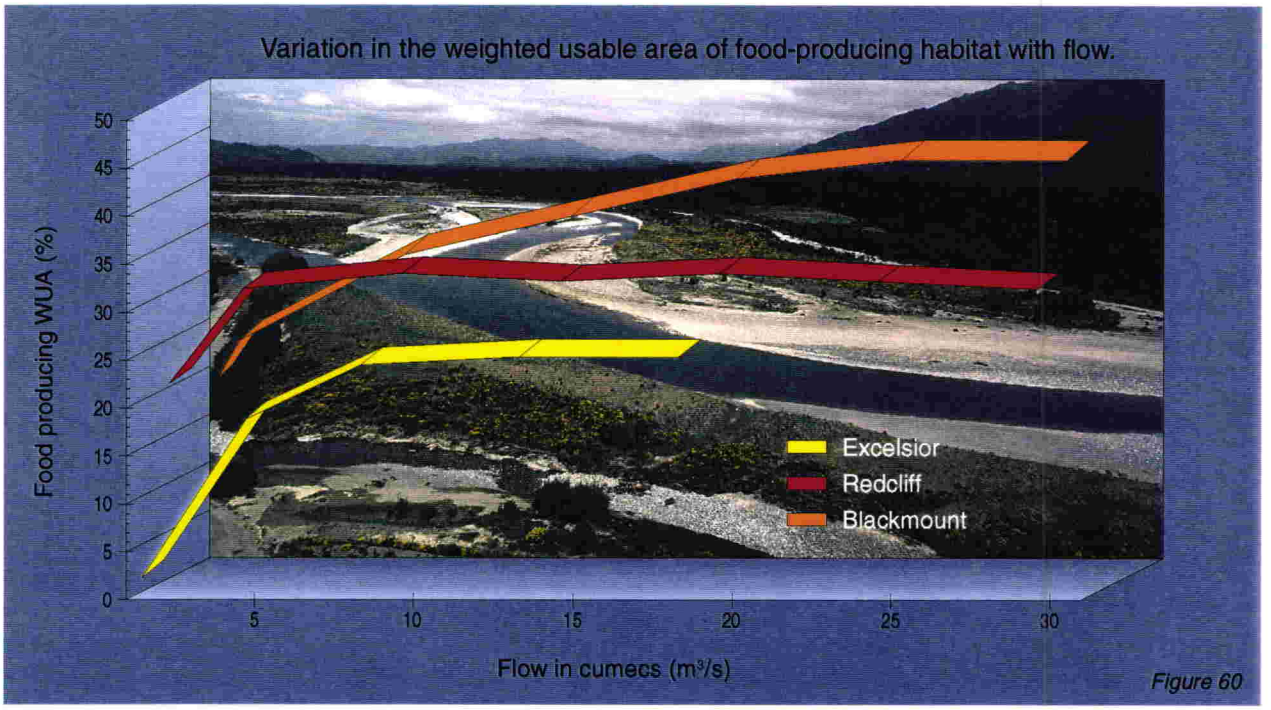


Figure 60

habitat, "food producing" habitat and *Deleatidium* habitat (*Deleatidium* are the main trout food species) all reach a plateau at flows around 20 cumecs, and thereafter they do not greatly improve. Conversely, these habitat values rapidly fall away at flows below 5 cumecs. Table 17 (from Jowett 1993) shows the "point of inflection" for these curves appearing at between 7 and 15 cumecs. "Excellent" (77% of the possible maximum) trout habitat would be created by a minimum flow of 12 cumecs, and native fish habitat exists at all flows. Even an arbitrary "absolute minimum" flow for the Excelsior reach of 6 cumecs would give a standard of trout habitat exceeded by only the top 15% of trout rivers studied in the New Zealand "100 rivers" survey and over 50% of the possible maximum.

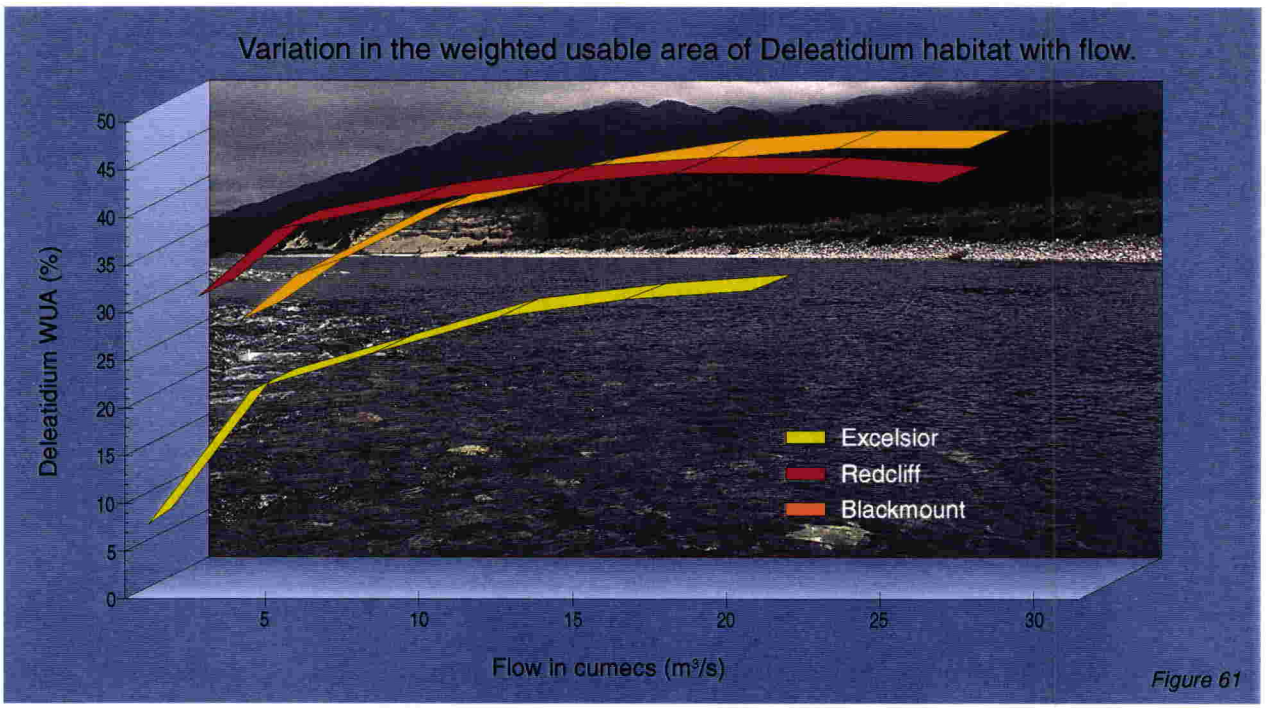


Figure 61

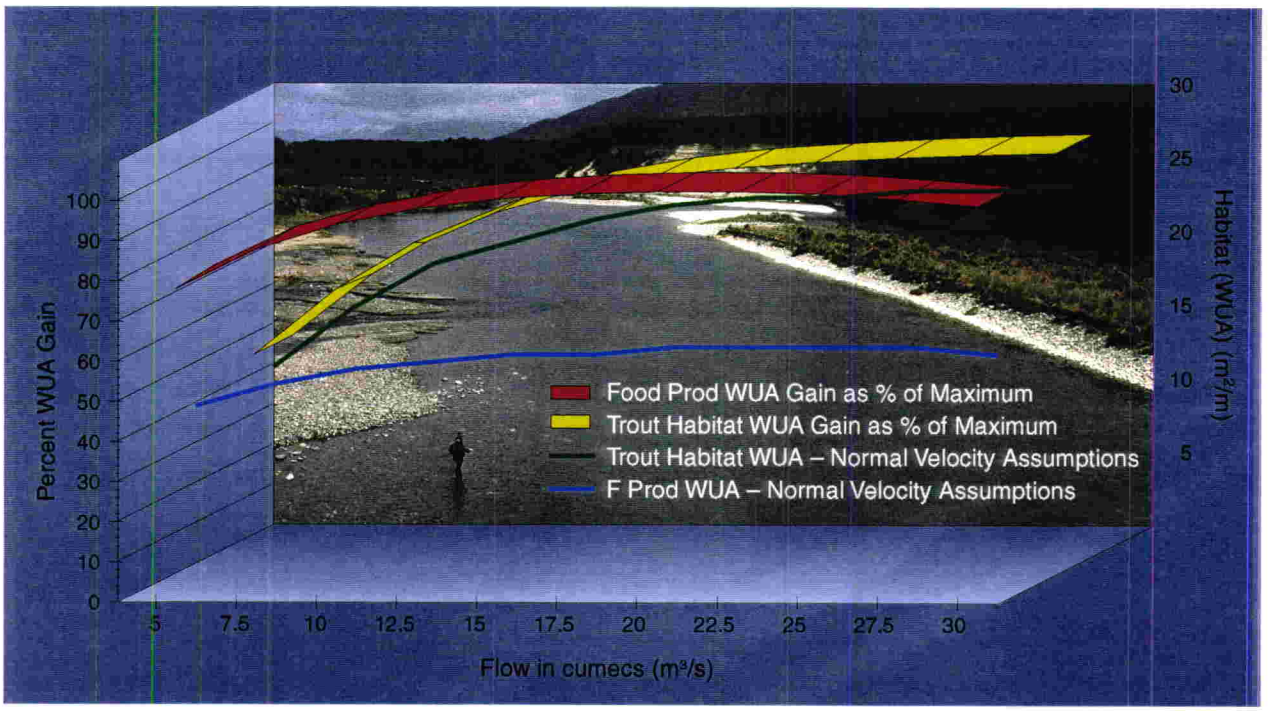


Figure 62 – Variation in weighted usable area of food-producing habitat with flow

Figure 62 summarises the gains in brown trout habitat from various flows. When using the calculation for WUA from normal flow velocity assumptions, it can be seen that doubling the flow from 15 to 30 cumecs between the weir and Blackmount would result in a less than 5% increase in habitat. Indeed, at 30 cumecs, trout habitat is maximised, but food producing habitat reduces from a maximum at 22.5 cumecs. The RMA requirement (S. 7b) for the "...efficient use of natural resources" suggests that this theoretical 5% increase to the maximum WUA should be foregone in favour of the extra power which could be generated by this 15 cumecs.

Therefore, a flow of 15 cumecs would significantly enhance and protect the trout habitat, while optimising the use of the natural water resource. However, a constant flow all year is considered by international fisheries scientists to be detrimental to fish production.[88] If the goal is to maintain maximum numbers of adult trout, the best strategy is considered to be a larger flow in summer, and a moderate flow in winter. During summer, in-river productivity is maximised, so greater flows at this time would provide for proportionately greater food productivity than gained by higher flows in winter. Furthermore, trout metabolism is reduced during winter's cold temperatures, so fish do not feed as voraciously. The requirement for food productivity in winter is therefore lessened.

The WWP has agreed to a minimum flow regime of 16 cumecs in summer, and 12 cumecs in winter. The reduction in potential brown trout habitat at 12-16 cumec flow is considered to be less than the value of this water to power generation. Therefore, ECNZ will provide funds to a trust to enhance fish and other wildlife values in the Lower Waiau catchment. The trust will allow SFGC and DOC to improve existing fish habitat to an extent that greater fishery benefits accrue than would have occurred from a continuous 15 cumec flow.

Conclusion: Habitat modelling studies have provided estimates of flows required for the protection and enhancement of trout habitat. Maximum habitat is provided at around 30 cumecs. Approximately 95% of the maximum is provided at 15 cumecs. A variable flow with flows lower in winter and greater in summer is required to further enhance trout habitat. Trout habitat can be further enhanced through methods other than providing minimum flows. Therefore, funding habitat improvements is a more efficient use of natural resources than increasing flows to meet theoretical brown trout habitat requirements.

Future Management: A variable minimum flow of 12 cumecs from April to September, and 16 cumecs from October to March is expected to provide trout habitat which will place the Lower Waiau River among the "top ten" trout rivers in New Zealand.[89] This minimum flow regime is also suitable to mitigate other effects of flow regulation in the Lower Waiau (eg. periphyton, Section 10.4.1).

ECNZ has agreed with the SFGC and DOC to provide sufficient funds to facilitate habitat enhancement through the Habitat Enhancement Trust (see Section 14.7), in addition to the variable minimum flow above and below 15 cumecs.

ECNZ proposes monitoring the trout fishery through drift diving and creel census. Monitoring macroinvertebrates and periphyton will provide an index of the health of trout food producing habitat (see Appendix IV).

Table 17 – Flows (cumecs) Required to Provide Optimum Habitat (WUA%) and Flows Below Which Habitat Begins to Decline Sharply in the Three Surveyed Reaches of the Lower Waiau River

Location	Excelsior		Redcliff		Blackmount	
	WUA	Flow (cumecs)	WUA	Flow (cumecs)	WUA	Flow (cumecs)
Optimum Flows						
Adult brown trout	51	18	>42	<30	58	30
Food producing habitat	27	16	33	20	44	30
Deleatidium habitat	30	20	45	20	44	>30
Point of Inflection						
Adult brown trout	43	8	38	14	45	15
Food producing habitat	22	7	32	8	34	10
Deleatidium habitat	26	7	43	11	39	11

10.4.4 Trout Passage

Issue: From the inception of the Manapouri Power Scheme there has been a belief that there is a need for a fish pass at the weir to allow brown and rainbow trout passage upstream to spawn.

Discussion: A "Borda" fishpass was installed in the weir during its construction in 1975 in response to calls from the Southland and Otago Acclimatisation Societies to fulfil the requirements of Section 5 of the Manapouri-Te Anau Development Act, 1963, which states:

> *"Before exercising any power conferred on him (sic) by section 4 of this Act within the Fiordland National Park, the Electricity Corporation of New Zealand Limited shall consult... The Minister of Conservation on measures to be taken to minimise any adverse effects on the trout fishery in Lakes Manapouri and Te Anau that may result from the exercise of the power"*

Monitoring of fish using the Borda fish pass was carried out between 1978 and 1982 (Table 18). Since 1975, the effectiveness of this fishpass has been reduced. It appears that, when functional, rainbow trout will move through it both up and downstream, but brown trout do not appear to readily use it. At times, large numbers of brown trout are seen congregating immediately below the fishpass, but do not move into or through it. Recently, the structure has become dysfunctional due to gravel deposition in the resting chamber clogging the entrance to the fishpass, variable flows below the weir and flow reversals above the weir. It appears that the fish pass has been rendered virtually inoperative because of a build-up of gravel in its internal structure. At times, migrating trout have been stranded below the weir, requiring salvage.

Table 18 – Numbers of trout found using the Borda fish pass

	1978	1979	1982
Adult brown trout	76	13	3
Juvenile	140	22	0
Adult rainbow trout	109	0	16
Juvenile	53	7	4

During salvage operations some fish were tagged by the Southland Acclimatisation Society before being released above the weir. Returns from these salvage and tagging operations suggest that:

- Rainbow trout will use the pass.
- Brown trout may move into the fish pass entrance, but generally will not use the pass.
- Of brown trout which have been manually transported over the weir, 47% will migrate into the Mararoa catchment, 38% will stay in the vicinity of the weir, and 15% will move back downstream of the weir.
- Of the rainbow trout which have been manually transported over the weir, 93% will migrate to the Mararoa catchment and 7% will move back downstream of the weir.

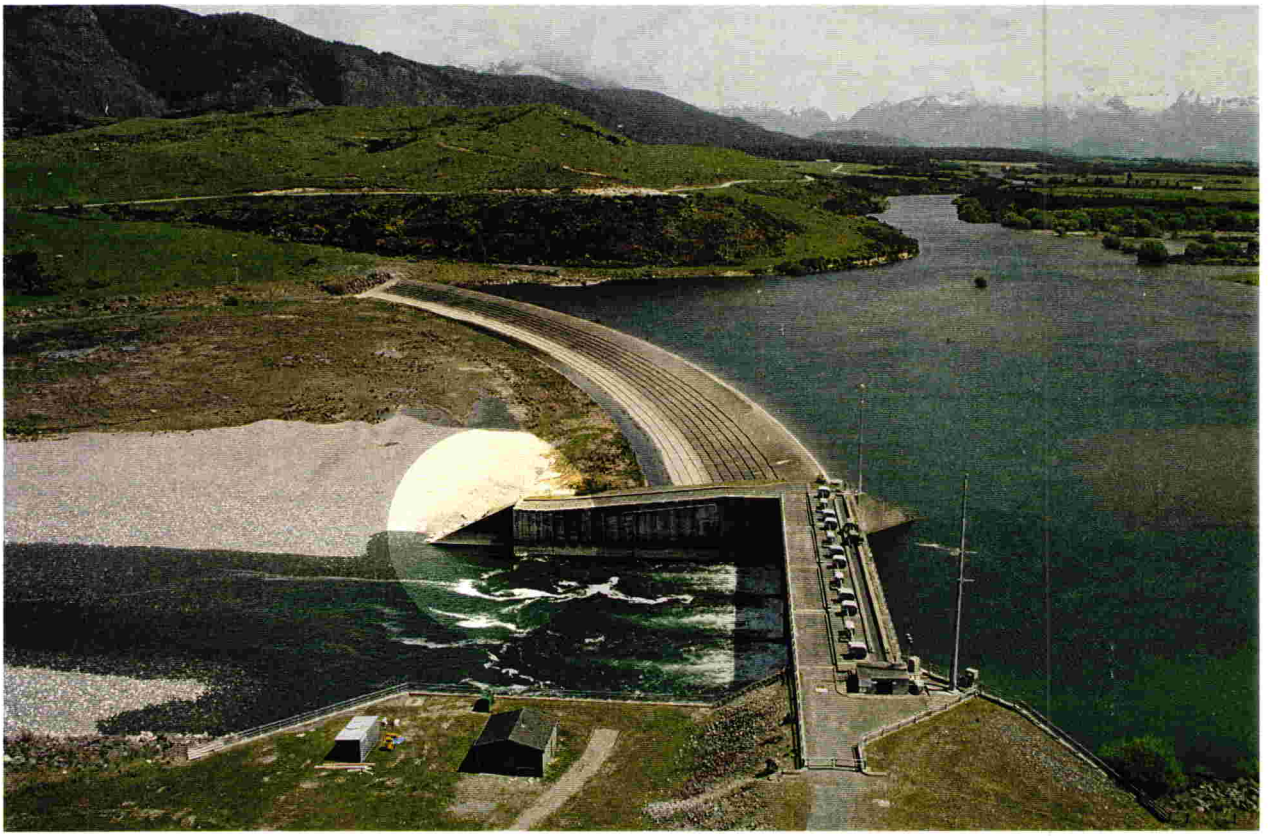


Figure 63 – Mararoa Weir – entrance to existing fish pass highlighted

Trout not able to gain passage to the spawning areas of the upper Mararoa River are able to spawn below the weir in the main Waiau channel and in tributaries such as the Wairaki River. Those that spawn in the main channel are in danger of their redds being lost through large flood flows. Despite this, the Lower Waiau continues to support a significant brown trout fishery. Currently accumulations of trout in the weir stilling basin causes stress and a lowered probability of successful spawning. It is desirable that this situation be avoided.

Conclusion: Trout passage from the Lower Waiau to the Upper Waiau and Mararoa catchments is restricted by the Mararoa Weir. The existing fishpass is not effective for brown trout, with some fish requiring salvage from below the Mararoa Weir after flood releases.

Future Management: To mitigate the problems with trout passage over the Mararoa Weir, ECNZ will install, within 3 years of the granting of consents, a fish pass suitable for brown and rainbow trout passage to the reasonable satisfaction of the SRC. This will be in consultation with the DOC and the SFGC, (in accordance with Part VI of the Freshwater Fisheries Regulations 1983). Three years will be necessary to design, erect, install and effectively monitor a newly-designed fish pass, given the past technical difficulties of making these structures effective for brown trout over the long term.

10.4.5 Native Fish Habitat

Issue: Reductions in flow of the Lower Waiau may affect the native fishery through reductions in the quality and quantity of habitat, and interruptions to natural spawning runs.

Discussion: Jowett (1993) suggested that suitable habitat for native fish would be available at practically any minimum flow on the Lower Waiau and tributaries. This assertion was investigated by McDowall (1994a). Despite finding an "impoverished" native fish fauna, the study concluded that the assertion that "*suitable habitat for the native fish of the Lower Waiau would be available at practically any flow*" was correct. In addition, there was no reason to consider that the "impoverished" state of the fauna had anything to do with flow diversions or fluctuations caused by the Mararoa Weir. Native fish live in the margins of the Lower Waiau River and prefer very slow current speeds (around 0.1m/s). Mitchell (1994b) considered the impacts of increasing the minimum flow in the Lower Waiau on whitebait species, and concluded that increasing the flow would merely cause the fish to move towards the new river margins into optimum water velocities. The difference to native fish habitat between a 10 cumec flow and a 14 cumec flow is therefore negligible. The controlling factor for native fish in the Lower Waiau is major floods, not minimum flows.

Conclusion: The proposed 12-16 cumec minimum flow immediately below the Mararoa Weir should not unduly affect native fish habitats.

Future Management: ECNZ will monitor changes to the native fish populations in the Lower Waiau River (see Appendix IV). Through the Habitat Enhancement Trust and the Mahika Kai Trust, ECNZ will sponsor the creation of additional native fish habitat.



Figure 64 – Native fish (Galaxies sp.)



Figure 65 – Whitebait habitat and whitebait (inset)

10.4.6 Whitebait Habitat

Issue: Whitebait catches have drastically reduced on the post-control Lower Waiau River. The Manapouri Power Scheme may be a contributing factor.

Discussion: A comparison of the whitebait fisheries in other Westland and Southland rivers concludes that "there is no reason why the Waiau River, in its "abstracted form", should not sustain a whitebait fishery of at least regional significance."[91] The high variability in catch rates between rivers and different years makes comparisons difficult, but if mouth blockage were prevented during the autumn and spring migrations, the fishery should not be unduly affected.

The majority of the whitebait catch is made up of the inanga *Galaxias maculatus*.[92] The mainstream Waiau River was probably not a major whitebait fishery because this species lives in lowland estuarine and swamp habitats, few of which exist in the Waiau apart from the Te Waewae Lagoon.

Conclusion: The whitebait fishery principally consists of the lowland estuarine inanga. There are no known effects of the Manapouri Hydro Scheme on this species. Enhancing the whitebait catch may require enhancing the lowland estaurine habitat of the inanga, principally in the Waiau Lagoon.

Future Management: It has been recommended that an existing series of former river channels in the Te Waewae Lagoon area be deepened to provide permanent ponding. In this way, an extra 5.38 km of inanga habitat could be constructed, plus one ponding area of 370m^2. Through the Habitat Enhancement Trust, ECNZ has agreed to fund the necessary works to fulfil these recommendations. This will be done in consultation with the SFGC, DOC and iwi. This work will have significant implications for the design of lowland wetland restoration and whitebait habitat enhancement throughout New Zealand.

10.4.7 Native Fish Passage

Issue: The Mararoa Weir presents a barrier to upstream fish (especially elver) migration. Reduction in flows may cause the Waiau River mouth to close over, preventing native fish migrations.

Discussion: Information on native fish captured in the Mararoa Weir fishpass is listed in Table 19. The data suggest that eels and lamprey are able to use the present fishpass without restriction. Nevertheless, evidence from other sources suggests that the Mararoa Weir presents a considerable barrier to upstream native fish passage. Mitchell (1994a) describes an incident when "tonnes" of elvers were stranded (and subsequently perished) below the weir. In addition, up to 92% of eels captured from above the weir were older than the structure itself.[93] It can therefore be concluded that recruitment of young elvers into the upper catchment is probably restricted by the Mararoa Weir. Most other native fish in the upper catchment are not obligate migrants, so their population viability is not affected by the Mararoa Weir. The exception is lampreys, which migrate from the sea to breed in fresh waters. They have been caught in the fishpass (Table 18), but Mitchell and Davis-Te Maire (1994) found no lamprey (ammocoete) larvae either above or below the weir.

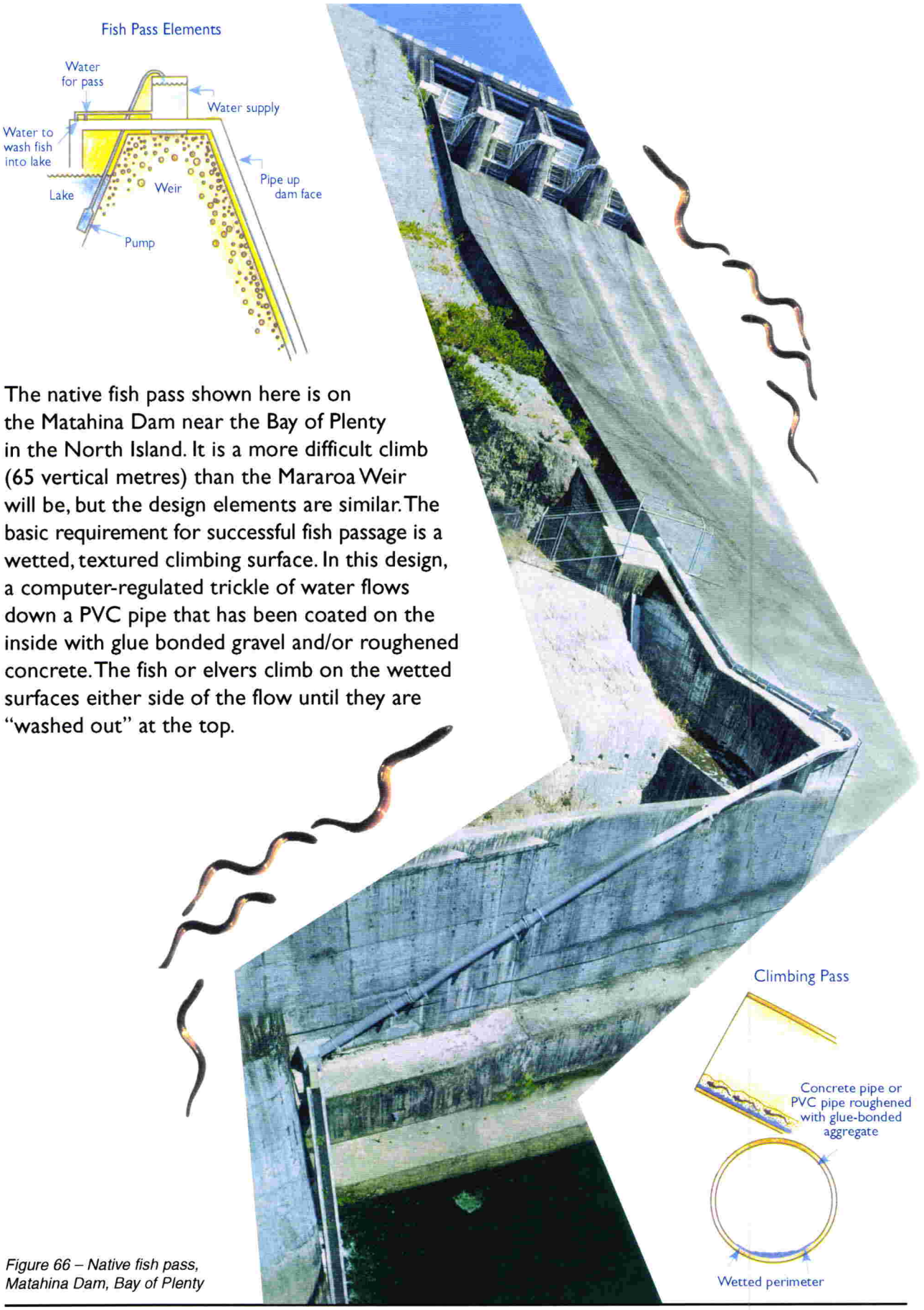
Native fish migrating to/from the Waiau River to the sea can have their passage impeded by the rivermouth closing. McDowall (1994b) recommends that rivermouth closure should be remedied during the peak native fish migration times of autumn (March, April, May) and spring (September, October, November).

Table19–Native Fish Captured in Mararoa Fish Pass (from Southland Fish and Game Council)

	1978	1979	1982
Long-finned eels	142	3	23
Lamprey	20	2	0
Bullies	3	0	0
Smelt	3	0	0

Conclusion: Elver passage is probably impeded by the Mararoa Weir, affecting eel recruitment into the Upper Waiau catchment. Native fish passage through the Waiau rivermouth should not be impeded during autumn and spring.

Future Management: ECNZ will install a native fishpass on the Mararoa Weir. Native fishpass designs are available, and are similar to those used for the Waitaki and Aviemore dams. In addition, native fish are expected to be able to travel over the Mararoa Weir via the proposed trout fishpass (see Section 10.4.4) which will allow the life cycles of these species to be restored, sustainable management of their populations in the freshwater ecosystem, and a sustainable resource for iwi and recreational purposes. The new flow regime (Section 10.2) has provision for opening the Waiau rivermouth during the important native fish migration periods (see also Section 10.3.5).



The native fish pass shown here is on the Matahina Dam near the Bay of Plenty in the North Island. It is a more difficult climb (65 vertical metres) than the Mararoa Weir will be, but the design elements are similar. The basic requirement for successful fish passage is a wetted, textured climbing surface. In this design, a computer-regulated trickle of water flows down a PVC pipe that has been coated on the inside with glue bonded gravel and/or roughened concrete. The fish or elvers climb on the wetted surfaces either side of the flow until they are "washed out" at the top.

Figure 66 – Native fish pass, Matahina Dam, Bay of Plenty

10.4.8 Birds

Issue: Reduced flows in the Lower Waiau may have allowed vegetation encroachment (mainly weeds) onto the riverbed, providing cover for introduced bird predators and reducing the available habitat for riverine birds.

Discussion: The 24 bird species recorded during the spring and autumn surveys are typical of South Island braided rivers. None of the recorded species is recognised as threatened or endangered. Recognising the limitation of a lack of previous baseline data, it is suggested that the reduction in mean flow has probably resulted in more bird habitat being available for breeding and feeding.[94] However, some of these benefits may be offset by the better access to island bird colonies by predators such as feral cats and mustelids. Encroachment of vegetation in the lower river may offset any benefits of increased habitat by smothering open gravel habitat and providing cover for predators. The form of the Te Waewae Lagoon does not appear to have been affected by lower flows; therefore, the coastal birds in this area are unaffected.[95]

Conclusion: An increase in the minimum flow to 12-16 cumecs in the braided river reaches would provide more instream feeding habitat while providing better isolation of breeding areas from predators.[96] Vegetation encroachment, partly caused by reduced flows, has the potential to adversely affect bird habitat in the Lower Waiau River.

Future Management: The proposed minimum flow below the Mararoa Weir will be a continuous flow of not less than 12 cumecs from May to 26 September, 14 cumecs in April and October, and 16 cumecs at all other times. The period during which the 16 cumec flow will be available includes the crucial breeding and fledgling season. Tributary flows below this reach are expected to raise flows to above 20 cumecs in the braided lower river reaches which provide the main bird habitats. ECNZ, in association with the local farming community, is continuing a comprehensive programme of riverbed vegetation control (see Section 12.2.1), which is expected to avoid any effects of vegetation encroachment on bird feeding and breeding habitat. Bird surveys will be carried out annually for the next five years to monitor the effects of these remedial measures (Appendix IV).

10.4.9 Te Waewae Bay Marine Environment

Issues: Reduction of lower Waiau River flows has brought concerns that the reduced freshwater discharge into Te Waewae Bay may have affected the Foveaux Strait marine ecosystem. This may have been a factor in the mass mortality of Foveaux Strait oysters which occurred in the late 1980's and recent toxic algal blooms.

Discussion: The Foveaux Strait marine environment is highly productive and supports a number of highly valuable fisheries [e.g. whales (historically), dredge oysters, mutton birds, squid, as well as spiny lobsters and blue cod]. Much of this productivity is generated from dissolved inorganic nutrients derived from the properties of the Subtropical Convergence which change rapidly across the front, tidal stirring, river water, and from an undefined oceanic source (probably uplift of sub-tropical water over the Puysegur Bank). The region is also significantly impacted by the general oceanic variability driven by weather, and climatic scale events by mechanisms, which are not wholly understood.

While river water might be expected to be a significant influence in the near shore region, through its contained dissolved inorganic nutrients and humic substances, it is difficult to separate its impact from that of the other processes contributing to nutrient renewal. Measurements of dissolved inorganic nutrients in 1978 in Foveaux Strait were relatively high while flows in the Waiau River were low.

Data, summarised by Robertson (1993), on the nutrient content of the Waiau River and Lake Manapouri suggests that the nutrient contribution the river makes to the south coast has probably decreased only slightly post control. The concentration of nitrate-nitrogen in Lake Manapouri is relatively low (25µg/l) compared with concentrations in the Waiau River (up to 50-325µg/l). This difference seems to be related to the different land uses – forestry and agriculture – in the two parts of the lake and river catchment. Nevertheless, the nutrients from the lake are not lost to the marine system; Lake Manapouri water enters the ocean from the Fiordland coast and is entrained into the flow down the southwest coast which turns east into Foveaux Strait.

Overall, there has probably been little impact of changed flows in the Waiau River on the salinity of Foveaux Strait, as the water of Lake Manapouri has not been lost to the system of southern New Zealand. This water eventually reaches Foveaux Strait via the Fiordland coast.

Natural seawater conditions during summer in Foveaux Strait often appear to be conducive to the development of phytoplankton blooms of unusual luxuriance and species composition compared to other New Zealand coastal regions. Bradford-Grieve (1996) noted that the early 1996 bloom followed a period of high rainfall, and subsequently by a calm spell, and concludes that phytoplankton blooms in the region and the occasional occurrence of toxic species are unrelated to human activities.

Declines in the oyster populations have been recorded about every 22-23 years in 1940, 1963 and 1986. These declines have occurred both before and after the Waiau River flow was controlled and have been related to periods when oysters were in poor condition and also to parasitic infections. The 1986 decline in oysters was accompanied by declines in muttonbird condition and shorebirds starved off the Otago coast. These events suggest that a widespread environmental disturbance had ocurred which was not restricted to Foveaux Strait.

Conclusion: While river water might be expected to be a significant influence on the nearshore marine ecosystem of Foveaux Strait, the reduction in flow of the Waiau River probably has not greatly altered the impact of river water, as dissolved inorganic nutrients and fresh water are not lost to the southern New Zealand system.[97]

Chapter 11 – Effects of Freshwater Discharge into Deep Cove

This AEE investigates the effects that are likely to have occurred to Doubtful Sound following the commencement of operation of the Manapouri Power Scheme and the resultant additional freshwater discharge to Deep Cove. There is also the potential, should a second tailrace be constructed at Deep Cove, for the maximum discharge to be increased from 509 to 630 cumecs. The median discharge would only increase from 392 cumecs to 397 cumecs. If the second tailrace flow is limited to 510 cumecs as proposed little change in the existing median discharge is expected.

11.1 Circulation in Doubtful Sound

The waters of Doubtful Sound comprise a low salinity layer (LSL) overlying sea water. The salinity of the LSL ranges from 0 - 33 psu (practical salinity units or parts per thousand) compared with the salinity of sea water of 35 psu. Water movement within the Sound is characterised by an estuarine circulation where the LSL moves seaward, entraining and causing a slower return of sea water towards the head of the Sound (refer Section 3.9.3).

Computer modelling studies of the effects of the freshwater discharge, both natural and from the station, on the circulation in Doubtful Sound have been used to attempt to predict the effects of the increased discharge, particularly the effects due to the proposed second tailrace. Known and possible impacts of increased freshwater discharge have been identified by Mladenov (1995), including:

(i) An increased level of freshwater discharge.

(ii) Increased velocity of surface currents.

(iii) Alteration of the structure of the intertidal communities in the Deep Cove area.

(iv) Changes to the upper and lower limits of subtidal benthic fauna.

This has helped to identify high priority physical and ecological parameters which can be monitored over time. This monitoring will provide the necessary information on the existing Doubtful Sound marine ecosystem and any additional effects of a possible future increase in the freshwater discharge from 509 cumecs to 630 cumecs.

11.1.1 Freshwater Influence in the Sound

Issue: Mladenov (1995) described a potential impact of the existing discharge into Doubtful Sound as an increase in the overall scale of freshwater influence.

Discussion: The existing tailrace discharge produces about twice the mean natural freshwater discharge (343 compared with 209 cumecs), giving the Doubtful Sound system the greatest freshwater influence (in terms of mean inflow to area ratio) of all the New Zealand fiords. It is almost comparable in this respect to Milford Sound. However, in terms of maximum freshwater inputs during flood conditions, the freshwater influence is likely to be much less than that of Milford Sound, which has a much larger ratio of catchment to fiord area than Doubtful Sound.[98] A circulation model of the tailrace discharge[99] shows that about 75% of the tailrace water discharges into the ocean via Doubtful Sound, and 25% via Thompson Sound.



Figure 67 – Discharge of tailrace channel and Lyvia River into Deep Cove

Initial work by Bowman and Deitrich (1995a) predicted changes in water currents, temperature and depth of the low salinity layer for 4 discharge scenarios. The early findings conclude:

- Under tailrace discharge of 200 cumecs and natural discharge of 67 cumecs, the low salinity layer (LSL) will reach a depth of 4m in Doubtful Sound and 1.5m in Thompson Sound.
- Under tailrace discharge of 350 cumecs and natural discharge of 135 cumecs, the low salinity (LSL) layer will reach a depth of 5.5m in Doubtful Sound and 3.2m in Thompson Sound.
- Under tailrace discharge of 465 cumecs and natural discharge of 270 cumecs, the LSL will reach a depth of 8m in Doubtful Sound and 4.5m in Thompson Sound.
- Under tailrace discharge of 650 cumecs (note that the maximum discharge for the resource consent is only 510 cumecs) and natural discharge of 270 cumecs, the LSL will reach a depth of 10m in Doubtful Sound and 6m in Thompson Sound.

In this initial work Bowman and Deitrich defined the depth of the LSL as where salinity first reaches 35psu; that is, the salinity of oceanic sea water. They note this is an arbitrary definition. Salinity measured on the surface varies from about 1psu near the discharge point of the tailrace into Deep Cove to 30psu near the entrance to the fiord. The tailrace "jet" is the body of water positioned at about 2m over most of the length of the fiord. The salinity at this depth is about 18psu.

The relative contribution of tailrace water has been compared with natural rainfall runoff during the extreme discharge scenario.[100] The natural runoff in Doubtful Sound is 4757 cumecs during the mean annual flood, and 7616 cumecs for the 10 year return flood. The mean natural runoff flow is 205 cumecs and the median flow 102 cumecs. The maximum existing tailrace discharge (509 cumecs) in relation to this natural runoff is therefore 10.7 % (mean annual flood) and 6.7% (10 year flood). The increase in discharge due to the second tailrace discharge is 121 cumecs, which is 2.5% of the mean annual flood and 1.6% of the 10 year flood.

Rainfall in Fiordland is a dominating influence on the environment. As a result, storm events influence the LSL in Doubtful Sound, even if that influence is of short duration. Peak flows during storm events occur over a period of the order of 24 hours.

Additional modelling undertaken by Bowman and Dietrich (1995b) shows that the LSL quickly deepens in response to a storm event, stabilises and then rebounds to pre-storm event levels at a much slower rate. Dependent on station discharge, the additional model runs reveal that maximum LSL thickness during 10 year return period storm events and 500 and 580 cumecs station discharge scenarios is 20.7m(±2m) to 21.9m(±2m) respectively. This depth is defined at the 33psu isohaline. For the one year return period storm event scenario concurrent with a station discharge of 500 and 630 cumecs, the 33psu isohaline reached a depth of 14m(±2m) and 20m(±2m) respectively. To date, validation of the model by direct comparison with real observations has not been done. Therefore the model results are only an indication of LSL behaviour and do not accurately predict the depth of the LSL.

Conclusion: The tailrace discharge possibly contributes significantly to the depth of the LSL during low and normal natural runoff conditions. However, under flood conditions, the modelling suggests that storm events have a major influence on the depth of the LSL. Precise model predictions are not yet possible.

Future Management: To correlate these predictions with natural events, ECNZ will commission an ongoing monitoring programme to measure the vertical distribution of salinity allowing the depth of the LSL to be determined in the fiord system. Milford Sound will be used as a "reference" site to further refine the predicted effects of the tailrace discharge on circulation. The study should allow the computer model to be validated, and more accurate predictions of LSL depth changes with increased tailrace discharge.

11.1.2 Surface Flow Velocity

Issue: Mladenov (1995) described a potential impact of the existing discharge into Doubtful Sound as a higher velocity of surface flows in Deep Cove.

Discussion: The tailrace discharge has a strong local effect, increasing the velocity of surface currents in Deep Cove under low and mean natural inflows. Preliminary conclusions from an uncalibrated model of the circulation of Doubtful Sound (Bowman and Deitrich 1995) suggested that the speed of the tailrace water flow entering Deep Cove is between 0.6 and 1.25 metres per second, depending on discharge volume. The actual surface flows have been measured with drifters as 0.8 to 1.4m/sec at the top of Deep Cove. The velocity of the jet slows as it leaves Deep Cove and enters the main sound.

The model developed by Bowman and Deitrich (1994) shows that it takes freshwater entering Deep Cove 6-8 days to travel through the fiord to the ocean. There is a weak return current of sea water under the freshwater jet, the speed of which is less than 0.03 metres per second. Pelagic larvae of marine organisms are likely to use this weak return current to facilitate colonisation of the inner sound. The changes in the velocity of this weak return current are unlikely to affect larval recruitment of the inner sound.

Conclusion: The tailrace discharge most probably has an effect on surface flow velocity in Doubtful Sound.

Future Management: Environmental effects of an increase in flow velocities will be monitored (see Appendix IV). The monitoring programme will further refine information from the computer model, allowing better predictions of the flow velocities in Doubtful and Milford Sounds including those under natural inflows during floods.

11.1.3 Ecological Effects of Freshwater Discharge

Issue: The ecological effects of the increased discharge of freshwater into Deep Cove are unknown.

Discussion: The only known impact of the increased freshwater discharge on the ecology of the fiord has been an alteration in the range of the intertidal communities in Doubtful Sound.[101] Observations made during a preliminary survey of this habitat[102] indicate an effect of the present freshwater discharge is that barnacles, mussels and other intertidal fauna, along with the brown alga *Hormosira banksii,* have been displaced from the intertidal zone in Doubtful Sound in favour of more freshwater-tolerant species.



Figure 68 – Intertidal biota near the junction of Crooked Arm, August 1995

It is considered that, since the commissioning of the Manapouri Power Scheme, any effects of the present tailrace discharge have stabilised, and the Doubtful Sound marine ecosystem has reached an equilibrium in relation to that discharge. A recent survey of Black Coral in eleven other fiords shows that the upper limit of Black Coral ranges between 5.7m and 15.2m. The average depth in Doubtful Sound is 10m. This suggests that there is no evidence that the existing tailrace discharge has affected Black Coral, an indicator species of the subtidal rock wall biota.[103,104] However, the effect of an increased freshwater discharge is currently unknown.
Possible impacts of an increased discharge (from 509 to 630 cumecs) on the flora, fauna, and ecology of Doubtful Sound are:[105]

- A change in black coral communities if their upper limit is reduced through thickening of the LSL.
- Changes in the upper and lower limits of other subtidal benthic fauna through changes in the thickness of the LSL, changes in light levels, and/or changes in plant productivity.
- A change in subtidal benthic algae growth through changes in light levels due to thickening of the LSL.
- Alteration of the frequency of phytoplankton blooms through changes in the seasonality and/or periodicity of freshwater discharge.

Changes in black coral and other subtidal benthic fauna appear likely to be or at least partially controlled by episodic deepening of the LSL caused by floods.[106] Section 11.1.1 indicates the likely contribution of the existing and second tailrace discharges to these flood events is small.

Conclusion: Recent studies have shown that Doubtful Sound distributions of subtidal rock wall biota are comparable with other fiords in the region and there is no evidence of any effect of the existing tailrace on these communities. However, there may be possible ecological effects of an increase in discharge above 510 cumecs. The state of current knowledge is not sufficient to predict the certainty or extent of any effects due to such an increase. For this reason, ECNZ propose to limit the freshwater discharge to it's current maximum of 510 cumecs.

Future Management: ECNZ intends to fund an ongoing monitoring programmes to measure changes in black coral communities and the density and distribution of the intertidal and subtidal fauna and detect any possible impacts of the freshwater discharge into Deep Cove. These studies will include a baseline study of Black Coral as well as other subtidal and intertidal fauna of Deep Cove. Milford Sound will be used as a reference site to identify changes that are not site specific.

It is proposed that the SRC be empowered in terms of the RMA to review the consent within six months of receiving a report from the Department of Conservation and ECNZ recommending review.

11.2 Water Quality

Issue: Mladenov (1995) considered a possible impact of increased freshwater discharge as an increased input of suspended sediment into the fiord system.

Discussion: Essentially, water drawn into the turbines from Lake Manapouri has a high visual clarity and contains little sediment, apart from some humic material which leachs into the water from native beech forest runoff, giving it a dark colour. Larger floating particles are caught in the trashrack at the intake gates. Mladenov's work concluded that particles smaller than 63 microns in size are likely to remain in suspension and be carried to the sea.

The visual clarity of the tailrace discharge is "very clear,"[107] with correspondingly low turbidity and low suspended sediment content, particularly in relation to similar New Zealand rivers surveyed in the NIWA "100-rivers survey".

The Lyvia River (being the main natural inflow into Deep Cove) is generally less clear than the tailrace water from Lake Manapouri. During flood conditions, the Spey and Lyvia Rivers are comparatively turbid and strongly coloured. As a result, the surface water layer in Deep Cove may be appreciably more coloured and turbid than normally.[108]

The Southland transitional Regional Coastal Plan[109] has classified the waters of the Fiordland coast, including those of Milford and Doubtful Sounds, as Class SB waters. The standards for SB waters are included in Appendix II. Current MfE guidelines for these receiving waters are that visual clarity should not be changed more than 20% where "visual clarity is an important characteristic of the water body". For other waters, visual clarity should not be changed by more than 33-50%, depending on site conditions.[110]

Available evidence suggests that effluent from construction of the second tailrace will probably contain appreciable strongly light-attenuating material. Refined calculations have been made of dilution flows in the tailrace to ensure that visual clarity will not be reduced more than 20, 33 and 50% lower than in the Lyvia River. These calculations show that for a change not greater than 20%, the tunnelling effluent (after flocculation treatment to < 30 gm^{-3} suspended solids), can be assimilated in the tailrace flow when dilution exceeds 110-fold. The dilution is greater except at very infrequent low flows from the station (less than 100, 62 and 34 cumecs) respectively, when effluent flow is at the predicted maximum of 0.9 cumecs). Flows less than 100 cumecs occur less than 4.5% of the time.[111] A model of light transmission, calibrated with data obtained on-site with optical instruments, suggests that discharge of treated construction effluent will have little effect on light penetration in Deep Cove so long as visual clarity is less than 20% (corresponding to 110-fold dilution).

Conclusion: There is no potential environmental effect due to levels of sediment from the tailrace discharge. Guidelines for water quality are available for avoiding environmental effects.

Future Management: The following rules have been developed to ensure any environmental effect is avoided, including protection of visual clarity, particularly during construction of the Second Tailrace Tunnel.

- Maximum Size of Sediment Discharged
  To ensure all construction sediment discharged does not settle in Doubtful Sound, the minimum level of treatment for all collected water shall be designed such that there is assurance that no sediment with a particle size greater than coarse silt (0.063mm) is discharged into the receiving waters.
- Quality of Discharge to Receiving Waters at All Times

Deep Cove

The receiving waters will be the waters of Deep Cove beyond the end of the tailrace berms.

The quality of the tailrace waters discharged to the receiving waters will comply with the following rules for minimum visual clarity.

- For a Q/q (dilution) ratio of < 100 ; the clarity of the tailrace water discharged shall not be less than 67% of the pre-determined median clarity of the Lyvia River. This is equiva lent to a 33% reduction standard. It is expected to be applicable to flow situations that occur at most 4.5% of the time and probably less than 2% of the time.
- Q = tailrace flow in cumecs and q = total construction effluent flow in cumecs
- For a Q/q (dilution) ratio of > 100 ; the clarity of the tailrace water discharged shall not be less than 80% of the pre-determined median clarity of the Lyvia River. This is equiva lent to a 20% reduction standard. It is expected to be applicable to flow situations that occur at least 95.5% of the time and probably more than 98% of the time.
- Except that if Lyvia clarity is naturally less than 80% of the pre-determined median clarity in any adjacent 12 hour period the clarity in the tailrace shall not be less than that naturally lesser clarity. The intent of this exception to the general rule is to cater for runoff, including the Spey River contribution, in the larger but infrequent storm events.
- The pre-determined median clarity of the Lyvia River is 5.68 metres.[112]

The concentration of total petroleum hydrocarbons at the discharge point to the tailrace will not exceed 15ppm.

During the planned station outage the visual clarity rules set out above will be complied with. However it is recognised that on station start up at the end of the outage there may be a short pulse of water which does not comply with these rules. All reasonable steps shall be taken to avoid, as far as practicable, the sediment discharged at this time.

West Arm

The receiving waters will be the waters of the Spey River.

The visual clarity of the water in the Spey River downstream of the discharge point will not be reduced by more than 20% of the pre-determined median clarity of that upstream after a zone of reasonable mixing.

The pre-determined median clarity of the Spey River is 6.36 metres.[113]

Chapter 12 – Social Impact Assessment

Socio-cultural assessment forms a crucial part of any AEE. The approach to both environmental and social aspects of the Manapouri Power Scheme has, over time, acknowledged the significance of public interest, knowledge, concerns and input to the programme.

In the Waiau catchment, there are clear interactions between the physical and social environments. Historically, the lakes, rivers and shores have been valued for their contributions to local livelihoods as well as for their aesthetic appeal. The consultation process, scoping and issues identification, outlined in Sections 5 and 6, address the role of social impact assessment in this resource consent application process as a means of facilitating the identification and mitigation of potential social impacts. The agreements entered into with the Waiau Working Party confirm the intent to both satisfy local requirements and ensure that issues are managed both at present and in the long term.

The assessment of the social impacts of the operation of the Manapouri scheme has focused on those aspects of water diversion, use and discharge which might affect the quality of life of nearby residents and their community, perceived inequities and questions of trust in both the scheme operator and its business base. Through the participation of a diverse group of people in the WWP and the community at large, ECNZ has developed environmentally and socially responsive impact mitigation and compensation policies.

Two aspects of public involvement are highlighted in this document: the way in which the public were part of the process to plan for future operation of the scheme and the ways in which their concerns were managed. The process focus of the former established a workable approach to the substantive issues of the latter and ensured that all factors of water use for the Manapouri Power Scheme were openly and fairly addressed.

It is generally acknowledged that social acceptance drives many technical project consent applications, and the outcome of the community and agreements process bears that out. Issues derived from changes in river flow have been raised throughout the consultation process. Those issues which have a strictly physical or ecological basis are discussed in Sections 8-11. It is those issues that cause a change in lifestyle, amenity, customs, values, aesthetics or fortune that are social issues and for which the majority of agreements have been developed.

Clearly, the Manapouri Power Scheme was initiated to generate electricity to serve business and community needs in Southland. While this project was initiated to meet an identified need and to contribute positively, benefits and impacts have had various distributions nationally, regionally and locally.

12.1 Iwi Issues

12.1.1 Introduction—The Mauri of the River

The mauri (life force) of a river is central to the beliefs and perceptions that Maori hold on the environment and their relationship with it. Mauri of a river can be depicted in terms of its size, quantity, quality, force, volume and flow; as well as the river's "amenity value" as a provider of water, food resources and habitats to the Maori community, and its uses in activities such as burials and purifying rituals.[114]

The effects on this life force are, in a broad sense, proportional to the reduction and modification of flows which have resulted from diversion, coupled with the corresponding reduction in "amenity value". However, where a continuous flow exists, the mauri will continue, the degree of which is dependent on the corresponding "amenity values" which also exist.

The reduction in flow down the Waiau River has depleted the mauri and impacted on cultural values and river uses, particularly mahika kai. Therefore, mitigation and enhancement measures taken as a result of deliberations relating to the diversion of water will allow some revival of the mauri of the Waiau River. When attempting to restore the mauri, it is perhaps most important to ensure:

- A continuous flow from headwaters to river mouth is provided at all times, as a necessary first step towards restoring the mauri.
- The Waiau River should be treated with respect. If the river is not respected then its mauri will be lost.



Figure 69 – Whitebaiting hut, Lower Waiau River

Measures outlined in this Application for Resource Consents are designed to both provide a continuous flow, and allow for the river to be respected through community participation in the identification and execution of mitigation measures.

12.1.2 Mahika Kai

Issue: A significant amenity value to Maori is the provision of traditional food resources (mahika kai). Numbers of eels in the river have lessened over the last 30 years. Reduction in flows may have contributed to this and possibly other mahika kai species dependent on the river.

Discussion: The mahika kai resource of the Waiau River is dominated by eels. Eels are more abundant in the lower river than the upper river catchment, but are still sufficient everywhere for the casual fisherman to take a catch.[115]

The river between the Monowai confluence and Mararoa Weir principally acts as a pathway for native fish migrations. The Mararoa Weir, Lake Te Anau Control Structure, and Monowai weir all present obstructions to eel and other native fish migrations. However, some eel recruitment still occurs, and eels are well adapted to maintaining stocks in areas where recruitment is poor.[116]

Conclusion: Mitchell and Davis-Te Maire (1994) explain that agricultural and forestry development, and commercial overfishing were major factors in the reduction of mahika kai resources. The only traditional foods still available for harvest (apart from fernroot) are of aquatic origin. These foods have long been under harvesting pressure, particularly from commercial eeling. The Te Waewae Lagoon remains the richest source of mahika kai in the catchment.

The Mararoa Weir presents a barrier to native fish migrations (see Section 10.4.7). However, some eel recruitment into the upper catchment still occurs.

Future Management: The new 12-16 cumec minimum flow regime will provide improved migration access for native fish to pass the Mararoa Weir. Development and installation of effective native fish passes on the Mararoa Weir (Section 10.4.7) and Te Anau control structure (see Section 9.4.1) will allow enhanced elver recruitment into the upper catchment. It is believed adult eels will also use the proposed Borland trout fish pass.

In addition to these mitigation measures, ECNZ will sponsor through trust agreements the following mahika kai enhancements:

1. Creation of further whitebait habitat in the Waiau Lagoon through the Habitat Enhancement Trust (see also Section 10.4.6).
2. In agreement with local iwi, identify and purchase one or more areas of private land to be vested with local iwi and managed as mahika kai areas through the Mahika Kai Trust. Such areas will also enhance the natural values of the Lower Waiau River.

12.1.3 Downstream Migration of the Heke (Mature Eels)

Issue: It has been thought that the majority of heke (mature eels) migrating from the Upper Waiau catchment to the sea to spawn are attracted to the outlet flow at the West Arm powerhouse. Heke and other native fish would probably be killed if they passed through the powerhouse turbines.

Discussion: The heke migrate on or just in advance of flood flows. It has been estimated that for 50% of the migration period (1 February to 30 April) there is a flow release at the Mararoa Weir. Furthermore, for 39% of time there is a flow release from Lake Manapouri at the Mararoa Weir. Although some heke will be attracted to the outlet flow at the West Arm powerhouse, it is expected that these flood releases over the Mararoa Weir will allow approximately 50% of the heke to migrate to the sea unharmed. The more productive eastern shores and the proximity of the Lake Te Anau outlet to the Lake Manapouri outlet mean that more heke may move along the short route of the eastern Manapouri shoreline to find the outlet to the Lower Waiau River, than follow the lake shore to West Arm. Therefore, this 50% estimate is possibly a minimum.[117]

Of concern to the sustainability of the eel fishery is the turbine mortality of eels migrating back to the sea to breed. It has been recommended that trapping the heke and releasing them elsewhere be investigated.[118]

Adult eels migrating through the power station may have a chance of surviving the turbines.[119] The chances of smaller heke surviving passage through the turbines was calculated to range between 13 and 25%.[120] Mitchell has calculated that eels smaller than 45 cm will survive. Larval fish, bullies and galaxiids are probably capable of passing through turbines with low mortality because of their small size.[121]

Conclusion: It is considered that approximately 50% of heke from the upper catchment migrate to the sea unharmed. Small heke and native fish can pass through the powerhouse turbines unharmed. Despite this, some heke are killed by attempting to migrate to sea via the powerhouse turbines.

Future Management: Initial studies into the actual movement of heke are proposed. If it is then evident that sufficient numbers are not escaping on the freshes, then a trapping and transport programme may be established to move heke past the power station intake for release into Deep Cove. This 5-year study programme will be carried out in association with DOC (in conservation areas) and Ngai Tahu through the Mahika Kai Trust (see Section 14.6).

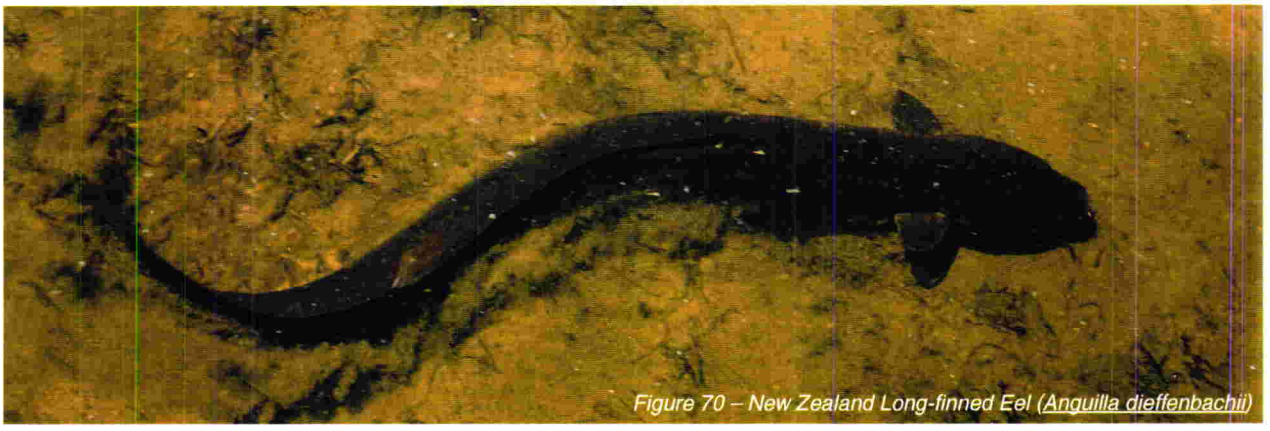


Figure 70 – New Zealand Long-finned Eel (Anguilla dieffenbachii)

12.2 Community Issues

12.2.1 Riparian Issues

Issues:

- Flow management in the Lower Waiau River has led to problems with noxious weeds and pest encroachment onto the exposed riverbed, and areas of weed recolonisation on productive lands.
- Flow reduction has caused riverbed exposure, negating the river's use as a stock boundary.
- Vegetation encroachment onto the riverbed was thought to exacerbate localised erosion in the riverbed, with loosely formed sand and gravel bars being stabilised by weed growths.



Figure 71 – Fencing along the Lower Waiau River

Discussion: Since the inception of the Manapouri Power Scheme, ECNZ and its predecessors have assisted in the funding of ongoing river works in the Lower Waiau riverbed including weed and pest control, erosion and river control works (including willow planting), and assistance with riparian stock fencing. In addition, ECNZ and its predecessors purchased various lands which had been prone to riverbank erosion.

Weeds in the river channel are frequently dominated by gorse, broom and willow, as well as toetoe and ragwort. Gravel bars in the riverbed mainly support grasses, gorse, broom and willow.[122] Weed encroachment onto the riverbed has intermittently been removed by spraying and occasional flood events, with most active gravel bars in the riverbed being sparsely vegetated.[123]

A series of reports from Duffill Watts and Davis on specific erosion problems along the Lower Waiau River mentioned willow planting as a factor in erosion management, but not weed encroachment. Further investigations into the causes of erosion by Brierley (1994a) found that erosion in the river channel was largely the result of major flood events (see Section 10.3.6). Therefore, the effects of vegetation encroachment on localised erosion in the riverbed are probably not significant.

Conclusion: Problems with weed/pest colonisation of the exposed riverbed, and stock fencing, have been managed since flow control began. Erosion in the Lower Waiau River channel is principally caused by large flood events, although willow plantings can have a contributory effect.

Future Management: A riverbed management programme will continue, in agreement with local landholders and SRC, or a rating district, to ensure problems with weed encroachment, stock fencing and erosion are properly managed. ECNZ will continue to fund this management programme.

12.2.2 Natural Character and Amenity Values

Issue: The "natural character" of the Waiau catchment has been adversely affected by the Manapouri Power Scheme. In particular, it should be determined whether river diversion has caused a loss of natural character, amenity value and aesthetic enjoyment along the Lower Waiau.

Discussion: A study on the landscape and amenity values of the Lower Waiau River [124] found the landscape effects of various flows to largely depend upon the physical characteristics of the river reach in question. The greatest effects of different flows occur in the braided reaches. In confined river reaches, flow changes have little impact on appearance. Landscape effects are most visible in reaches from the Mararoa Weir to Sunnyside, at Clifden and at Tuatapere. The effects on landscape values are reflected in changes to river flows and access to the river.

The greatest benefit from a minimum flow regime occurs with flows between 11 and 18 cumecs, and then gradually diminishes after that.[125,126] The landscape effects of a minimum flow regime generally diminish further downstream as the effects of tributary flows become more prominent. There is little overall increase in landscape and amenity values during flow releases greater than 18 cumecs, except when tributary flows are very low, and in the area immediately below the Mararoa Weir. In particular, the old Duncraigen rock weir forms an artificial constriction which downgrades the landscape value of the area at low flows.

The natural character of the Lower Waiau River at Tuatapere is retained at flows greater than 70 cumecs. Rackham (1995) was unable to assess the natural character of the Lower Waiau River at Tuatapere below 70 cumecs. However, controlling flows at the Mararoa Weir to provide a 70 cumec minimum flow at Tuatapere would be difficult, because tributary influences are strong and there would be considerable adverse ecological effects of constantly varying flows below the weir. Rackham (1995) states that even at very low flows, during dry periods, the Lower Waiau River will retain a natural character similar to other Southland rivers. The Lower Waiau River continues to retain a "natural character" of its own, but hydro-electric power development has changed this natural character from a "big river" to a "smaller river" environment. The Lower Waiau has a natural character similar to that of the Mataura River in places (Figure 72).

The effect of the discharge at Deep Cove has had no noticeable effect on the natural character of the coastal environment. The water added from the discharge is not easily perceivable since the discharge is joining a much larger mass of water. There are no perceivable effects on colour or clarity.

Conclusion: Reinstatement of a "big river" would not be possible without significant loss of power generation. However, Rackham (1995) considered that restoration of a "considerable degree of landscape and amenity value over most of the river" was achievable at minimum flows of between 11and 18 cumecs.

Future Management: Restoration of landscape character features will be achieved with the 12-16 cumec minimum flow regime. As part of the Habitat Enhancement Trust, modifications to the area will occur around the Duncraigen rock weir to enhance the instream habitat and landscape values of this area at 11-18 cumec flows.

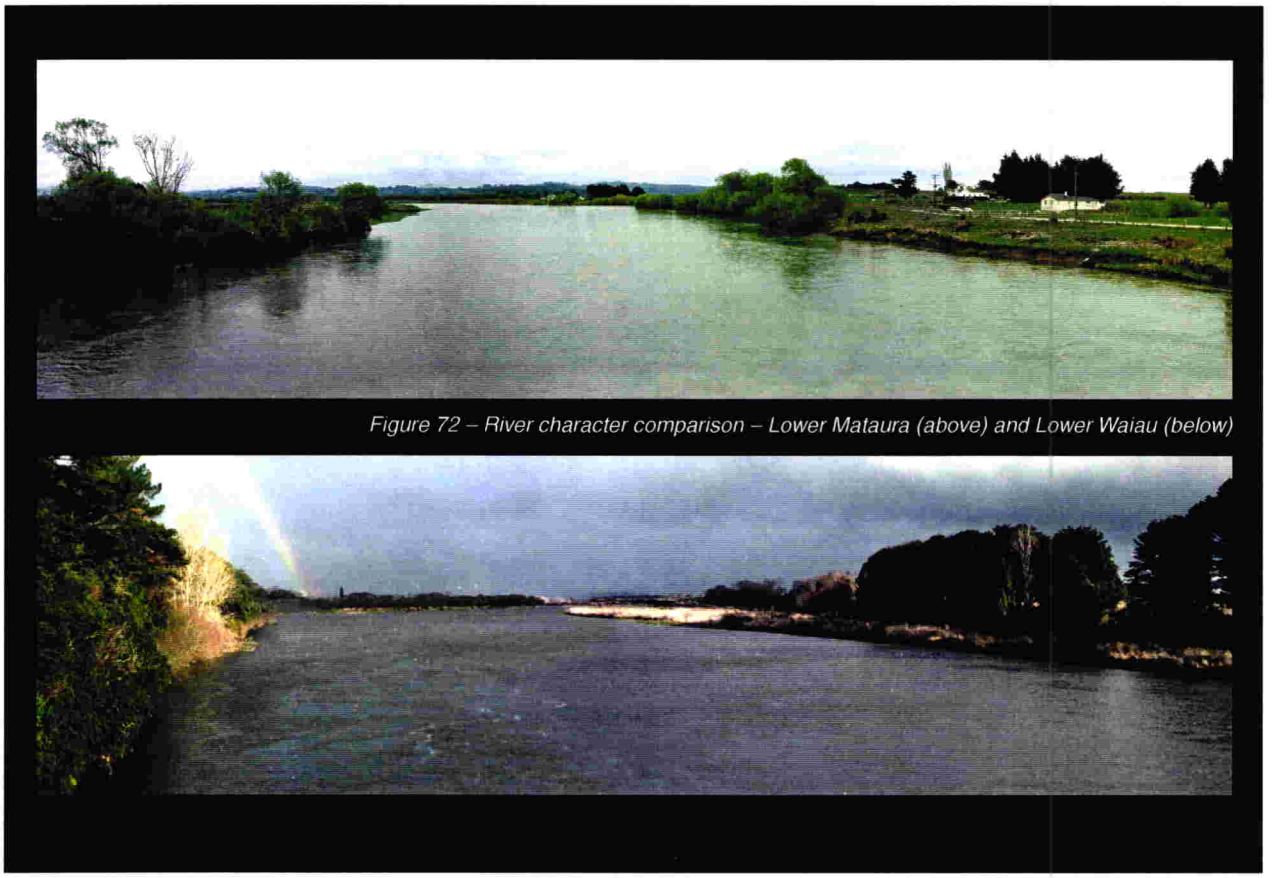


Figure 72 – River character comparison – Lower Mataura (above) and Lower Waiau (below)

12.2.3 Tuatapere Water Supply

Issue: Difficulties with the river water supply to Tuatapere township have occurred since river control in 1974. The town's river pumps are often inoperable for months when the river is too high and turbid.

Discussion: The river pumps can supply water at about twice the rate of bore pumps. 55% of the town's water is from the river, and 45% from groundwater. Generally, town supply water is sourced from groundwater bores for protracted time periods because of the long time the river takes to clear.[127] As the present supply arrangement seems inadequate, it has been recommended that investigations be made of alternative schemes to deliver high quality water with 100% continuity of supply (see Section 12.4.2). It is noted that difficulties with water supply coincided with the change from rain water supplying the town.

An analysis of the methods for improving the Tuatapere water supply has been conducted by Royds Consulting Ltd (1995). Their recommendations for upgrading will enable the township to enjoy good quality, reliable, sustainable, good tasting drinking water, equivalent to at least a Department of Health "B" ("satisfactory") grading.

Compensation: Through the Waiau Valley Amenities Payment (see Section 14.8), ECNZ has agreed to sponsor the community to cover the capital costs of upgrading, operating and maintaining the water supply.

12.2.4 Groundwater

Issue: Reduction in the flow of the Lower Waiau River has led to a reduced water table, making extraction of water from groundwater bores more difficult.

Discussion: Detailed groundwater analysis was undertaken around the time of construction of the Mararoa Weir, and this information has been updated. ECNZ instigated a quarterly groundwater monitoring programme beginning in January 1993[128] which showed that the groundwater levels bear little relationship to river levels. Because of the high permeability of the soils in the region, the water table is mostly affected by groundwater seepage from surrounding hill country. Indeed, stream water is supplemented to a considerable extent by groundwater runoff during dry periods.[129]

Conclusion: Reduction in river flows has not affected groundwater levels.

12.2.5 General Amenity Effects

Issue: Consultation via the WWP revealed a perception within the Tuatapere community that there has been a loss of general amenity value and opportunity resulting from the Lower Waiau River changing from a "big river" to a "smaller river".

Discussion: The Tuatapere community has discussed the general amenity values and opportunities which may have been affected by reduction in flows. These include:

- Loss of potential industrial opportunity. Large industrial opportunities requiring a major water resource (eg. pulp and paper mills) are now less able to establish in the area.
- Loss of local nature and adventure tourism opportunities. With the reduction in the unique "big river" grandeur, there is less attraction for tourists to visit the area. While there are major regional benefits to tourism through development at West Arm (see Section 7.4.1), these benefits have not been enjoyed by the Tuatapere community.
- Loss of general amenity value of the large water resource may have affected property capital values.

Conclusion: The Tuatapere community believes it has suffered a loss of general amenity values from reduction in flows. Although a 12-16 cumec minimum flow is to be restored in the upper reaches of the river, this will have only a minor effect at Tuatapere and not restore the lost amenity values there.

Compensation: In addition to upgrading the water supply, ECNZ has agreed to provide the Tuatapere community with funds, held in trust (the Tuatapere Amenities Trust), which the community can use to develop infrastructure to improve other "amenity" values and opportunity in the community, independent of the flow situation in the river.



Figure 73 – Kayaking the Lower Waiau River

12.3 Recreation

General recreation will be enhanced by the new flow regime restoring aesthetic and amenity values for these activities.

12.3.1 Access

Issue: Although reduced flows have made pedestrian access along the river somewhat easier, recreational access by boats has been limited (see Section 12.3.2). Weed growth in the riverbed and excessive periphyton on the rocks can also impede foot access along the riverbed.

Discussion: Access will be especially important for the community to enjoy the maximum benefits of the new flow regime, particularly the expected enhancement to landscapes and fishery. The issue of vegetation encroachment onto the riverbed is discussed in Sections 10.4.8 and 12.2.1. The issue of algal growths in the riverbed is discussed in Section 10.4.1.

Compensation: To enhance the opportunities for recreational enjoyment of the Lower Waiau, ECNZ has proposed to upgrade two legal access points leading from the main road to the river for passage by foot or four-wheel drive vehicles, funded as part of the Habitat Enhancement Trust.

12.3.2 Jetboating

Issue: The Waiau is the only river in Southland which has no speed restrictions for jetboating. However, reduced flows have made the river above the Monowai confluence virtually unusable for jetboating except during freshes and organised flow releases. Lower flows have also made physical access to boat launching areas more difficult.

Discussion: Jetboating club events occur about twice a year. A trial of flows required for safe jetboating for these events was conducted by the Southland Jet Boat Association and showed that a 35 cumec flow was sufficient for jet boating events on the Waiau River, and possibly other boating activities. Timing of "recreational flow releases" was crucial, as the increased flows take some time to filter through the system.[130]

Conclusion: Consultation with the Southland Jet Boat Association has resulted in a new flow regime to be specifically designed to allow sufficient jet boating opportunities during the summer months.

Future Management and Compensation: To further enhance the enjoyment of additional "recreational flows" for jetboating, ECNZ has, in consultation with the Southland Jet Boat Association and the WWP, agreed to sponsor, through the Waiau Valley Amenities Payment (see Section 14.9), installation of two new boat ramps on the Lower Waiau. One will be placed at Monowai, the other at Tuatapere. In addition, the existing boat ramp at the Waiau estuary will be upgraded, together with the provision of toilet facilities. Other boat ramps which are not easily used during times of low water levels will be extended. Maintenance of the boat ramps and toilet facilities will be the responsibility of SDC.

ECNZ proposes to enable passage all the way to the weir for specific events by release of "recreational flows" from the Mararoa Weir the fourth Sunday in each month from October to April. Such flows will be 35 cumecs, for 24 hours at a time (to allow the flow to continue through daylight hours in the summer months). Two of these flows may be increased to 45 cumecs by agreement between ECNZ and the Southland Jet Boat Association.



Figure 74 – Jetboating on the Lower Waiau River



Figure 75 – Angling near Redcliffs

12.3.3 Angling

Issue: River control on the Lower Waiau has reduced flows considerably and, consequently the amount of water available for fish habitat and fishing. Representatives of the Tuatapere community have mentioned that a safari fishing venture on the Lower Waiau ceased operation shortly after flows were reduced in 1974 because the fishing was not considered as good as it had previously been. Further opportunities for fishing guides were therefore lost.

Discussion: Studies of recreation in the Waiau catchment conclude that the rivers of the Upper Waiau are of "high" value.[131] The Lower Waiau has an importance grade similar to the Aparima River in Southland.[132]

Anglers' perceptions have suggested that, before control, the Lower Waiau had been amongst the top trout fishing rivers in the South Island. The proposed 12-16 cumec minimum flow would restore this river as one of the top 10 trout rivers in New Zealand[133] (see also Section 10.4.3). A 12 cumec flow would also prevent the buildup of periphyton and sediment in the riverbed.[134]

Conclusion: The 12-16 cumec minimum flow should restore many of the fishery values of the Lower Waiau, while retaining the benefits of improved angler access along the river. Access to the river will be further improved by provision of 2 more public access points (see Section 12.3.1). It is expected that the improved fishery will also restore fishing guiding opportunities. Flows greater than 15 cumecs could reduce angler access along the river, and make river crossings dangerous.

Future Management: The proposed 12-16 cumec minimum flow regime will restore the Lower Waiau fishery to its place amongst the "top 10" in NZ. Fishing access will be maximised by the proposed flow regime.

12.3.4 Public Safety

Issue: Flood releases and other flow releases for recreational or river mouth opening purposes pose a threat to recreational users of the river.

Discussion: During a flow release, the Mararoa gates are opened progressively in "steps" as the flows increase. The step effect does reduce with distance downstream, but it is still quite evident at Tuatapere. This step effect occurs for both flow increases and decreases.

Although there is a rapid change in flows which can occur along the length of the river, the graduated flow releases from the Mararoa Weir will provide a measure of safety for recreational users. Users might be unable to cross the river on foot after a flow release, but this is a normal hazard for recreational users of flood-prone rivers in New Zealand. Signs have been erected at all public access points warning of the potential rapid changes in flow. Signs will also be erected where new access points are developed.

Conclusion: The graduated flow releases from the Mararoa Weir prevent dangerously rapid changes in flow from occurring. Signs have been erected at public access points.

Future Management: Warning signs will remain at existing public access points, and be erected at new public access points on the river.

Part 5

Outcomes of Consultation

Chapter 13 – Summary of Environmental Effects

13.1 National and Regional Effects of Lake Control

Effect	Actual/ Potential	Future Management to Avoid/Remedy/Mitigate/Monitor	Reference Section
Altered lake level regime	P	Guidelines established to manage levels within natural extremes to provide optimum generation potential while protecting the natural environment. Levels continuously monitored.	8
Flood control	A	Positive benefits. Allows capture and some control of rapid inflows.	10.3.2
Shoreline and beach erosion	P	Mitigated through setting of guidelines. Regular monitoring established.	8.3
Shoreline vegetation damage	P	Mitigated through setting of guidelines. Regular monitoring established.	8.4
Damage to littoral ecosystem	P	Mitigated through setting of guidelines. Regular macrophyte monitoring established.	8.5
Damage to aquatic birds	P	Mitigated through setting of guidelines.	8.6

13.2 Effects of Flow Control on Upper Waiau

Effect	Actual/ Potential	Future Management to Avoid/Remedy/Mitigate/Monitor	Reference Section
Impediments to smaller fish passage	A	Remedy through installation of native fish pass on control structure. Ongoing fishpass monitoring proposed.	9.4.1
Rapid flow fluctuations	P	Minimised through gate operating procedures. Flows continuously monitored.	9.1
Natural extreme low flows	A	Positive effect. Avoided through gate operating procedures.	9.1
Excessive bank erosion	P	Monitoring transects installed. Minimised through gate operating procedures.	9.2
Trout redd dewatering	P	Minimised through gate operating procedures. Spawning surveys ongoing.	9.4.3
Loss of boating through lake outlet	A	Mitigated through installation of boat ramp at Queen's Reach via WAA with SDC.	12.4.4

13.3 Effects of Manapouri Power Station and Deep Cove Tailrace

Effect	Actual/ Potential	Future Management to Avoid/Remedy/Mitigate/Monitor	Reference Section
Death of migrating eels through turbines	A	Investigation of the need for an artificial trap-transport program via Mahika Kai Trust.	12.1.3
Increase in average fresh water discharge	A	Ongoing monitoring to assess effects.	11.1.1
Faster surface flows in Deep Cove	A	Ongoing monitoring to assess effects.	11.1.2
Reduction in black coral communities	P	Monitoring black coral, using Milford Sound as "reference".	11.1.3
Changes in littoral flora and fauna	P	Littoral flora and fauna monitoring using Milford sound as "reference".	11.1.3

13.4 Effects of Flow Control on Lower Waiau River

Effect	Actual/ Potential	Future Management to Avoid/Remedy/ Mitigate/Monitor	Reference Section
Flow reversal of Lake Manapouri outlet	A	Does not occur when sediment levels exceed 30 NTU. Positive effect of enhancing rainbow trout spawning. Elver recruitment monitoring to continue.	10.3.1
Enhanced flood control capacity	A	Positive effect.	10.3.2
River channel maintenance	P	Erosion accretion monitoring proposed. Flushing flows instigated.	10.3.6 10.3.3 10.3.7
River mouth closure	P	Remedied through "mouth-opening" flows (150 cumecs) during spring and autumn. Lagoon water level recorder.	10.3.5
Excessive algal growths	A	Remedied through minimum flows and flushing flows. Algae monitoring to continue.	10.4.1
Macroinvertebrate habitat	P	Remedied through minimum flows and flushing flows. Macro invertebrate monitoring to continue.	10.4.2
Reduction in fish habitat	A	Mitigated through minimum flows and creation of habitated via WHET. Native and trout fisheries to be monitored.	10.4.5 10.4.3
Trout passage impeded at weir	A	Remedied through installation of trout fishpass at weir.	10.4.4
Native fish passage impeded at weir	A	Remedied through installation of native fishpass at weir	10.4.7
Native fish passage impeded at mouth	P	Remedied through "mouth-opening" flows (150 cumecs) during spring and autumn. Lagoon water level recorder.	10.4.7
Whitebait catch reduced	P	Mitigated through rehabilitation of whitebait spawning habitat on ECNZ-owned lands.	10.4.6
Flow effects on bird habitat	P	Mitigated through weed-spraying program in riverbed. Bird monitoring to continue.	10.4.8

13.4 Effects of Flow Control on Lower Waiau River *(continued)*

Effect	Actual/ Potential	Future Management to Avoid/Remedy/ Mitigate/Monitor	Reference Section
Restrictions on jetboating	A	Mitigated through recreational flow releases, two new boat ramps, upgrade one further boat ramp on the lower river via WAA with SDC.	12.3.2
Reduced recreational access	P	Provide 2 access tracks to the lower river under the objects of the Waiau Habitat Enhancement Trust.	12.3.1
Reduced recreational safety	P	Warning signs on all access points. Gate operating procedures to minimise "ramping rates".	12.3.4
Changes in aesthetic attraction from a "big" to "small" river	A	Minimum flow will restore aesthetics below Mararoa weir. Mitigated through recreational flows and trust agreements.	12.2.5
Loss of river life force ("mauri")	A	Mitigated through continuous minimum flow. Iwi consultation and Mahika Kai agreement.	12.1.1
Loss of mahika kai species - eels	A	Enhancement of eel passage through catchment. Upgrade of wetland areas via Habitat and Mahika Kai Enhancement Fund.	12.4.3 12.1.2 12.1.3
Riverbed weed and pest control	A	Remedied through an annual grant and rating subsidy by ECNZ for work carried out by the SRC.	12.2.1
Tuatapere water supply problems	A	Mitigated through WAA with SDC.	12.4.2

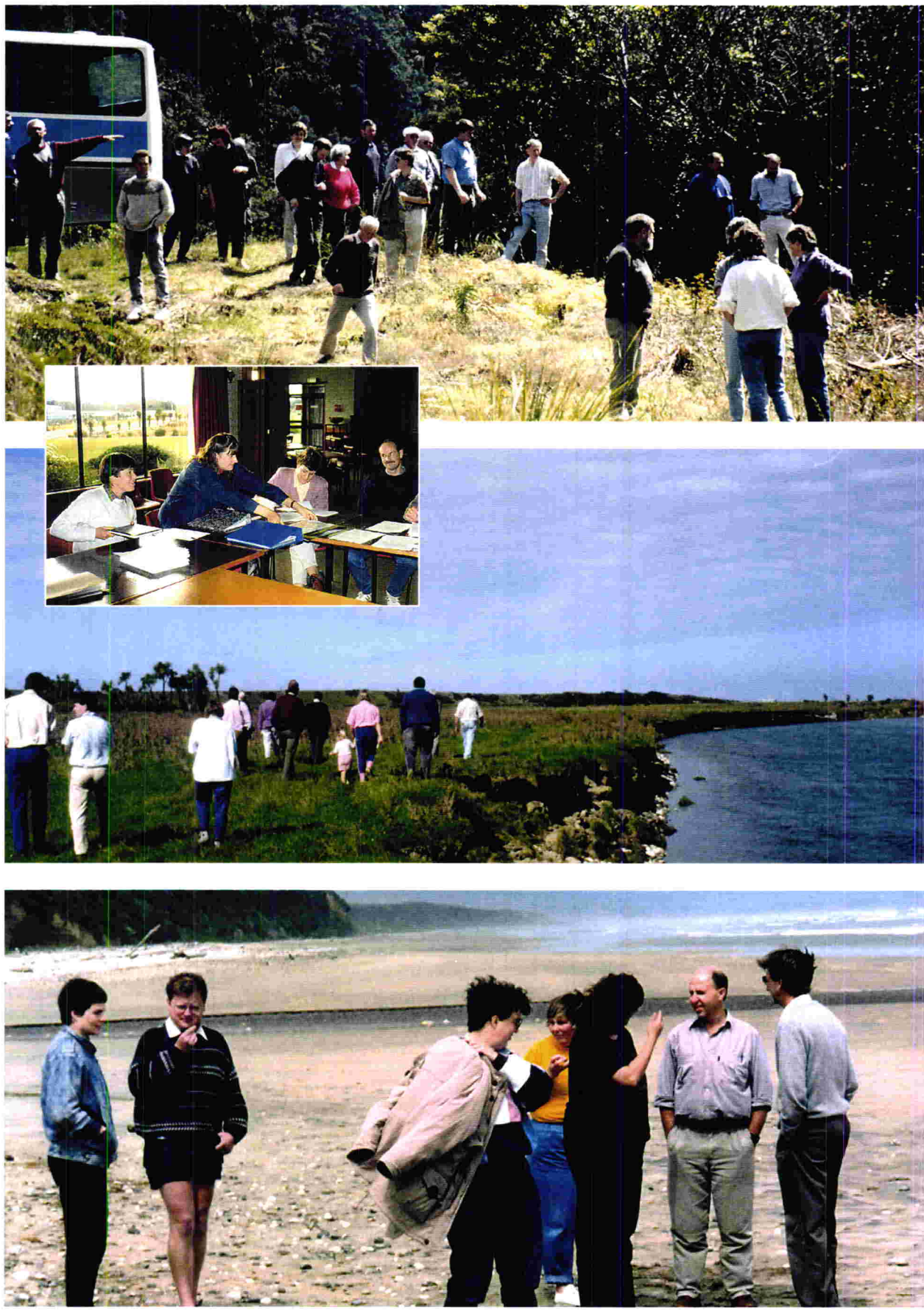


Figure 76 – The consultation process

Chapter 14 – Summary of Outcomes of Consultation

A. Introduction

ECNZ recognises the Manapouri Power Scheme has had a number of actual and some possible effects in the Waiau catchment as a whole and in Doubtful Sound. The major actual effect has been the significant reduction in the flow of the Lower Waiau River such that it has been changed from a "big river" to a "small river" in both normal flow and in landscape terms.

Large flows still occur during floods. Many potential effects have been minimised due to current management procedures such as the lake and gate operation guidelines. Others have been mitigated by measures such a riparian fencing and weed control.

There are also potential effects from the possible construction of a second tailrace tunnel to enhance the efficiency of the power station.

These matters have been the subject of public consultation which has extended over more than five years. The fora for this consultation have been:

- Public meetings
- Waiau Working Party meetings
- Meetings with individual stakeholders such as the Tangata Whenua, the Guardians of Lakes Manapouri and Te Anau, statutory authorities, and other interest groups.
- Latterly, over nearly two years, the Environmental Liaison Group meetings in relation to the effects of the proposed second tailrace tunnel, including discharges to Doubtful Sound.

Many issues have been raised, discussed, and studied. For those that have resulted in the conclusion that there is indeed an actual, potential or possible effect as a result of the Manapouri Power Scheme, ECNZ has developed a future management strategy and agreements for mitigation with affected parties.

The major element in this strategy is the provision of a new minimum flow regime for the Lower Waiau River that achieves a continuous flow from the lakes to the sea at all times. This will restore some proportion of the river's former cultural, recreational, landscape and habitat values. However it is recognised that the former "big river" will not be restored.

B. Future ECNZ Management of Effects

ECNZ's future management strategy to address the issues identified will be guaranteed as a set of conditions on water rights for future operation of the power scheme granted by the Southland Regional Council in terms of the Resource Management Act.

The measures to be implemented under this strategy are outlined in the following pages.

14.1 Lakes

14.1.1 Lake Control

Potential lake control effects will continue to be minimised by operation of the lakes within the Gazetted Guidelines.

To prevent or minimise any significant unforeseen adverse effects the Guidelines will continue to be reviewed as provided for under the existing legislation.

14.1.2 Monitoring

In addition to assessing the effects of this lake level management regime, the following will be re-measured within 5 years of water permits being granted and then monitored at 5 yearly intervals thereafter:

- Shoreline Sediments
- Shoreline Vegetation
- Littoral Macrophytes

14.2 Upper Waiau River

14.2.1 Minimum Flows

A minimum flow of 115 cumecs will be maintained except in the following circumstances:

- If lake inflows are low ECNZ may reduce flows to between 115 and 80 cumecs with the prior agreement of the Guardians and in consultation with the Southland Fish and Game Council.
- ECNZ will only release flows of less than 80 cumecs if required by the Southland Regional Council.

14.2.2 Flow Fluctuations

The potential effects of flow fluctuation on macroinvertebrates and trout spawning will continue to be minimised by maintaining gate operating procedures that restrict the rates of change of flow and flow fluctuations in any one day.

To prevent or minimise any significant unforeseen adverse effects the rates of change and fluctuations of flow will be made conditional to a review. It is proposed the Southland Regional Council be empowered in terms of the RMA to review the rates of change and fluctuations of flow within 6 months of receiving a report from the Waiau Working Party recommending review.

14.2.3 Native Fishpass Installation

A native fishpass will be installed on the TLC structure to ensure elver and native fish passage into Lake Te Anau is not hindered.

14.2.4 Monitoring

14.2.4.1 Periphyton and Macrophytes

To assess the effects of gate operating procedures and resultant flow regime, up to 5 transects will be established and assessed within 5 years of water rights being granted and then monitored at 5 yearly intervals thereafter.

Re-measurement will also be undertaken if flows of less than 115 cumecs occur for periods of 7 days or more.

14.2.4.2 Fish Passage

Provision for monitoring the effectiveness of the native fishpass will be made.

14.2.4.3 Erosion

Riverbank erosion will continue to be monitored by pegline survey at the Rainbow Reach and Village Pond sites. This will require re-establishment of the Rainbow Reach pegline.

Erosion monitoring will occur annually or after every flow event greater than 800 cumecs (10 year return period flood), measured at TLC.

14.3 Lower Waiau River

14.3.1 Gate Control

The potential effects of turbid water entering Lake Manapouri during Mararoa freshes will continue to be minimised by gate operating procedures which require water to be spilled when the turbidity of the Mararoa River exceeds 30NTU.

Current gate and lake control will continue to have a positive effect in reducing the volume of large floods by the combined effect of lake storage and power station discharge.

14.3.2 Erosion

ECNZ will continue to seek to prevent erosion, or remedy damage from erosion which occurs as a result of the exercise of it's permit.



Figure 77 – 16 cumec flow release – Mararoa Weir

14.3.3 New Flow Regime

The new flow regime proposed for the Lower Waiau River below the MLC structure is:

- A continuous flow of not less than 12 cumecs in the months of 1 May to 30 September, 14 cumecs in April and October, and 16 cumecs at all other times.
- Two flushing flows of not less than 35 cumecs for 24 hours released during the winter months of June and August.
- One flow of not less than 150 cumecs for 24 hours will be provided during each of the periods March to May and September to November in any one year. These flows will be released only if necessary to ensure the mouth of the river is sufficiently open to enable passage of migratory fish during these periods and the gazetted guidelines can be complied with by the release of such flows.
- Seven recreational flows of not less than 35 cumecs, for 24 hours, released on the fourth Sunday of each month between October and April. Two of these flows may be increased to 45 cumecs for specific events subject to ECNZ's ability to comply with the lake level Guidelines.

To prevent or minimise any significant unforeseen adverse effects the minimum flow regime of 12 to 16 cumecs will be made conditional to a review. It is proposed the Southland Regional Council be empowered in terms of the RMA to review the minimum flow regime within 6 months of receiving a report from the Waiau Working Party.

The issues addressed by the proposed flow regime are:

- Restoration of some of the mauri of the river by maintaining a continuous flow.
- Restoration of some natural character of the river commensurate with the flow regime, particularly over the braided sections of the river between MLC and the Monowai confluence. The landscape change from the original "big river" to a "small river" is recognised, however.
- Reduced threat of river mouth closure.
- Removal of excessive periphyton growth.
- Restoration of native fish habitat over the river between MLC and the Monowai confluence.
- Restoration of trout habitat between MLC and the Monowai confluence to about 88% and food producing habitat to about 97% of their respective possible maxima irrespective of inflow from tributaries. The balance will be further mitigated by agreement with the Southland Fish and Game Council and the Department of Conservation.
- Provision for recreation (jet boating and other river activities) below Monowai at all times and above Monowai during recreational flow releases.
- Improvement of angling opportunity in the section of the river between MLC and Monowai.

Provision of the minimum flow regime has implications for the MLC structure. Unchanged the minimum flow could be delivered most of the time. However based on historical lake levels and Mararoa River flows it is may be predicted that there about 15 days per year when less than the full minimum flow would be provided through the gates at their existing level.

Also maintenance of a continuous flow will not be possible during construction of the proposed trout fishpass or future stilling basin maintenance without making special provisions for by-passing that flow.

It is anticipated that provision can be made within the first year of grant of consents for maintaining a continuous flow within the constraints imposed by the existing gate sill level, Manapouri Lake Levels, and the flow in the Mararoa River. During the second year of the consent period a gate sill would be lowered concurrently with construction of the Borland fishlift to the level necessary to provide the full minimum flow at all times.

Consequently during the two years of grant of consents the flow at times may be less than the minimum flow prescribed above. In addition during the first year the flow would be stopped during times of construction, below the minimum flow level in the stilling basin, of a means of by-passing the minimum flow. After the first two years the full minimum flow would be continuous.

14.3.4 Native Fishpass Installation

A native fishpass will be installed on the MLC structure to ensure native fish (including elver) passage from the Lower Waiau into Manapouri is not hindered.

14.3.5 Trout Fishpass Installation

To address the problems with the existing fishpass in the MLC structure, particularly with regard to the passage of brown trout, a Borland fishpass will be installed in part of the right hand gate opening. Prior to proceeding a full expert review will be undertaken to confirm the final design.

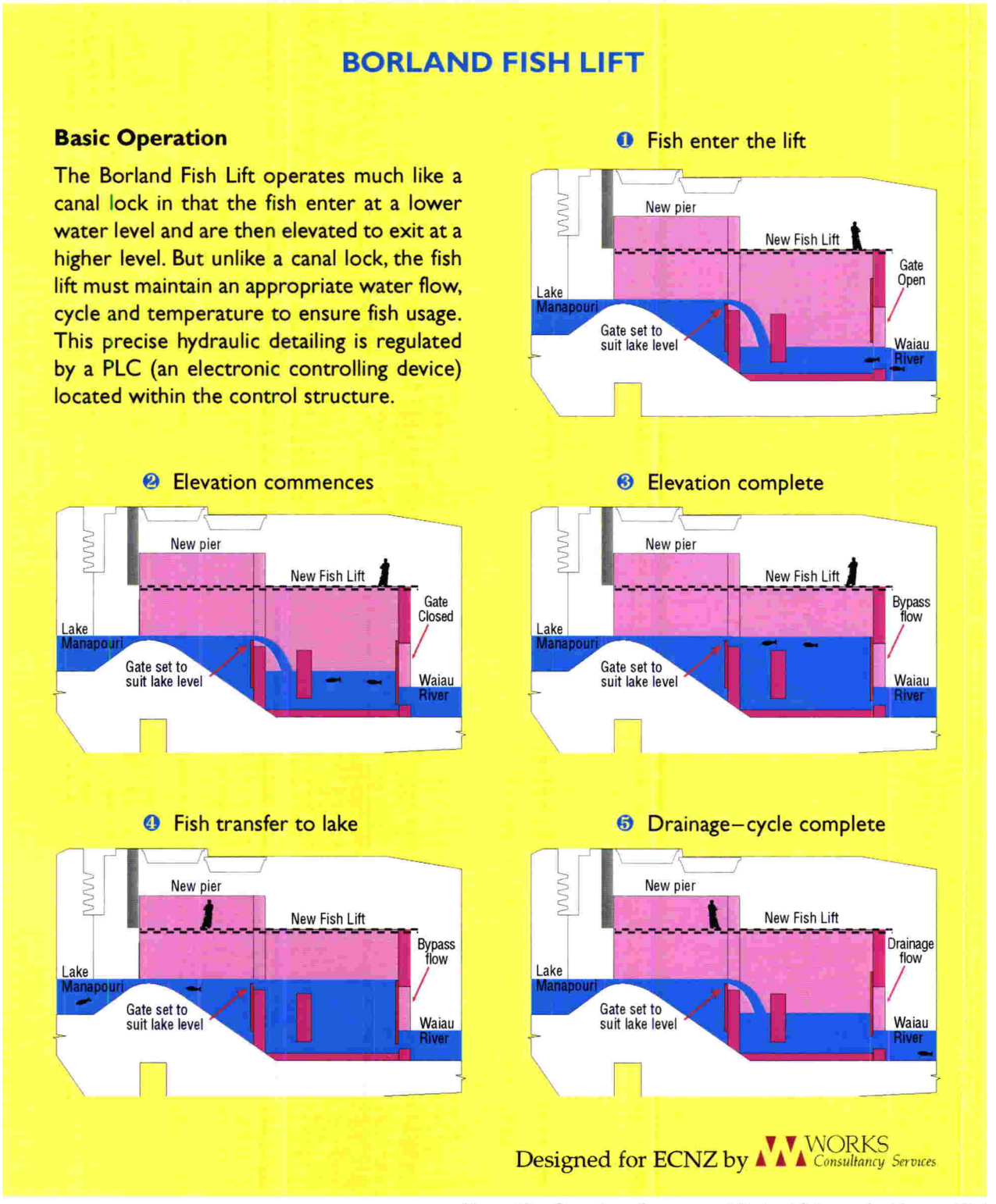


Figure 78 – Operation of a proposed Borland fishpass for Mararoa Weir

14.3.6 Monitoring

14.3.6.1 Eel Recruitment

The age structure of eels will be reassessed within 5 years of water rights being granted and then monitored at 5 yearly intervals thereafter.

14.3.6.2 Trout

Trout will be monitored annually for the first 5 years of the water right to monitor the effects of the new flow regime. This will include drift diving and angler surveys.

14.3.6.3 Native Fish

Native fish will be monitored annually for the first 5 years of the water right to monitor the effects of the new flow regime.

14.3.6.4 Fish Passage

Provision for monitoring the effectiveness of the Borland fishlift and native fishpass will be made.

14.3.6.5 Periphyton and Macroinvertebrates

Periphyton and macroinvertebrates will be monitored annually for the first 5 years of the water right to monitor the effects of the new flow regime.

14.3.6.6 Birds

Annual monitoring of birds will continue for the first 5 years of the water right, then reviewed thereafter in the light of the information provided by that monitoring.

14.3.6.7 Channel Morphology

Channel morphology will be monitored at:

- All 11 existing transects below Tuatapere.
- Two new transects just below the Wairaki and Lillburn confluences respectively.
- Twenty eight cross sections at the Mararoa confluence above and below MLC
- Three cross sections at the Home Creek confluence.

A survey will be undertaken within 5 years of water rights being granted. Thereafter, the Wairaki and Lillburn transects and those below Tuatapere will be monitored at 5 yearly intervals or after every flow event greater than 1200 cumecs (10 year return period flood), measured at MLC. The Mararoa and Home Creek transects will be monitored at 5 yearly intervals. Channel changes will continue to be monitored concurrently by aerial photography.

14.3.6.8 Landscape and Amenity Value

The public perceptions of the improvements to the intrinsic, amenity and natural character values of the Lower Waiau River will be monitored.

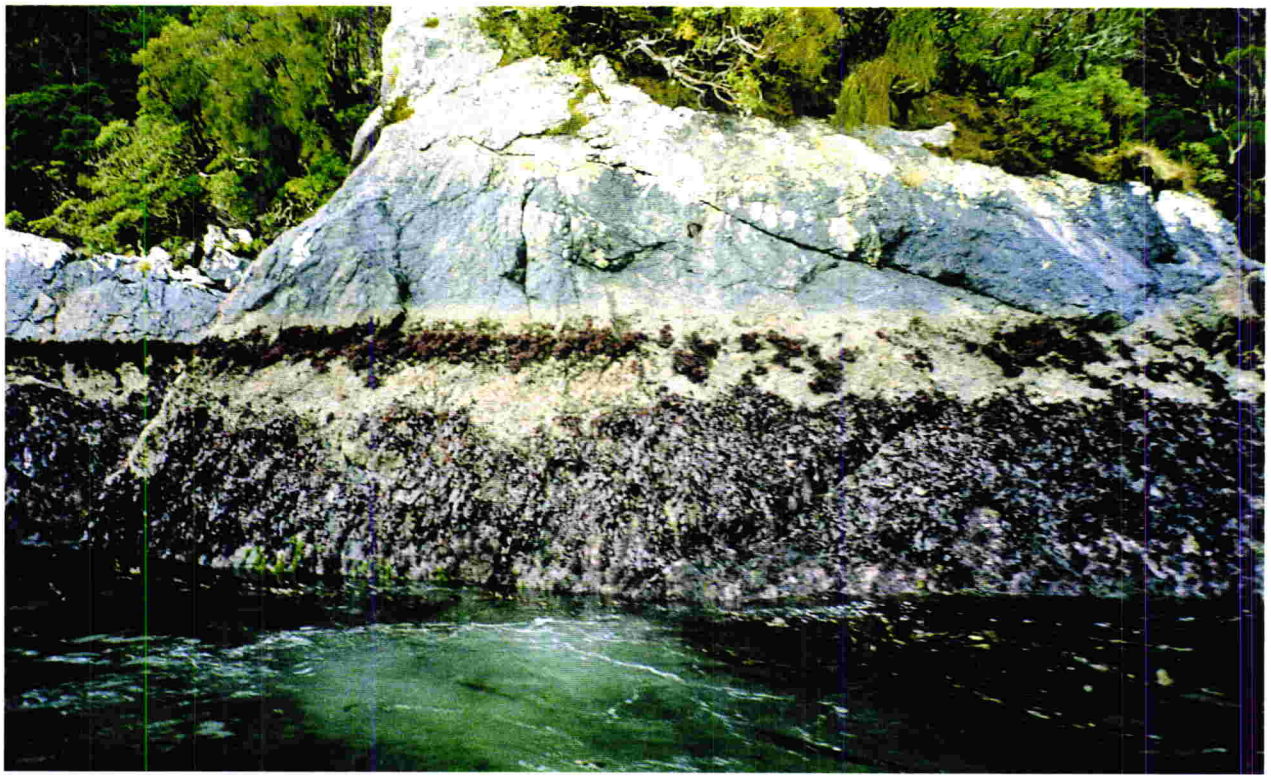


Figure 79 – A very diverse intertidal community – Doubtful Sound, 1995

14.4 Doubtful Sound

14.4.1 Freshwater Influence

Freshwater inflows into Doubtful Sound mix with the underlying seawater to create a Low Salinity Layer (LSL) in the upper levels of the Sound. The depth of the LSL varies depending on the total amount of both natural and Power Station freshwater discharged at any one time.

Recent comparative studies both in Doubtful and adjacent Sounds by the Department of Marine Science (DMS)[135] suggest that since the first power station discharge of freshwater to Deep Cove in 1969 the ecology of the Sound has attained a state of sustainable equilibrium. The range of intertidal biota has changed since 1969. However there is no evidence to suggest the subtidal rock wall biota including Black Coral as an indicator species has been affected.

The results of studies have shown Black Coral is more tolerant to lowered salinity than was previously thought to be the case. Tolerance to water of between 30 and 25psu is indicated. This is consistent with the results of overseas research on the tolerance of stenohaline marine organisms

The proposal to enhance the efficiency of the power station by construction of a second 10m diameter tailrace tunnel, and thus reducing the headloss imposed by the existing tunnel, would result in an increase in the maximum freshwater discharge from the Power Station from 509 cumecs to 630 cumecs. However the median discharge would only be increased by about 1% from 392 cumecs[136] to about 397 cumecs. It is anticipated discharges of more than 504 cumecs would only occur about 11% of the time.

The proportionate effect of an increase of this order on the depth of the Low Salinity Layer has been modelled by DMS[137] in relation to the effect of freshwater discharged into the Sound naturally during 1 and 10 year return period storms (4757 and 7616 cumecs respectively). To substantiate the model a number of conductivity, temperature and depth (CTD) measurements[138] have been taken in the Sound over a range of power station discharges. These indicate that the model is a realistic representative of the actual behaviour of the LSL due to variations of freshwater inflow. However, the model has yet to be fully validated and at this stage cannot be said to accurately predict precise changes in the depth of the LSL.[139]

Although the studies to date have increased the knowledge of the fiord marine environment and for some conclusions to be drawn, there is no basis yet for predicting the effect of increasing the tailrace discharge above the current 509 cumecs maximum.

Consequently ECNZ will limit the future discharge from the Power Station to 510 cumecs until the results of further monitoring and modelling indicate that an increase in the flow would be acceptable.

In terms of the proposed review condition, the Southland Regional Council would be empowered in terms of the RMA to review the consent within 6 months of receiving a report. This will prevent or minimise any significant unforeseen adverse effects.

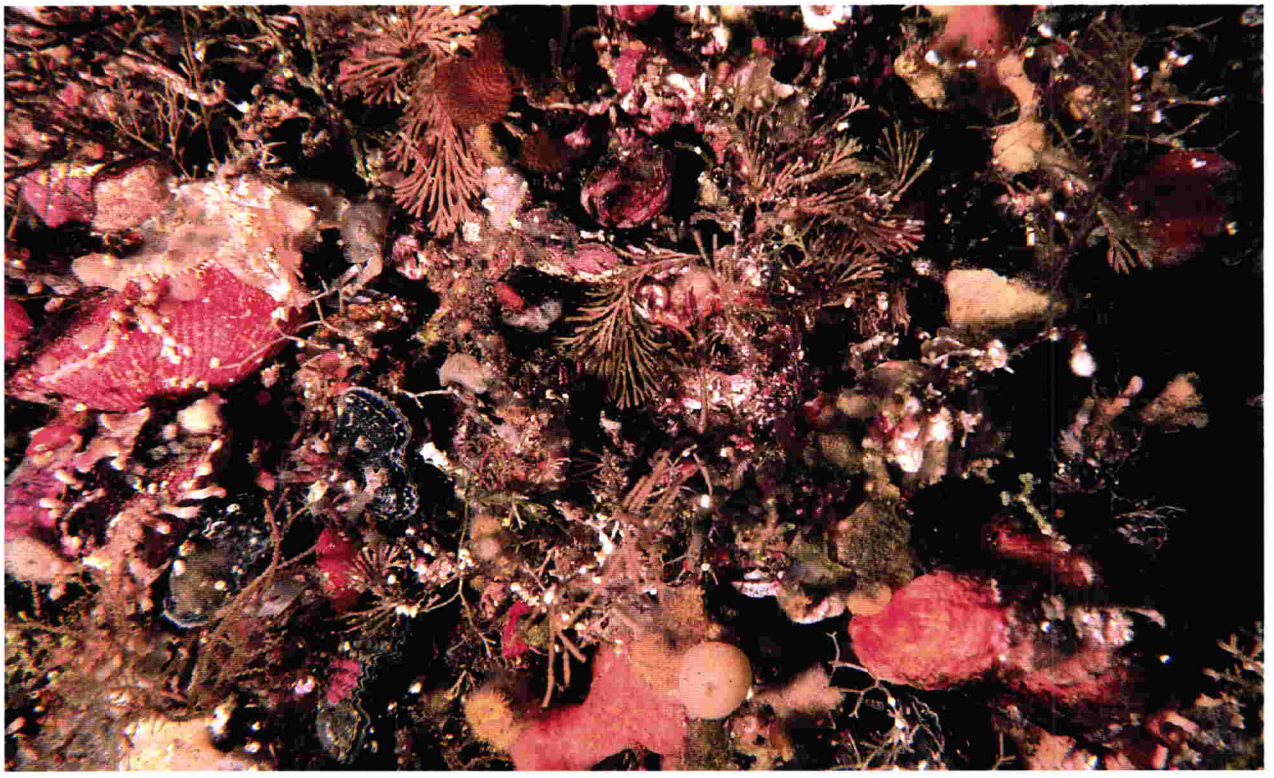


Figure 80 – Subtidal rock wall biota

14.4.2 Water Quality

14.4.2.1 Quality of Discharge to Receiving Waters of Deep Cove

The receiving waters for tailrace discharge are the waters of Deep Cove beyond the end of the tailrace berms. The Southland transitional Regional Coastal Plan[141] has classified the waters of the Fiordland coast, including those of Milford and Doubtful Sounds, as class SB waters. However the current MfE guidelines for good practice, that visual clarity should not be changed more than 20% where "visual clarity is an important characteristic of the water body", have been followed in designing criteria for tailrace discharge.

The quality of the tailrace waters discharged to the receiving waters will comply with the following rule for minimum visual clarity:

- Q = The tailrace flow in cumecs discharged to the receiving waters but excluding the effluent contribution, q.
- q = The effluent flow in cumecs discharged to the tailrace excluding any natural flows into which the treated effluent discharges prior to entering the tailrace.
- y_{bd} = The visual clarity measured by the black disc method as outlined in Appendix A.2 of MfE Resource Management Water Quality Guidelines No 2.
- y_{med} = The pre-determined median clarity of the Lyvia River and has been calculated[142] to be 5.68m.
- For a Q/q (dilution) ratio of < 100 ; the visual clarity of the tailrace water discharged shall not be less than 3.79m (67% of y_{med}).

  This is equivalent to a 33% reduction standard. It is expected to be applicable to flow situations that historically have occurred at most 4.5% of the time and in combination with high construction flows will probably occur less than 2% of the time.
- For a Q/q (dilution) ratio of > 100 ; the visual clarity of the tailrace water discharged shall not be less than 4.54m (80% of y_{med}).

  This is equivalent to a 20% reduction standard. It is expected to be applicable to flow situations that historically have occurred at least 95.5% of the time and in combination with high construction flows will probably occur more than 98% of the time.
- Except that if the visual clarity of the Lyvia River in any adjacent 12 hour period is naturally less than 4.54m (80% of y_{med}), the visual clarity in the tailrace shall not be less than that naturally lesser visual clarity.

  The intent of this exception to the general rule is to cater for runoff, including the Spey River contribution, in large but infrequent storm events.

During the planned station outage the visual clarity rules set out above will be complied with. However it is recognised that on station start up at the end of the outage there may be a short pulse of water which does not comply with these rules. All reasonable steps shall be taken to avoid, as far as practicable, the sediment discharged at this time.

Other requirements will be:

- No sediment with a particle size greater than coarse silt (0.063mm) will be discharged to the receiving waters.
- The concentration of total petroleum hydrocarbons in effluent entering the tailrace waters will not exceed 15ppm.

14.4.3 Monitoring

14.4.3.1 Freshwater Discharge

Further to the studies already completed a long term monitoring programme is proposed to fully establish the appropriate baseline data and then to assess the ecological and flow effects of the increased freshwater discharge.

Inter alia, the programme would measure changes in black coral communities and the density and distribution of the littoral fauna. Conductivity (as a measure of salinity), temperature and depth (CTD) and velocity changes will also be measured. These measurements should enable the Doubtful Sound circulation model to be fully validated.

The long term monitoring programme will proceed for 7 years from the date of grant of consents and then will evaluated and continued if deemed to be necessary by the Department of Conservation and ECNZ.

As a consent condition ECNZ will be able to apply to the SRC to change the consent condition should the results of monitoring indicate that such a variation is warranted.

14.4.3.2 Water Quality

Water quality will be monitored in terms of visual clarity and measured by the black disc method as outlined in Appendix A.2 of MfE Resource Management Water Quality Guidelines No 2.

The potential effect on water quality will be greatest during construction of the second tailrace tunnel. During this time water quality will be monitored with sufficient frequency to ensure construction discharge is controlled such that the above criteria are met.

14.5 Cost

The total cost of implementing the above management strategy is assessed to be

- Initial Capital Cost $2,000,000
- Average Annual Maintenance Cost $500,000
- **Total Discounted NPV Cost over 35 years** **$8,645,000**

This cost excludes lost generation cost as a result of providing the new minimum flow regime.

This equates to lost generation of about 115 GWh calculated as follows:

Table 20: Effects of New Flow Regime on Electricity Generation

Description of Additional Flow Release Under New Minimum Flow Regime	Flow (cumecs)	Loss in MW Equivalent (1 MW = 0.755 cumecs)	Annual Duration days	Annual Duration hours	% of Time when Spill would not have occurred in any case	Average Annual Loss in GWh Equivalent
Minimum Flow Nov - March	16	21.2	146	3504	65%	48.3
Minimum Flow April & Oct	14	18.5	58	1392	65%	16.8
Minimum Flow May - Sept	12	15.9	150	3600	65%	37.2
Recreational Flow	35	46.4	7	168	65%	5.1
Flushing flows	35	46.4	2	48	65%	1.4
River Mouth Opening Flows	150	198.7	2	48	65%	6.2
Average/Total	15.1	20.2	365	8760	65%	114.9

The cost of implementation of the management strategy represents 2.3% of the average annual generation of 4271GWh.

On the basis of an average household requiring 8,330 units (kWhr) of electricity a year (i.e. 1 GWhr of electricity provides for 120 households) then the flow regime provided represents a power loss equivalent to that required to meet the requirements of 13,800 households per year. Assuming an average of 2.5 persons per household, the proposed flow regime represents the ongoing power requirements for 34,500 people.

C. Agreements / Trusts

In addition to addressing environmental effects in its future management strategy ECNZ will further mitigate effects by concluding the following trusts and agreements with various affected parties:

14.6 Te Waiau Mahika Kai Trust Agreement

The objects of this trust are are outlined in the Resumé of Agreements attached to the appliction. They include:

- To provide an accessible mahika kai resource by acquisition, restoration improvement and/or creation of fish and wildlife habitats suitable for this purpose within the Waiau catchment.
- To study, amongst other things, the migration habits of spawning adult eels (heke) in Lake Manapouri. Should it be found eels are lost attempting to use the Manapouri Power station intakes as a means of egress to the ocean, then a practicable means of trapping and transporting to mitigate this loss will also be studied.
- Subsequently, to fund the implementation of any trapping and transporting measures found necessary to sustain the eel fishery.

Following creation of the trust, ECNZ will donate a sum of $1m for its operation. This agreed sum has been calculated by ECNZ on the following basis:

• Mahika Kai Creation and Restoration	$750,000
• Eel Fishery Study and Transfer Programme	$250,000
• **Total**	**$1,000,000**

These amounts have been assessed on the assumption that both capital expenditure and ongoing maintenance costs need to be provided for. The structure of the trust is to be arranged on this basis.

14.7 The Waiau Habitat Enhancement Trust Agreement

This agreement has eight objectives fully outlined in the Resumé of Agreements.
They include:

- To mitigate the difference between the maximum predicted brown trout and food producing habitat attainable with a river flow of up to 30 cumecs and the habitat predicted as attained with the proposed minimum continuous flows of 12, 14 and 16 cumecs. Mitigation will occur by creation of equivalent habitat elsewhere within the Waiau catchment.
- To mitigate for lost native fish and wildlife habitat not reinstated by the proposed new minimum flow regime in a similar manner to that provided for trout habitat within the Waiau catchment. It is assumed in establishing the level of native fish and wildlife mitigation that although in some instances the creation of trout habitat will also provide habitat for native fish this will not always be the case.
- To provide for 2 access tracks for anglers access in the vicinity of the Whare Creek and Redcliff Stream confluences such that advantage can be taken of the improved fishery resulting from the new minimum flow regime. It is intended both the capital cost and ongoing maintenance be provided for.
- To provide for the creation of additional areas of whitebait habitat on land owned by ECNZ and the Department of Conservation adjacent to the Waiau Lagoon at the mouth of the River.
- To provide, if necessary, for the rearrangement and ongoing maintenance of the rock weir immediately below the Duncraigen Bridge such that habitat for fish and the aesthetic sense of landscape between the weir and MLC are optimised at minimum flows. It is intended that this be achieved by undertaking rearrangement of the rocks comprising the weir so the flow is distributed rather than channelled across the weir.
- To provide for study of fish in Lakes Manapouri and Te Anau over 5 years to determine the present state of the trout fishery and any trends.

Following creation of the trust ECNZ will donate a sum of $5m for its operation. This agreed sum has been calculated by ECNZ on the following basis:

• Habitat Creation	$4,340,000
• Whare Creek and Redcliff Anglers Access	$220,000
• Whitebait Habitat Creation	$180,000
• Duncraigen Rock Weir Rearrangement	$55,000
• Lakes Fisheries Monitoring	$205,000
• **Total**	**$5,000,000**

These amounts have been assessed on the assumption that both capital expenditure and ongoing maintenance costs need to be provided for. The structure of the trust will be arranged on this basis.

14.8 The Tuatapere Amenities Trust Agreement

The objective of this agreement is to mitigate the loss of general amenity resulting from the change in the natural character of the lower Waiau River from a "big river" to a "small river". Lost opportunities include those of industrial and tourism potential.

It is intended that alternative sustainable amenities for the long term betterment and advantage of the Tuatapere community alone be provided for.

Following creation of the trust ECNZ will donate a sum of $800,000 for its operation.

This agreed amount have been assessed by ECNZ on the assumption that both capital expenditure and ongoing maintenance costs are to be provided for. The structure of the trust will be arranged on this basis.

14.9 The Waiau Amenities Payment

This agreement with the Southland District Council has four objectives:

(1) to mitigate the lost boat access to the lakes and Upper and Lower Waiau Rivers at low levels. It is intended this be provided by undertaking such lengthening, reconstruction or relocation of existing ramps and provision of new ramps such that acceptable access is provided at all times.

The specific sites identified, in consultation with the local community, where remedial work or the provision of new ramps is needed are:

Lakes and Upper Waiau River Ramps

(a) Te Anau Downs	Partly reconstruct & lengthen
(b) Te Anau Public	Partly reconstruct & lengthen
(c) Te Anau Camping Ground (Steamer Bay)	Partly reconstruct & lengthen
(d) Pearl Harbour Public Ramp	Lengthen
(e) Queens Reach	Relocate to new site & reconstruct

Lower Waiau River Ramps

(a) Monowai	Construct new ramp
(b) Tuatapere Domain	Construct new ramp
(c) Te Waewae Lagoon	Lengthen

(2) to provide for 2 field toilets in association with the ramp at Te Waewae Lagoon.

(3) to mitigate degradation of the Tuatapere water supply due to the increased turbidity of the river that has occurred with reduced flows providing less dilution of turbid tributary waters. It is intended this be achieved by providing alternative sources of supply.

(4) to provide for Manapouri community works which have either some past or current association with the Manapouri Power Scheme and to which ECNZ considers it proper to contribute as a good community member. Works in this category specifically identified in consultation with the local community are:

(a) Reconstruction of the retaining wall at Pearl Harbour. This was originally constructed by community groups to protect the left bank of the lower Waiau River at Pearl Harbour.

(b) Repainting of the Manapouri Community Hall. This was relocated from the original construction village and donated to the community by the predecessor of ECNZ.

Following creation of the trust ECNZ will donate a sum of $450,000 for its operation. This sum has been calculated and agreed on the following basis:

• Lakes and Upper Waiau River Boat Ramp Works	$95,000
• Lower Waiau River Boat Ramp Works	$50,000
• Te Waewae Lagoon Toilets Installation	$5,000
• Tuatapere Water Supply Upgrading Works	$200,000
• Pearl Harbour Retaining Wall Reconstruction	$40,000
• Manapouri Hall Maintenance Works	$10,000
• Costs of Resource Consents, Legal and Professional Services and a sum for contingencies not already allowed for in the preceding sums	$50,000
• **Total**	**$450,000**

These amounts have been assessed on the understanding that only capital expenditure will be provided for. Ongoing maintenance of the above facilities is to be provided for by the Southland District Council.

However, surplus moneys that might eventuate by carrying out the above works at a lesser cost may be retained by the Council for use in providing other suitable amenities in the Waiau catchment.

14.10 Agreement between ECNZ, Federated Farmers of NZ Limited and the SRC

This agreement has the following provisions:

- Fund the reasonable costs of the council in carrying out an agreed programme of annual spraying of vegetation growth in the Waiau River flood channel.
- Maintain or fund the maintenance of the fences between the Mararoa Weir and the mouth of the Waiau River erected as a consequence of the Manapouri Power Project in a stock proof condition, and will rebuild or repair those fences when damaged by flooding, slips or trees falling; and
- ensure the annual spraying programme, and the work needed to maintain the fences, shall be detailed in a three year rolling plan to be agreed by the parties. The plan will require that any work not undertaken in any year shall be performed in the following year and financial provision for the same shall be carried forward and added to that succeeding year's work programme.

This Agreement will continue in force for the term of the resource consents unless a special rating district for the Waiau Catchment is established. Should the rating district come into force, this Agreement shall be suspended.

The special rating district is to be established for:

- the maintenance of an effective flood channel in the Waiau riverbed from the Mararoa Weir to the river's mouth; and
- the maintenance of the fences erected as a consequence of the Manapouri Power Project; and
- the maintenance of the corridor through which the fences pass in a vegetation free state

If the special rating district is established, then ECNZ shall pay to the Council on behalf of the land occupiers represented by the farmers:

- the sum of $200,000 a year annually; and
- an additional sum at the rate of $1.00 for every dollar collected from ratepayers in the special rating district other than ECNZ; and
- any surplus funds to be accrued as a capital fund for disaster relief in the Waiau Catchment.

Chapter 15 – Conclusion

ECNZ is empowered under MTADA to use the lakes and rivers in the Waiau catchment for the purposes of generating electricity, and to construct, use and operate all necessary and requisite works to use those lakes and rivers to generate power. The existing water, discharge and coastal permits expire on 1 October 2001.

ECNZ has been consulting members of the local, regional and national community formally through the Waiau Working Party, and in other ways, for over five years. It has now reached agreement with the members of the Working Party and wishes to apply for renewal of its consents, taking into account the potential increased discharge rate required for the proposed second tailrace project.

Issues have been identified through a comprehensive process of consultation and research. Through the Waiau Working Party, made up of stakeholders and representatives of interested agencies and special interest groups, studies have been undertaken to determine the effects of water diversion at the Mararoa Weir.

Based on data collected since the inception of the scheme, it is recognised that change has occurred. However, subsequent change for the purposes of on-going operation (the basis of this application) is not expected to impact negatively. The most significant change is the restoration of a base flow of 12-16 cumecs of water through the Mararoa Weir and down the Lower Waiau River which is expected to restore an equilibrium in the river and impact positively on natural, cultural and recreational features.

Environmental effects have been acknowledged as actual or potential and suitable mitigation procedures proposed. Based on data collection and consultation input, ECNZ has initiated a range of monitoring programmes designed to ensure understanding and remedying of environmental effects caused by the Manapouri Power Scheme.

Bibliography

Allen, G. 1996. Observations of the Response to the Low Salinity Layer (LSL) to Changes in Freshwater Discharge and Comparisons to Numerical Modelling Results. Report to ECNZ, Dunedin.

Anderson, M. 1992. Report on Tourism and Recreation in the Waiau Catchment. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Andrews, P.B.; McKellar, I.C. 1973. Lake Manapouri Shoreline Stability and the Effects of Lowered Lake Levels. Report of Geological Survey, New Zealand Department of Scientific and Industrial Research.

Bamford Associates 1984. Triune Water Resources - Deep Cove Water Export, Environmental Impact Report.

Batham, E.J. 1965. Rocky Shore Ecology of a Southern New Zealand Fiord. Transactions of the Royal Society of New Zealand Zoology 6 (21): 215-227.

Bennett, S. 1993. Vegetation of the Lower Waiau.
In: Brierley, G.J. 1993. River Reach Analysis of the Waiau River, Southland, from Mararoa Weir to Te Waewae Bay. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Biggs, B.J.F. 1993. Report on Periphyton and Invertebrate Communities in the Waiau River, February 1993. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Bowman, M.J.; Dietrich, D.E. 1995a. The Influence of the Manapouri Power Station on the Circulation of Doubtful Sound. Report to ECNZ, Dunedin.

Bowman, M.J.; Dietrich, D.E. 1995b The Effects of One Year and Ten Year Flood Events on the Circulation and Mixing in Doubtful Sound - Numerical Model Simulations. Report to ECNZ, Dunedin.

Bradford-Grieve, J.M. 1996. Assessment of the Impact of Reduced Flows in the Waiau River Since 1969 on the Primary Production System of Foveaux Strait, Report to ECNZ, Wellington.

Brierley, G.J. 1992. River Reach Analysis of the Waiau River, Southland, from Mararoa Weir to Te Waewae Bay. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brierley, G.J. 1994a. Channel Adjustments Along the Waiau River, 1946-1992: Assessment of the Impacts of Flow Regulation. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brierley, G.J. 1994b. Reach Analysis of Waiau River Tributaries Immediately Downstream of Mararoa Weir (Lake Manapouri Control Structure). Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brierley, G.J. 1994c. Tributary River Reach Analysis of Waiau River Catchment, Southland. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brierley, G.J.; Beveridge, A. 1994. Tributary Characterisation and Assessment of Tributary Impacts on Geomorphic Behaviour of Waiau River, Southland, New Zealand. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brierley, G.J.; Beveridge, A.; Hajnal, A. 1994. Waiau River Regional Setting and Whitestone River Reach Analysis. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Brown, R.; Casinader, R.; Fleming, R.; France, M.; Murray, C. 1993 Manapouri Power Station Efficiency Upgrade. Tailrace Tunnel Duplication Feasibility Report. Report to ECNZ, Wellington.

Chisholm, W.P. 1992a. Avian Information from the Waiau Catchment. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Chisholm, W.P. 1992b. A Review of the Aquatic Macrophytes of the Waiau Catchment. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Corry, S.; Puentener, R. 1993. Tikanga Maori Cultural, Spiritual and Historical Values of the Waiau River. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Dacker, Bill 1990. The People of the Place: Mahika Kai. "Belonging Here: Toi Taketake". New Zealand 1990 Commission.

Davies-Colley, R.J. 1995. Manapouri Tunnelling Project. Optical Effects of Construction Discharges to Deep Cove, Doubtful Sound. Report on Phase I Investigations. NIWA Consultancy Report ELE 60208/1.

Davies-Colley, R.J.; Nagels, J.W.; Schwarz, A.M. 1996. Manapouri Tailrace Investigations Project. Optical Effects of Construction Discharges to Deep Cove, Doubtful Sound. Report on Phase II Investigations. NIWA Consultancy Report ELE602/13/1.

Day, D. 1993. Historical Review of the Waiau River and Coastal Area. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Department of Marine Science, Otago University. 1994. Environmental Impact Assessment. Manapouri Tailrace Discharge into Doubtful Sound New Zealand. Progress Report No. 1 to ECNZ Dunedin.

Duffill Watts and King Ltd. 1993. ECNZ Sediment Transport Monitoring Program Baseline Survey Te Waewae Reach - Waiau River Southland Data Record. Report to ECNZ

Duffill Watts and King Ltd. 1991. ECNZ Sediment Transport Monitoring Waiau River - Southland. Report to ECNZ

Duffill Watts and Davis Ltd 1991. Lower Waiau River. River Erosion Management - Sanderson Property. Report to ECNZ.

Duffill Watts and Davis Ltd. 1990. ECNZ River Erosion Management Options C.J. Carr Property Waiau River, Southland. Report to ECNZ.

Duffill Watts and Davis Ltd 1990. ECNZ River Erosion Management Options D.B. & P.R. Stalker Property Waiau River, Southland. Report to ECNZ.

Duffill Watts and Davis Ltd 1990. Waiau River. Possible Erosion Control Options for WK and FL Allen Property. Report to ECNZ.

Duffill Watts and Davis Ltd 1990. ECNZ River Erosion Management Options R.G. Pearce Estate Property. Report to ECNZ.

ECNZ Production Control, Wellington. 1991. Proposed Operating Procedures for the Lake Te Anau Control Structure. Discussion Document. Report to ECNZ.

Electricorp Production, South Island Hydro Group 1988. Lower Waiau River. Interim Report. Investigations into Cause and Remedies for: Flood Damage October/November 1988. Report to ECNZ.

Elliott: J.M 1994. Quantitative Ecology and the Brown Trout. Oxford Press.

Freestone, H.J.; Carter, B.J.; Rogers, N.C. 1991. Mararoa Flood - 8/9 August 1991. Works Consultancy Services Report to ECNZ.

Graybill, J.P.; Palmer, K.L.; Jowett, I.G.; Rutledge, M.J.; Pierce, L.A.; James, G.D.; Graham, A.A.; Bloomberg, S. 1988. Fisheries Requirements and Design Features of a Residual River Within the Proposed Lower Waitaki Power Scheme. Report to ECNZ by Freshwater Fisheries Centre, MAFFish, Oamaru.

Greer, M.L.; Freestone, H.J.; Maslin, D.C. 1993. Manapouri Lake Control Audit, Flood Event and Dirty Water Spill 5-26 October 1993. Works Consultancy Services Report to ECNZ .

Hayes, J.W.; Davis, S.F.; Jellyman, D.J.; Jowett, I.G. 1992. Review of Fish Distribution in the Waiau River Catchment, Southland. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Howie, R.; Brasell, R.; Powell, S. 1993. The Role of Manapouri Within the ECNZ Generation System. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Irwin, J. 1974. Shoreline Profiles of Selected Sites on Lakes Manapouri and Te Anau. Oceanographic Field Report No. 1 February 1974. NZ Oceanographic Institute, Wellington. 22p.

Irwin, J. 1975. Shoreline Profiles of Selected Sites on Lake Te Anau.
Oceanographic Field Report No.5 September 1975. NZ Oceanographic Institute, Wellington. 43p.

James, M.; James, G.; Hawes, I.; Hicks, M. 1995. The Effects of Lake Level Changes on the Ecology of Lake Coleridge. Report to the Lake Coleridge Working Party, ECNZ, Dunedin.

Johnson, P.N. 1972a. Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 1: Vegetation of Lake Manapouri Shoreline. Proceedings of the New Zealand Ecological Society 19: 120-142.

Johnson, P.N. 1972b. Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 2: The Lake Edge Flora - Habitats and Relations to Lake Levels. Proceedings of the New Zealand Ecological Society 19: 120-142.

Johnson, P.N. 1988. Lakes Manapouri and Te Anau: Vegetation Resurveys. DSIR Botany Division Report.

Jones, D.H. 1978. Power Development and Environmental Protection of Lakes Manapouri and Te Anau. Report to ECNZ

Jowett, I.G. 1993. Minimum Flow Requirements for Instream Habitat in the Waiau River, Southland, From the Mararoa Weir to the Borland Burn. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Kearsley, G.W. 1986. The Waiau River Recreation Survey. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Kirk, R.M. 1985. Foreshore Erosion and Shoreline Management: Te Anau Township.
Report to Electricity Division, Ministry of Energy: The Guardians of Lakes Manapouri and Te Anau: The Te Anau Community Council and the Wallace County Council. June 1985.

Kirk, R.M. 1989a. Catamaran Wake from the "Fiordland Flyer", on the Shoreline of Lake Manapouri. Report to Guardians of Lakes Manapouri and Te Anau, March 1989.

Kirk, R.M. 1989b. Shoreline Erosion, Lower Waiau River (Pearl Harbour to Home Creek), Manapouri. Report to ECNZ

Kirk, R.M.; Single, M.B. 1988. Beach Changes on Lakes Manapouri and Te Anau 1973-1988. Report to ECNZ and Guardians of Lakes Manapouri and Te Anau 1988.

Kirk, R.M.; McGowan, A.C. 1989. Beach Changes at Stockyard Cove, Lake Manapouri, Feb to Dec 1989. Report to ECNZ

Kirk, R.M.; Shulmeister, J. 1994. Geomorphic Processes and Coastal Change in the Lagoon System, Lower Waiau River, Southland. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Kirk, R.M.; Single, M.B.; Guernsey, P.F. 1988. Lakes Manapouri and Te Anau: - Beach Changes February to August, 1988 with Special Reference to Earthquake-Related Effects on and After June 4th. Report to ECNZ and Guardians of Lakes Manapouri and Te Anau 1988.

Kirk, R.M.; Single, M.B.; Harrowfield, D.L.; McGowan, A.C. 1989. Beach Changes on Lakes Manapouri and Te Anau, August 1988 to February 1989. Report to Guardians of Lakes Manapouri and Te Anau, March1989.

Langbein, J.A. 1972. The Manapouri Power Project, New Zealand. Proceedings of the Institute of Civil Engineers 50: 311 - 351.

Macky, G.H. 1994. Possible Origins of Turbidity and Suspended Sediment in the Mararoa - Whitestone Catchment. NIWA Christchurch Miscellaneous Report No. 155.

Mark, A.F. 1972. Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland. General Introduction. Proceedings of the New Zealand Ecological Society 19: 100-101.

Mark, A.F. 1988. Manapouri-Te Anau: Case Study of its Hydro-Electric Development From Conflict to Resolution. Proceedings of "Ecopolitics III" Conference, University of Waikato, Hamilton, September 1988.

Mark, A.F. 1992. Managing lakes Manapouri and Te Anau for Conservation and Hydro-electric Generation: A Case Study in Conflict Resolution to Integrate Conservation with Development. In Prospectives on the History of Science in Otago - A Series of Public Lectures, University of Otago, Division of Science, January 1992, pp. 29-72.

Mark, A.F.; Johnson, P.N. 1972. Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 4: Recommendations. Proceedings of the New Zealand Ecological Society 19: 100-101.

Mark, A.F.; Johnson, P.N. 1985. Ecologically Derived Guidelines for Managing Two New Zealand Lakes. Environmental Management 9: (4): 355-363.

Mark, A.F.; Kirk, R.M. 1987. Lake Levels and Lakeshore Erosion.
In: W.N. Vant (ed.). "Lake Managers Handbook". Ministry of Works and Development Water and Soil Miscellaneous Publication No. 103: 215-222.

Mark, A.F.; Crush, J.R.; Meurk, C.D. 1972. Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 3: Vegetation of the Lake Te Anau Shoreline. Proceedings of the New Zealand Ecological Society 19: 143-154.

Mark, A.F.; France, M.J.; Lauder, G. 1993. Are Hydro-Electric Generation and Lake Conservation Compatible? A Case Study in Conflict Resolution From New Zealand's Largest National Park and World Heritage Area. In: G. Guissani and C. Callieri (eds). "Strategies for Lake Ecosystems Beyond 2000". Proceedings of the 5th International Conference on the Conservation and Management of Lakes. 17-21 May 1993, Stresa, Italy. pp 475-478.

Mark, A.F.; Johnson, P.N.; Wilson, J.B. 1977. Factors Involved in the Recent Mortality of Plants From Forest and Scrub Along the Lake Te Anau Shoreline. Proceedings of the New Zealand Ecological Society 24: 34-42.

McClelland, P.J. 1994. The Waiau River (Southland) Inanga Spawning Survey 1994. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

McDowall, R.M. 1990. New Zealand Freshwater Fishes: A Natural History and Guide. Heinemann-Reed, Auckland.

McDowall, R.M. 1993. Waiau River (Southland) Whitebait Fishery: a Consideration of the Impacts of the Mararoa Dam, and Flow Diversion From the River.
Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

McDowall, R.M. 1994a. Native Fish Populations of the Waiau River (Southland) and the Impacts of the Lake Manapouri Control Structure (the Mararoa Weir). Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

McDowall, R.M. 1994b. A Calendar of Fish Migrations Through New Zealand River Mouths. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

McKellar, I.C. 1974. Te Anau Lakeshore Beach Sediments. Report of Geological Survey, New Zealand Department of Scientific and Industrial Research.

Mills, G.W.; Freestone, H.J. 1992. Manapouri Lake Control, April 1992 Cross Section Survey. Works Consultancy Services Report to ECNZ. Wellington NZ.

Ministry for the Environment, 1994. Guidelines for the Management of the Colour and Clarity of Water. Water Quality Guidelines No. 2. Ministry for the Environment. Wellington, 77pp.

Mitchell, C.P. 1994a. Fish Passage Problems and Options for Fish Passage at Mararoa Weir. Report to ECNZ and the Waiau River Working Party.

Mitchell, C.P. 1994b. Enhancement of Whitebait Habitat in the Lower Waiau River. Report to ECNZ Dunedin for the Waiau River Working Party.

Mitchell, C.P.; Davis-Te Maire, K.T.A. 1994. Mahika Kai Values of the Waiau River. Report to ECNZ, 1994.

Mladenov, P. 1995a. Overview of Research on the Doubtful Sound Fiord System with an Assessment of Possible Marine Environmental Impacts Resulting from Increased Freshwater Discharge. Report to ECNZ, Dunedin.

Mladenov, P.V. 1995b. Environmental Impact Assessment. Manapouri Tailrace Discharge into Doubtful Sound New Zealand. Department of Marine Science, Otago University. Progress Report No. 2 to ECNZ Dunedin.

Mladenov, P. 1996. Community Equilibrium to Doubtful Sound, Report to ECNZ, Dunedin.

Mladenov, P. and Brewin, P. 1996. Tolerance of the Black Coral *Anthipathes fiordensis* to Lowered Salinity. Report to ECNZ, Dunedin.

Mladenov, P. and Smith, F. (1996). Comparative Survey of the Bathymetric Distribution of Black Coral in New Zealand Fiords. Report to ECNZ, Dunedin.

NWASCA (National Water and Soil Conservation Authority) 1983. Erosion Map of New Zealand.

Patrick, B.H.; Woods, C.S. 1995. Reaffirmation of the Type Locality of Stokell's Smelt in Southland. Journal of the Royal Society of New Zealand 25 (1): 95-97.

Peat, N. 1995. Manapouri Saved! Longacre Press, Dunedin.

Pickrill R.A.1976. The Lacustrine Geomorphology of Lakes Manapouri and Te Anau. PhD Thesis, University of Canterbury, Christchurch. 402p.

Pickrill, R.A. 1978a. Effects of Boat Wakes on the Shoreline of Lake Manapouri. New Zealand Engineering 33: 194-198.

Pickrill, R.A. 1978b. Beach and Nearshore Morphology of Lakes Manapouri and Te Anau, New Zealand; Natural Models of the Continental Shelf. New Zealand Journal of Geology and Geophysics 21: 229-242.

Rackham, A. 1995. Manapouri Power Scheme - Waiau River Landscape Assessment. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Richardson, J.; Jowett, I.G. 1995. The Effects of Upper Waiau River Flow Control on Aquatic Macroinvertebrates. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Richardson, J.; Teirney, L.D.; Unwin, M.J. 1986. The Relative Value of Southern Lakes Wildlife Conservancy Rivers to New Zealand Anglers. MAF Fisheries Research Division. Fisheries Environmental Report No. 72.

Riddell, D.C 1991. Hydrological Database Index. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Riddell, D.C 1993a. Separation of Manapouri Lake Control Spill into Mararoa River and Lake Manapouri Components. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Riddell, D.C 1993b. Cursory Analysis of Tuatapere Water Supply Data. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Riddell, D.C.; Freestone, H.; Nutting, S. 1993. Waiau River Hydrology. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Riddell, D.C 1994. Lower Waiau River. Flow Attenuation and Times of Travel (Part A) and Flow Recession Profile and Times of Travel (Part B). Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Robertson, B.M. 1993. Waiau Catchment. Water Quality Review. Report to Southland Regional Council.

Rogers, N.C.; Ritchie, P.D.; Wild, M.; Webby, M.G.; Freestone, H.J. 1995a. Report on Residual Flows and Fishpass Improvement. Works Consultancy Services Report to ECNZ Dunedin.

Rogers, N.C.; Currie, B.; Stapp, C. 1995b. Supplementary Report on Residual Flows and Fishpass Improvement. Works Consultancy Services Report to ECNZ Dunedin.

Royds Consulting Ltd 1994. Waiau River Working Party. Tuatapere Water Supply Headworks and Treatment Study July 1994. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Sagar, P.M. 1986. The Effects of Floods on the Invertebrate Fauna of a Large, Unstable Braided River. New Zealand Journal of Marine and Freshwater Research 20: 37-46.

Sagar, P.M. 1994. Aquatic Birds of the Waiau River November 1993 and March 1994. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Single, M.B. 1993. An Annotated Bibliography of the Shorelines of Lakes Manapouri, Te Anau, Monowai, Hauroko, North Mavora and South Mavora. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Smith, F. 1995. Structure of Subtidal Rock Wall Invertebrate Communities of Three Reference Sites in Doubtful Sound. Report to ECNZ, Dunedin.

Smith, A.M. 1996. Defining Ecologically Relevant Estuarine Salinity Zones. Report to ECNZ, Dunedin.

Smith, A.M.; Mladenov, P.V. 1995. Suspended Sediment Discharge Study, Manapouri Duplicate Tailrace Proposal. Report to ECNZ, Dunedin.

Southland District Council 1995. Draft Southland District Plan.

Southland Regional Council 1995. Draft Regional Coastal Plan.

Stark, J. 1990. Report on Macroinvertebrate Survey of Upper Waiau River. Report to ECNZ, Dunedin.

Talbot, H.; Sommerville, R.; Callaghan, A. 1994. Legislation Hierarchy Report; Part A - Summary; Part B - Report. Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

Teirney, L.D.; Unwin, M.J.; Richardson, J. 1984. The Relative Value of Southland Rivers to New Zealand Anglers. MAF Fisheries Research Division. Fisheries Environmental Report No. 50.

Watson, N. 1989. Management of Wilderness Fisheries. A Discussion Paper. Otago Fish and Game Council Report. 1989.

Waugh, J.R.; Devgun, M.S. 1995. Sediment Input into Doubtful Sound - Natural Inputs From the Lyvia River. Works Consultancy Services Report to ECNZ, Dunedin.

Wells, R.D.S.; Clayton, J.S.; de Winton, M.D. 1993. The Submerged Vegetation of Lakes Hauroko, Te Anau, Manapouri and Monowai, Fiordland, New Zealand and Effects of Water Level Fluctuations. NIWA Hamilton Report to ECNZ. No ELE121.

Wilson, J. (ed.). 1987. From the Beginning. The Archaeology of the Maori. Penguin Books in Association with the Historic Places Trust.

Works Consultancy Services 1994. Waiau River Valley Groundwater Monitoring. Report to ECNZ, Dunedin

References

1 ECNZ Annual Report, 30 June 1994

2 Jones 1978

3 Jones 1978

4 Langbein 1972

5 Riddell et al 1993

6 Brown et al 1993

7 Woodward-Clyde Consultants, June 1995

8 Howie et al 1993

9 Langbein 1972

10 ECNZ Generation Production Memoranda 5.01 and 5.02

11 Rackham 1995

12 Rackham 1995

13 Robertson 1993a

14 Bennett 1993

15 Robertson 1993

16 Riddell et al 1993

17 Riddell et al 1993

18 Riddell et al 1993

19 ECNZ pers. comm. (Mladenov July 1995)

20 Robertson 1993

21 NWASCA 1983

22 Kirk and Schulmeister 1994

23 Brierley 1994b

24 Wells et al 1993

25 Mark and Kirk 1987

26 McDowall 1990

27 Patrick and Woods 1995

28 Hayes et al 1992

29 Robertson 1993a

30 Stark 1990

31 Robertson 1993a

32 Robertson 1993a

33 Mitchell and Davis-Te Maire 1994

34 Sagar 1994

35 O'Reagan, in Wilson 1987:23

36 Corry and Puentener 1993

37 Dacker 1990:17

38 Corry and Puentener 1993

39 Bamford Associates 1984

40 Peat 1995

41 Southland District Plan 1994

42 ECNZ Annual Report, 30 June 1994

43 France et al 1995

44 ECNZ Annual Report, 30 June 1994

45 ECNZ Annual Report, 30 June 1994

46 Anderson 1992

47 Riddell et al 1993

48 Kirk 1985

49 Kirk and Single 1988

50 Kirk et al 1988, 1989

51 Mark and Kirk 1987

52 Kirk et al 1988

53 Kirk et al 1989

54 Kirk et al 1989

55 Kirk 1985

56 Mark et al 1992

57 Wells et al 1993

58 Chisholm 1992a

59 NZ Gazette 29 April 1993

60 Brierley 1994a

61 Brierley 1994a

62 Richardson and Jowett 1995

63 Elliot 1994

64 Mitchell and Davis-Te Maire 1994

65 Mitchell and Davis-Te Maire 1994

66 Watson 1989

67 Bill Jarvie pers. comm.

68 Elliot 1994

69 Freestone et al 1991

70 Robertson 1993

71 Riddell et al 1993

72 Riddell et al 1993

73 Riddell et al 1993

74 Riddell 1994

75 Brierley 1994

76 Kirk and Shulmeister 1994

77 Kirk and Shulmeister 1994

78 Kirk and Shulmeister 1994

79 Mills and Freestone 1992

80 Kirk 1989a

81 G Lauder pers. comm.

82 Biggs 1993

83 Graybill et al 1988

84 Sagar 1986

85 Graybill et al 1988

86 Jowett 1993

87 Jowett 1993

88 Ian Jowett pers. comm.

89 Jowett 1993

90 C. Mitchell pers. comm.

91 McDowall 1993

92 Mitchell 1994b

93 Mitchell and Davis-Te Maire 1994

94 Sagar 1994

95 Sagar 1994

96 Sagar 1994

97 Bradford-Grieve 1996

98 Waugh and Devgun 1995

99 Bowman and Deitrich 1995a

100 Waugh and Devgun 1995

101 Mladenov 1995

102 Mladenov 1995

103 Mladenov 1995b

104 Mladenov and Smith 1996

105 Mladenov 1995

106 Mladenov 1995

107 Davies-Colley 1995

108 Davies Colley et al 1996

109 Southland Regional Council 1995

110 MfE 1994

111 Riddell 1991

112 Davies-Colley et al 1996

113 Davies-Colley et al 1996

114 Corry and Puentener 1993

115 Mitchell and Davis - Te Maire 1994

116 Mitchell and Davis - Te Maire 1994

117 C. Mitchell pers. comm.

118 C. Mitchell pers. comm.

119 Mitchell et al 1994

120 Mitchell and Davis - Te Maire 1994

121 Mitchell and Davis - Te Maire 1994

122 Bennett 1993

123 Brierley 1994a

124 Rackham 1994

125 Jowett 1993

126 Rackham 1994

127 Riddell 1993b

128 Works Consultancy Services 1994

129 Riddell et al 1993

130 Riddell 1994

131 Richardson et al 1986

132 Tierney et al 1984

133 Jowett 1993

134 Biggs 1993

135 Mladenov and Smith 1996

136 Riddell 1993

137 Bowman and Deitrich 1995a

138 Allen 1996

139 Bowman and Deitrich 1995a

140 Waugh 1995

141 Southland Regional Council 1995

142 Davies-Colley 1996

Appendices

Appendix I

Gazetted Lake Level Guidelines
New Zealand Gazette
29 April 1993

Designation of Approved Persons: Waitaki Power Trust

Pursuant to section 2 of the Energy Companies Act 1992 ("the Act"), I hereby approve the trustees for the time being of Waitaki Power Trust, being the trust referred to by that name in the establishment plan approved by me in respect of the Waitaki Electric Power Board on the 23rd day of March 1993, as approved persons for the purposes of Part IV of the Act.

Dated at Wellington this 21st day of April 1993.

MURRAY JOHN FINLAY LUXTON, Minister of Energy.
go3371

Designation of Approved Persons: Waitomo Energy Services Customer Trust

Pursuant to section 2 of the Energy Companies Act 1992 ("the Act"), I hereby approve the trustees for the time being of Waitomo Energy Services Customer Trust, being the trust referred to by that name in the establishment plan approved by me in respect of the Waitomo Electric Power Board on the 17th day of March 1993, as approved persons for the purposes of Part IV of the Act.

Dated at Wellington this 21st day of April 1993.

MURRAY JOHN FINLAY LUXTON, Minister of Energy.
go3372

Designation of Approved Persons: West Coast Electric Power Trust

Pursuant to section 2 of the Energy Companies Act 1992 ("the Act"), I hereby approve the trustees for the time being of West Coast Electric Power Trust, being the trust referred to by that name in the establishment plan approved by me in respect of the West Coast Electric Power Board on the 23rd day of March 1993, as approved persons for the purposes of Part IV of the Act.

Dated at Wellington this 21st day of April 1993.

MURRAY JOHN FINLAY LUXTON, Minister of Energy.
go3373

Manapouri-Te Anau Development Act 1963

Operating Guidelines for Levels of Lakes Manapouri and Te Anau

Pursuant to section 4A of the Manapouri-Te Anau Development Act 1963, I, John Luxton, Minister of Energy, based upon the recommendations of the Guardians of Lakes Manapouri and Te Anau and of the Electricity Corporation of New Zealand Limited, hereby give the following notice of the operating guidelines for the levels of Lakes Manapouri and Te Anau aimed to protect the existing patterns, ecological stability, and recreational values of their vulnerable shorelines and to optimise the energy output of Manapouri power station.

Notice

1. Title and commencement—(1) This notice may be cited as the Manapouri-Te Anau Development Act (Operating Guidelines) Notice 1992.

(2) This notice shall come into force on its publication in the *Gazette*.

2. Application and Interpretation—(1) This notice applies to Lakes Manapouri and Te Anau.

(2) In this notice, unless the context otherwise requires:

"*Duration*" means the number of continuous days any of the Lakes was within a particular range of level specified within the *High or Low Operating Ranges*:

"*Corporation*" means the Electricity Corporation of New Zealand:

"*High Operating Ranges*" are those set out in clause 5 of this notice:

"*Interval*" means, in relation to either of the Lakes, the number of continuous days that a Lake was below a particular range of level specified for the *High Operating Ranges* for that Lake:

"*Lakes*" means lakes Manapouri and Te Anau:

"*Level*" means height, in metres, above mean sea level:

"*Low Operating Ranges*" are those set out in clause 6 of this notice:

"*Main Operating Ranges*" are those set out in clause 4 of this notice:

"*Maximum duration*" means, in relation to any of the Lakes, the number of continuous days that a Lake may be within a particular range of level specified for the *High or Low Operating Ranges*, and in relation to the *High Operating Ranges*, subject to the specified minimum interval:

"*Minimum interval*" means the number of continuous days that should elapse from either of the Lakes moving below a particular range of level, until that Lake returns to within that range of level:

"*Parties*" means the Guardians of the Lakes and the Corporation:

"*Specified ratio*" means the ratio derived from dividing the minimum interval by the maximum duration, and applies only to the *High Operating Ranges*:

3. Lakes Management—The parties recognise three separate operating ranges of levels for each of the lakes within which the Corporation may operate, being Main, High, and Low, as set out in clauses 4, 5, and 6 of this notice.

4. The Main Operating Ranges—(1) The Main Operating Ranges, within which the Corporation shall endeavour to maintain continuous variation, are:

(a) For Lake Manapouri, levels from 176.8m to 178.6m; and

(b) For Lake Te Anau, levels from 201.5m to 202.7m.

(2) The Corporation shall, for each of the lakes, aim to achieve annual mean levels within the applicable Main Operating Ranges as specified in this notice.

5. The High Operating Ranges—(1) The Corporation shall use its best endeavours to:

(a) Not exceed the maximum durations; and

(b) Achieve the specified ratio in relation to the ranges of level set out in subclause (2) of this clause, where the actual interval (in days) between the Lake moving below a particular range of level and returning to within that range of level is divided by the actual duration (in days) that the Lake was originally within that range of level.

(2) Subject to subclause (3) of this clause, the High Operating Ranges are:

(a) For Lake Manapouri, above 178.6m, in accordance with the following maximum durations, minimum intervals, and specified ratios for the ranges of level set out:

Level (m)	*Maximum Duration*	*Minimum Interval*	*Specified Ratio*
At 180.5	1	100	100.0
Above 180.4	3	100	33.0
Above 180.1	9	100	11.0
Above 179.8	22	80	3.6
Above 179.5	35	40	1.1
Above 179.2	44	40	0.9
Above 178.9	99	20	0.2
Above 178.6	119	20	0.2

(b) For Lake Te Anau, above 202.7m, in accordance with the following maximum durations, minimum intervals, and specified ratios for the ranges of levels set out:

Level (m)	*Maximum Duration*	*Minimum Interval*	*Specified Ratio*
At 204.3	1	100	100.0
Above 204.2	3	100	33.0
Above 203.9	10	60	6.0
Above 203.6	22	30	1.4
Above 203.3	39	30	0.8
Above 203.0	65	30	0.5
Above 202.7	125	20	0.2

(3) Where the ratio derived from dividing the interval between the lake level moving below a particular range of level and returning to that range of level by the duration that the lake was in that range of level immediately prior to the interval—

(a) Results in a ratio greater than or equal to the specified ratio, then the guidelines are deemed to be complied with:

(b) Results in a ratio less than the specified ratio, then subject to subclause (4) of this clause, the interval occurring after a particular duration shall be added to that duration along with the duration occurring after that interval, in order to determine the duration for which the specified ratio must be achieved.

(4) The period of duration within any range of level, including accumulations as provided for in paragraph (b) of subclause (3) of this clause, shall not exceed the relevant maximum duration.

6. The Low Operating Ranges—(1) Subject to subclause (2) of this clause, the Low Operating Ranges are:

(a) For Lake Manapouri levels from 175.86m to 176.8m, with an absolute minimum level of 175.86:

Level (m)	*Maximum Duration*
Below 176.8	107
Below 176.5	66
Below 176.2	20
At or below 175.9	5

(b) For Lake Te Anau from 200.86m to 201.5m, with an absolute minimum level of 200.86m:

Level (m)	*Maximum Duration*
Below 201.5	88
Below 201.3	46
Below 201.1	21

(2) For the purposes of the Low Operating Ranges outlined in subclause (1) of this clause, the Corporation shall use its best endeavours to:

(a) Not exceed the maximum durations for the individual ranges of levels specified;

(b) Avoid lake levels below 201.1m for Lake Te Anau, and below 176.2m for Lake Manapouri, during the equinoxial periods (March, April, October and November);

(c) Not exceed, in any continuous period of 365 days, twice the maximum duration specified for any particular range of level; and

(d) Ensure the rates of drawdown do not exceed the natural rates of drawdown averaged over four days, being 0.05m per day for Lake Manapouri, and 0.03m per day for Lake Te Anau.

(3) The parties record that:

(a) In the period of natural record the level of Lake Manapouri has been below the absolute minimum level of 175.86m; and

(b) These guidelines are based on the mean of three extreme events during the period of natural record and may result in low ranges of level being experienced more often than would have occurred naturally.

7. Gate Opening and Closing Procedures—(1) The Parties have agreed upon and adopted gate opening and closing procedures which are designed amongst other things:

(a) In the case of the Lake Te Anau Control structure, to reduce or eliminate scour action on the upper Waiau River banks, to facilitate repair following periods of extremely high flow, and to facilitate the successful spawning of salmonids; and

(b) In the case of the Lake Manapouri Control structure, to reduce potentially dangerous increases in river flow downstream of the gates, and to bypass flood flows from the Mararoa River in such a manner as to prevent dirty debris-laden water from entering Lake Manapouri.

(2) It should be noted that the procedures referred to in subclause (1) of this clause are modified from time to time by agreement between the Parties.

8. Benchmarks—For the purposes of this notice:

(a) The level of Lake Te Anau at any time shall be determined by reference to the Department of Survey and Lands Information Benchmark Z58, national grid co-ordinates (176 284) yards east (319 170) yards north, which is adjacent to the lake water level recorder and staff gauge, which benchmark shall be deemed to represent a height 205.127 metres above mean sea level; and

(b) The level of Lake Manapouri at any time shall be determined by reference to the Department of Survey and Lands Information Benchmark Z47, National grid co-ordinates (170 051) yards east (305 873) yards north which benchmark shall be deemed to represent a height of 208.910 metres above mean sea level.

9. Consequential revocation—The notice entitled "Manapouri-Te Anau Development Act 1963" dated 1 March 1990 and published in the *Gazette* of 8 March 1990 at pages 701/702, is hereby consequentially revoked.

Signed at Wellington this 14th day of April 1993.

J. LUXTON, Minister of Energy.

Note: The Guardians and the Corporation may review these guidelines from time to time with a view to having a new notice of the guidelines published.

go3297

Radio Communications Act 1989

Notice of Corrections to Register of Radio Frequencies

In accordance with section 24 (4) of the Radiocommunications Act 1989, I hereby give notice that the records in the Register of Radio Frequencies of the names and addresses specified in the Schedule to this notice have been corrected in the manner indicated in that Schedule.

Schedule

Corrections to Register of Radio Frequencies

Capital FM Limited

Old Addresses: 35C Oriel Avenue, Tawa.
P.O. Box 1891, Wellington.
Care of P.O. Box 1691, Wellington.
10–49 Boulcott Street, Wellington.

New Address: P.O. Box 27-000, Wellington.

Coromandel FM Limited

Old Address: Care of 10 Copperfield Terrace, Howick, Auckland.

New Address: P.O. Box 99-109, Newmarket, Auckland.

Appendix II

Classification
Class C and SB Waters

Appendix II: Classification of "Class C and SB" Waters

Standards for Class C Water Quality

(a) The natural temperature shall not be changed by more than 3 degrees Celsius.
(b) The acidity or alkalinity of the waters as measured by the pH shall be within the range 6.5 to 8.3 except when due to natural causes.
(c) The waters shall not be tainted so as to make them unpalatable, nor contain toxic substances to the extent that they are unsafe for consumption by humans or farm animals, not shall they emit objectionable odours.
(d) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances.
(e) The natural colour and clarity of the waters shall not be changed to a conspicuous extent.
(f) The oxygen content in solution in the water shall not be reduced below 6 milligrams per litre.
(g) Based on not fewer than 5 samples taken over not more than a 30-day period, the median value of the faecal coliform bacteria content of the water shall not exceed 200 per 100 millilitres.

Although the Water and Soil Conservation Act was repealed by the Resource Management Act 1991, the classifications have been adopted as rules under the Transitional Regional Plan and the concepts transferred to the third schedule of the Resource Management Act.

Standards for Class SB Waters

The quality of Class SB waters shall conform to the following requirements:

(a) The natural water temperature shall not be changed by more than 3 degrees Clesius.
(b) The natural pH of the waters shall not be changed by more than 0.1 unit and at no time shall be less than 6.7 or greater than 8.5.
(c) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances nor shall the waters emit objectionable odours.
(d) The natural colour and clarity of the water shall not be changed to a conspicuous extent.
(e) The dissolved oxygen content in solution in the waters shall not be reduced below 5 milligrams per litre.
(f) Based on not fewer than 5 samples taken over not more than a 30-day period, the median value of the total faecal coliform bacteria content of the waters shall not exceed 200 per 100 millilitres.
(g) *Repealed by s.30(e), 1973 No. 24.*

Appendix III

Macroinvertibrate Records
Lake Te Anau and Lake Manapouri
Stark 1993

Appendix B14: Macroinvertebrates and plants recorded in core samples (0.0135m² area, 0.5mm mesh) from Lake Te Anau (31 January 1992). P=present, R=rare, C=common, A=abundant, VA=very abundant. Numbers are counts per sample for macroinvertebrates and dry weights (g) for plants.

Code No.		Hand net samples			0.5m (site1)			0.5m (site 2)			1m			2m			3m			4m			8m		
		a	b	c (S.2)	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
	ODONATA																								
6	*Procordulia grayi*			R																			1		
	PLECOPTERA																								
11	*Zelandobius furcillatus*			R																					
	LEPIDOPTERA																								
15	*Hygraula nitens*	R		R																					
	DIPTERA																								
28	*Chironomus sp a*	R	R								1	2		14	17	37	15	8	19	9	7	3	57	12	55
29	*Chironomus zealandicus*																						10		
30	*Cladopelma curtivalva*																								1
31	*Corynocera sp.*								1																
33	Orthocladinae	A	C	A		6	5	40	12	9	1	14	3	4	12	18	8	12	6	3	8	3	8		5
	" " " (P)	C	R	R		2		2	1					2	4	3				1					2
35	*Polypedilum sp*					6																			
36	Tanypodinae			C				2	1	2							1		2	3			15	9	13
	" " " (P)			R								1						1							
37	*Tanytarsus funebris*							1			1												2		
39	*Xenochironomus canterburyensis*													1			1	2	8	3	2	1		2	2
45	Ceratopogonidae			R																		1		1	
47	*Paralimnophila skusei*										1														
52	Tanyderidae	R																							
	TRICHOPTERA																								
60	*Hudsonema amabilis*			R																					
61	*Oecetis unicolor*			R																					
62	*Oxyethira albiceps*	C	C	A		3	2	4	3	8		1								1					
63	*Paroxyethira hendersoni*	C	C			1						1				2									1
65	*Paroxyethira (complex)*	C	C														1								
66	*Paroxyethira (caseless)*	A	C	A				13		1	2						1				1				1
72	OLIGOCHAETES	VA	A	VA	2	1		27	322	33	78	23	24	60	37	66	211	83	169	158	244	86	45	89	130
73	NEMATODA	R	R	C				8	35	28			3										8	14	14
74	NEMATOMORPHA										4		1												
75	NEMERTEA			R																					
	MOLLUSCA																								
79	*Hyridella menziesi*													1	2		5	10	7	8	3	7	4	7	3
82	*Potamopyrgus antipodarum*	VA	C	VA				8	38	14	9	14	33	15	3	17	28	30	61	44	22	22	1	16	27
83	*Physa sp.*	R		R					6																
85	Sphaeriidae		R	A	1				29	2		2	3	10	2	10	44	46	8	29	27	27	1	3	4
	ACARINA																								
86	*Flabellitronipoda sp.*											1													
87	*Hydrachna maramauensis*														1										
88	Oribatidae	R								1	2							1							4
89	Plonidae	A	A	R					1	1										1				2	1
	CRUSTACEA																								
91	Copepoda																								
92	Cyclopoidea																							3	
100	Ostracoda																					1	2		2
103	COLLEMBOLA																	1							

Code No.		Hand net samples			0.5m (site1)			0.5m (site 2)			1m			2m			3m			4m			8m		
		a	b	c (s2)	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
	Number of taxa	15	12	19	2	6	2	9	11	10	9	9	6	8	8	7	10	10	8	11	8	9	12	11	16
	Number of animals				3	19	7	103	449	97	99	59	67	107	78	153	315	194	280	260	314	151	150	158	265
	PLANTS																								
	Chara corallina	R	R	R	trace	trace			0.05			0.02		0.23		trace	0.15	trace	trace	trace	0.06	trace	0.61	0.43	0.83
	Elatine gratioloides			R					0.70				trace												
	Elodea canadensis	R													0.19	1.28	0.22	0.37	0.14	0.10	0.32	0.40			0.12
	Glossostigma diandrum	R		C					0.10		0.07														
	Isoetes kirkii			R									0.01												
	Liliaeopsis sp.								0.13																
	Myriophyllum triphyllum			A				8.33	1.41	3.73				trace	0.19										
	Pilularia novae-zelandiae			A					0.20																
	Potamogeton cheesemanii			C				trace			0.06	0.07	0.05	0.13	0.11	trace			0.06						
	Algae	R	C			0.03	0.02											trace	trace			trace			trace
	Moss (Lycopodium spp.)	R	R	R					trace	trace	0.02	trace		trace	0.02	trace	0.04	0.03	0.04	0.03	0.03	0.02	0.11	0.10	0.59
	Detritus				0.31	0.85	0.36	5.00	8.94	9.58	21.81	1.46	1.70	12.32	18.00	10.96	21.58	16.03	13.06	21.38	18.70	24.15	60.15	51.73	63.45
	FISH																								
	Gobiomorphus cotidianus		P	P																					

Appendix B15: Macroinvertebrates and plants recorded in core samples (0.0135m² area, 0.5mm mesh) from Lake Manapouri (31 January 1992). P=present, R=rare, C=common, A=abundant, VA=very abundant. Numbers are counts per sample for macroinvertebrates and dry weights (g) for plants.

Code No.		Hand net samples			0.5m			1m			2m			3m			4m			10m
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a
	ODONATA																			
6	*Procordulia grayi*	R																1		
7	*Xanthocnemis zealandica*																1			
	LEPIDOPTERA																			
15	*Hygraula nitens*			R		1														
	COLEOPTERA																			
21	*Berosus sp. (A)*		A	R																
	Berosus sp.	R	C	R			11													
27	*Liodessus sp.*		R																	
	DIPTERA																			
28	*Chironomus sp a*	R	A	C			1	60	20	10	13	40	26	8	7	5	2	12	2	8
	• • • *(P)*									1	1									
29	*Chironomus zealandicus*													2	1			2		2
33	Orthocladiinae	A	A	C	3	6	2	3	14	14	3	3	2	1	2	2		1	1	
	• • • *(P)*					1				1		1	1	3	4		1		1	
36	Tanypodinae	R	A		1		3	4	2	4	14	15	8	2	11	6	7	15	8	17
	• • • *(P)*		R								1									
39	*Xenochironomus canterburyensis*										1		1							
44	Eriopterini	R																		
45	Ceratopogonidae			R			2													
48	*Molophilus sp.*		R		1		1													
	TRICHOPTERA																			
61	*Oecetis unicolor*	R	R				1	2		1		2	1			1		1		
62	*Oxyethira albiceps*			R																
63	*Paroxyethira hendersoni*		C	R			1	1	1	1	10	2	2	2	3	4	4	3	4	3
64	*Paroxyethira tillyardi*										2	1				1	2	1	1	
65	*Paroxyethira (complex)*			R																
66	*Paroxyethira (caseless)*		C	R			1	2			3	2	7	7	7	7	3	4	4	1
70	*Triplectides cephalotes*									1										
72	OLIGOCHAETES	A	VA	A	7	3	404	126	122	103	123	105	38	60	41	102	91	131	66	79
73	NEMATODA	C	C	R		1	63	12	14	21	2	1	35	6	2	2	2	1		4
74	NEMATOMORPHA	R		R			4	2	2	6	2	1	1							
75	NEMERTEA		C																	
	MOLLUSCA																			
78	*Gyraulus corinna*																		1	
79	*Hyridella menziesi*										1		2		3	1	1		1	2
80	*Lymnaea tomentosa*		R	R			1													
82	*Potamopyrgus antipodarum*	C	VA	A	2		11	21	6	9	51	13	8	48	53	54	58	178	46	17
84	*Physastra variabilis*		R											4	5	6	4	13	2	15
85	Sphaeriidae		R								4	2		2	4	8	12	10	6	53
	ACARINA																			
86	*Flabellifrontipoda sp.*		R							2	1									
88	Oribatidae			R																
89	Pionidae	R	C	C			1	3	3	9	10	2	1	9	8	5	3	7	4	
	CRUSTACEA																			
91	Copepoda																			
92	Cyclopoidea							1						1	1	2				3

Code No.		Hand net samples			0.5m			1m			2m			3m			4m			10m
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a
100	Ostracoda													1						
104	HYDRA		R																	
	Number of taxa	12	21	17	5	5	15	12	9	14	17	14	14	15	15	15	14	15	14	12
	Number of animals				14	12	507	237	184	183	242	190	133	156	152	206	191	380	147	204
	PLANTS																			
	Chara coralina	R	R	R	trace		trace	0.37	0.05									trace		0.92
	Crassula sinclairii									trace										
	Elatine gratioloides		R																	
	Elodea canadensis	C	C	C							1.77	1.71	0.93	2.09	2.91	2.70	1.71	1.10	1.84	
	Glossostigma diandrum		R	C	0.02		trace			trace										
	Isoetes kirkii	C	C							0.17										
	Myriophyllum triphyllum	C		C	0.63	0.35	0.07								trace					
	Potamogeton cheesemanii	C	C	C	0.08		0.31		0.02											
	Algae		C	C				trace	1.43	0.14										
	Moss (Lycopodium spp.)		R	R			trace	trace		trace	trace									
	Detritus				0.51	0.13	1.37	0.40	0.76	0.51	0.42	1.52	0.13	0.32	0.24	0.24	0.35	0.43	0.37	1.50
	Fish																			
	Gobiomorphus cotidianus		P	P																

Appendix IV

Monitoring Programme

APPENDIX IV

Manapouri Power Scheme Resource Consents Monitoring Program

A. Lakes Te Anau and Manapouri

Guidelines for lake level management are overseen by the Guardians of Lakes Manapouri, Te Anau and Monowai. These guidelines are derived by monitoring aspects of the shoreline vegetation and beach morphology. Ongoing monitoring of these is necessary to allow the Guardians to continue their assessment and refinement of the guidelines.

1. Shoreline vegetation.

Objective: *To assess the effects of the lake level management regime on the shoreline vegetation of Lakes Manapouri and Te Anau.*

Methods: Monitoring will use the vegetation transects and photopoint sites established by the Guardians. Shoreline vegetation transect monitoring methods are described in Johnson (1972). Photopoints have also been installed along the lake shorelines for community comparisons over time. Shoreline transects have been established at Lake Hauroko, which acts as a "control" area for comparison between managed lake levels and natural lake levels. The monitoring transects established by these earlier surveys are a suitable baseline for ongoing monitoring.

Re-measurement of selected transects in Lakes Manapouri, Te Anau and Hauroko will occur within 5 years after grant of consents, and at 5 year intervals thereafter. Re-measurement of selected transects will also occur if the high-level lake operating guidelines are exceeded ("event-driven" monitoring).

For "event-driven" monitoring surveys of the shoreline vegetation of the lakes, the number of transects and/or photopoints may vary, at the recommendation of the Guardians, depending on the nature and extent of the "event".

Reference: Johnson, P.N. 1972. Applied ecological studies of shoreline vegetation at Lakes Manapouri and Te Anau, Fiordland. Part 1: Vegetation of Lake Manapouri shoreline. Proceedings of the New Zealand Ecological Society 19: 120-142.

2. Beach sediments

Objective: *To assess the effects of the lake level management regime on the beach stability of Lakes Manapouri and Te Anau.*

Methods: Beach sediment monitoring has been carried out using 89 shoreline monitoring sites established by Pickrill (1976). Ongoing monitoring will utilise these sites, but the number of sites may be refined down to those which are most likely to reveal trends in beach

sediment movement and beach stability. Dr R.M. Kirk (pers comm) has recommended that approximately 40 of the 89 sites would be appropriate to identify and quantify long-term trends in shoreline change. Concurrent monitoring of selected sites in Lake Hauroko will also occur if deemed necessary by the Guardians. Monitoring will be supplemented with photographic records made at the time of each survey.

Re-measurement of the selected shoreline monitoring sites in Lakes Manapouri and Te Anau and Hauroko will occur within 5 years after grant of consents, and at 5 year intervals thereafter. Re-measurement of selected monitoring sites will also occur if the lake operating guidelines have been exceeded ("event-driven" monitoring).

For "event-driven" monitoring surveys the number of shoreline monitoring sites may vary, at the recommendation of the Guardians, depending on the nature and extent of the "event".

Reference: Pickrill, R.A. 1976. Lacustrine geomorphology of Lakes Manapouri and Te Anau. Unpublished PhD thesis, University of Canterbury. 402pp.

3. Littoral macrophytes

Objective: *To assess the effects of the lake level management regime on the aquatic macrophytes of Lakes Manapouri and Te Anau.*

Methods: There are 30 established macrophyte transects on Lake Manapouri, and 33 on Lake Te Anau. These transects, or an appropriate sample of them (as recommended by the expert engaged) will be re-measured within 5 years after grant of consents, and at 5 year intervals thereafter.

Re-measurement of selected transects will also occur if the low-level guidelines have been exceeded ("event-driven" monitoring). For "event-driven" monitoring surveys the number of transects may vary, at the recommendation of the Guardians, depending on the nature and extent of the "event". Assessments will include species diversity, cover frequencies and biomass. As a control measure, each 5 year and "event driven" monitoring survey will include concurrent monitoring of established transects in Lake Hauroko.

B. Control Structures

1. Fish passage

Objective: *To monitor the numbers of native and introduced fish passing upstream through installed fishpasses.*

Methods: Structures will be installed on the Mararoa weir for upstream native and introduced fish passage. A native fishpass will be installed on the Te Anau Control Structure. Provision for counting fish will be included in the design.

2. Eel recruitment

Objective: *To monitor eel recruitment in the Upper Waiau catchment (ie above the Mararoa weir).*

Methods: Elvers returning from the sea have difficulty in negotiating the Mararoa weir. Consequently, most eels found upstream of it are older than the structure itself. A monitoring baseline assessing the age structure of eels above and below the weir has been established by Mitchell and Davis-Te Maire (1994). The age structure of eels will be reassessed within 5 years after grant of consents, and at 5-yearly intervals thereafter. This would require capture of younger aged eels from riffle areas of the Mararoa river, and a comparison with eels caught from riffle areas in Excelsior reach of the Lower Waiau, using electric fishing. Aging of young eels can be done by sectioning otoliths and counting their annual rings. Liaison with Kai Tahu and commercial eels fishermen may assist with gaining samples of young eels.

Reference: Mitchell, C.P.; Davis-Te Maire, K.T.A. 1994. Mahingakai values of the Waiau river.
Report to ECNZ, 1994.

3. Upper Waiau River periphyton and macrophytes

Objective: *To assess the effects of the refined flow regime on periphyton and macrophytes in the Upper Waiau River.*

Methods: For periphyton and macrophyte monitoring, up to 5 transects will be selected in different habitat types (as recommended by the expert engaged, and with agreement with the Southland Regional Council). Transects will be reassessed within 5 years after grant of consents, and at 5-year intervals thereafter. Re-measurement of transects may also occur after 7 consecutive days with flows of less than 115 cumecs ("event-driven" monitoring).

For macrophytes, assessments of species diversity, cover frequencies and biomass may be made. Periphyton analysis may include ash-free dry weight, chlorophyll-a and species composition.

C. Lower Waiau River

1. Trout

Objective: *To monitor trout densities in the Lower Waiau River, upstream of the Monowai confluence, when the new flow regime has been established.*

Methods: Annual drift diving assessments of trout abundance have been made along the three transects in the Lower Waiau river, as established by Jowett (1993). A further transect, established at Sunnyside will also be remeasured. These will be used as a baseline for ongoing monitoring for the next 5 years. The transects for drift diving will therefore be: (i) Excelsior reach (ii) Redcliffs reach (iii) Blackmount reach (iv) Sunnyside.

There will also be angler surveys carried out on the Lower Waiau River to assess catch rates, species composition and qualitative measures such as "the angling experience".

Reference: Jowett, I.G. 1993. Minimum Flow Requirements for Instream Habitat in the Waiau river, Southland, from the Mararoa Weir to the Borland Burn.
Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

2. Native fish

Objective: *To monitor native fish densities in the Lower Waiau River, upstream of the Monowai confluence, when the new flow regime has been established.*

Methods: Suitable sampling sites, representative of native fish habitats in the river, will be established on the advice of a suitable specialist, and agreed with the Southland Regional Council. These sites will be sampled at annual intervals for 5 years. Electric fishing and/or seine netting methods could be used.

3. Periphyton and macroinvertebrates

Objective: *To monitor periphyton and macroinvertebrates in the Lower Waiau River, upstream of the Monowai confluence, when the new flow regime has been established.*

Methods: Periphyton sampling has been carried out on the Lower Waiau river by NIWA (Biggs 1993). It is envisaged that the transects and methods used by Biggs (1993) would be used as a baseline for periphyton and macroinvertebrate monitoring. An extra monitoring transect will be installed near the Duncraigen bridge, to assess the "lake outlet" characteristics expected to be exhibited at this site. All sites will be re-measured annually for the next 5 years. Re-measures will occur during the same time of year (February) as Biggs (1993). Periphyton analyses may include ash-free dry weight, chlorophyll-a and species composition. For macroinvertebrates, monitoring sites and methods will be selected by the expert engaged, and agreed with the Southland Regional Council. Analyses may include species composition, numbers and biomass.

Reference: Biggs, B.J.F. 1993. Report on Periphyton and invertebrate communities in the Waiau River, February 1993.
Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

4. Birds

Objective: *To assess the riverine bird density and distribution in the Lower Waiau river after the new flow regime has been established.*

Methods: A baseline survey of birds associated with the Lower Waiau river has been undertaken by Sagar (1994). Monitoring of riverine birds in the Lower Waiau will continue, during the same season (the breeding season, October-December), post-breeding (March-April), and Winter (June-July) seasons, using the same sites and methods used by Sagar (1994). This will be done annually for 5 years, and then reviewed.

Reference: Sagar, P.M. 1994. Aquatic birds of the Waiau river November 1993 and March 1994.
Report to the Waiau River Working Party, Southland Regional Council, Invercargill.

D. Channel morphology

1. Upper Waiau River

Objective: *To continue to measure the amount of riverbank erosion in the Upper Waiau river, after establishment of the refined flow regime.*

Methods: Two "peglines" were installed in the Upper Waiau river in 1983. These were at Rainbow Reach and "Village Pond". Re-establishment of the Rainbow Reach pegline will be necessary. Offset measurements of the peglines will enable the magnitude of erosion to be assessed annually, and after flows in excess of 800 cumecs (approximately 10 year return period).

2. Mararoa confluence and Home Creek delta

Objective: *To periodically survey the Mararoa and Home Creek deltas.*

Methods: For the Home Creek delta, Mills and Freestone (1992) recommended that cross section numbers 43, 44 and 45 be re-surveyed. For the Mararoa river confluence the recommended cross sections are numbers 1 to 13, and then the even numbered sections from 14 to 42.

These cross section transects will be reassessed within 5 years after grant of consents, and at 5-year intervals thereafter.

Reference: Mills, G.W.; Freestone, H.J. 1992. Manapouri lake control. April 1992 cross section survey.
Works Consultancy Services report.

3. Lower Waiau River

Objective: *To continue to measure changes in erosion and accretion in the Lower Waiau River after the establishment of the new flow regime.*

Methods: The monitoring program will require an initial resurvey of the 11 existing transects installed by Duffil Watts and King in the Te Waewae reach of the Waiau river below Tuatapere, and the establishment of two additional transects immediately downstream of the Wairaki and Lillburn confluences respectively. The survey will be a topographical resurvey of the channel and the immediate margins of the river fairway where changes in bed level have been seen to occur. A photographic record will provide a comparison with the previous photographic baseline taken. For the new transects, installation will include:

(i) Permanent marking of transects.
(ii) Survey of the transects to establish a baseline.
(iii) Provision of a photographic record.

Future re-surveys will occur within 5 years after grant of consents, and at 5-year intervals thereafter. Re-surveys will also be undertaken after flows of greater than 1200 cumecs, as

measured at the Mararoa weir. These are considered by Brierley (1994) to be channel-forming flows.

4. Aerial photography

Objective: *To monitor the channel morphology in the Lower Waiau River and its response to the new flow regime.*

Methods: The existing aerial photographic survey of the Lower Waiau river channel will be updated within 5 years after grant of consents, and at 5-year intervals thereafter. Re-surveys will also be undertaken after flows of greater than 1200 cumecs, as measured at the Mararoa weir. These are considered by Brierley (1994) to be channel-forming flows. Tracings of the main tributary confluences and the lowland plain will be taken to record any changes.

Reference: Brierley, G.J. 1994. Channel adjustments along the Waiau River, 1946-1992: Assessment of the impacts of flow regulation.
Report to the Waiau Working Party, Southland Regional Council, Invercargill.

Monitoring the Marine Environment of the Doubtful Sound System

Philip Mladenov and Graham Allen
Department of Marine Science
University of Otago
P.O. Box 56
Dunedin

31 May 1996

Report prepared for:
Electricity Corporation of New Zealand

Information contained in this report should not be used without prior consent of the client

1.0 Introduction

The purpose of this report is to describe the plan for monitoring the marine environment of the Doubtful-Thompson-Bradshaw Sounds system (the Doubtful Sound System) in order to meet ECNZ's obligations in terms of the proposed consent conditions for the ongoing operation of the Manapouri Power Station. The monitoring programme is designed to meet these obligations by (i) gathering sufficient information to confirm and, where appropriate, establish the current environmental condition of the Doubtful Sound system and a reference fiord (Milford Sound), and (ii) monitoring the environmental condition of the Doubtful Sound system and the reference fiord over the term of the resource consents and reporting any changes in the marine environment of Doubtful Sound system resulting from the ongoing operation of the Manapouri Power Station.

The monitoring programme covers the initial period of seven years from the grant of consents. Any change or extension to this programme will be in accordance with the provisions of consent condition 7.6.

2.0 Monitoring Objectives and Techniques

2.1 Monitoring Key Physical Parameters

2.1.1 Objectives

The objectives of this aspect of monitoring are to:

(i) Improve our understanding of how the (Low Salinity Layer) LSL of Doubtful Sound and the reference fiord responds spatially and temporally to changes in freshwater input from rainfall and, in the case of Doubtful Sound, Power Station discharge.

(ii) Generate a database of physical characteristics of the LSL which, together with the data collected as part of the biological monitoring (see section 2.2), can be used to assess the effect of continued Power Station discharge on the biological communities of Doubtful Sound.

2.1.2 Basic methodology

To meet these objectives monitoring will involve:

(i) Recording continuously key physical parameters of the LSL at four sites in the Doubtful Sound system and one site in the reference fiord.

(ii) Conducting periodic synoptic surveys (i.e., surveys that provide a large-scale overview) of LSL characteristics of both the Doubtful Sound system and the reference fiord.

(iii) Conducting a series of synoptic surveys of LSL characteristics of the Doubtful Sound system as soon as practicable after a storm event equivalent to or greater than a five year return period storm event.

(iv) Collecting time series of rainfall, air temperature, wind speed and direction for the Doubtful Sound system and the referenec fiord over the period of continuous monitoring.

2.1.3 Continuous monitoring

Instrumented moorings will be deployed at five sites:

- Deep Cove
- a central site in Doubtful Sound
- a central site in Thompson Sound
- a central site in First Arm
- a central site in the reference fiord

All moorings will be equipped with Temperature-Conductivity (T-C) chains which will record temperature and salinity at twelve discrete depths in the upper 25 m. Additionally, at the Deep Cove site, current speed and direction will be recorded at 4 and 25 m depths with current meters and light levels will be recorded at 3 and 24 m depths with submarine light sensors. All sampling will be at intervals of not more than one hour.

At the commencement of the monitoring programme all instrumented moorings will be deployed. During monitoring the instruments will be recovered, serviced and all data downloaded at periods not greater than three months.

The outcome of continuous monitoring of physical parameters will be a detailed, long-term database of the physical characteristics of the LSL at specific sites in the Doubtful Sound system and the reference fiord that can be related to weather events and Power Station discharge, as well as to information from biological monitoring.

2.1.4 Synoptic surveys

The spatial variability of the LSL will be assessed in conjunction with the servicing of the moored instruments by measuring temperature, salinity and light levels using a CTD and submarine light meter between the surface and 50 m depth at six sites in Doubtful Sound, one site in each of First Arm, Crooked Arm and Hall Arm, four sites in Thompson Sound and one site in Bradshaw Sound. These parameters will also be measured at four sites along the length of the reference fiord.

The outcome of the synoptic surveys of physical parameters will be a long-term series of seasonal overviews of the Doubtful Sound system and the reference fiord that can be used to more fully characterise the physical state of the LSL throughout these fiords over a period of many years.

2.1.5 Post-storm surveys

A daily series of synoptic surveys of the temperature, salinity, and light levels of the LSL using a CTD and submarine light meter will be carried out at the 14 sites in the Doubtful Sound system used for the synoptic surveys (see section 2.1.4) as soon as practicable after the commencement of a storm event equivalent to or greater than a five year return period storm. No more than one post-storm survey will be conducted per annum. If a post-storm survey is not initiated during the first three years of monitoring, then such a survey will be initiated after a storm of a lesser magnitude.

The outcome of post-storm synoptic surveys of physical parameters of the Doubtful Sound system will be a database leading to a better understanding of the influence of major storm events on the physical features of the LSL.

2.1.6 Weather monitoring

A continuous time series of hourly rainfall, air temperature and wind speed and direction recorded at the permanent weather stations on Secretary Island, Doubtful Sound and at Milford Sound airport will be obtained. Freshwater discharge rates from Manapouri Power Station will be acquired from ECNZ.

2.2 Monitoring Key Biological Parameters

2.2.1 Objectives

The objectives of this aspect of monitoring are to:

(i) Obtain quantitative baseline information on the present distribution and species composition of the intertidal and shallow subtidal encrusting rock wall communities in the Doubtful Sound system and the reference fiord.

(ii) Generate a database of information on the long-term health and status of black coral colonies in the Doubtful Sound system and the reference fiord.

(iii) Generate a database of information on spatial and temporal variation in primary production in the Doubtful Sound system and the reference fiord.

(iv) Show experimentally that the observed patterns of species distribution of the encrusting rock wall communities, as determined during monitoring, are linked to long-term fluctuations of the LSL, and to provide data on biologically relevant salinities for fiord communities.

2.2.2 Basic methodology

To meet these objectives monitoring will involve:

(i) Conducting an annual quantitative survey of intertidal communities in the Doubtful Sound system and the reference fiord.

(ii) Conducting an annual quantitative survey of encrusting rock wall subtidal communities in the Doubtful Sound system and the reference fiord.

(iii) Monitoring annually the status of tagged black coral colonies in the Doubtful Sound system and the reference fiord.

(iv) Conducting a synoptic survey of chlorophyll a levels and distribution in both the Doubtful Sound system and the reference fiord in conjunction with servicing of the moored instruments.

(v) Monitoring at the same time as the post-storm survey of physical parameters the status of black coral colonies and other biota in the Doubtful Sound system to capture the immediate effects of severe flood events on fiord biota.

(vi) Conducting a controlled transplantation experiment at four sites in Doubtful Sound, together with a companion laboratory experiment, in the first year of the monitoring programme.

2.2.3 Monitoring the intertidal community

The intertidal communities at 10 permanently marked sites in the the Doubtful Sound system and at four permanently marked sites in the reference fiord will be monitored. These sites will be located in close proximity to sites where periodic monitoring of physical parameters takes place.

The sites will be surveyed quantitatively once a year in February at spring low tides using a video camera in an underwater housing and a stratified random design.

The outcome of intertidal monitoring will be a long-term database that can be used to characterise intertidal communities in the Doubtful Sound system and the reference fiord, detect any changes in the structure of these communities over time, and relate these to any changes in the physical aspects of the LSL.

2.2.4 Monitoring the encrusting rock wall subtidal community

The subtidal communities will be monitored quantitatively once a year in February in the Doubtful Sound system and the reference fiord at the same sites as where intertidal monitoring will be conducted. At each site the biota in a strip along seven randomly allocated vertical transects will be recorded using an underwater video camera from the surface to a depth of 20m.

The outcome of subtidal monitoring will be a long-term database that can be used to characterise the structure of subtidal encrusting rock wall communities in the Doubtful Sound system and the reference fiord, detect any changes in the structure of these communities over time, and relate these to any changes in the physical aspects of the LSL.

2.2.5 Periodic monitoring of black coral colonies

The health of black coral colonies will be monitored at each of the sites used for intertidal and subtidal monitoring. Ten black coral colonies over a range of sizes (lower limit of 100 mm in

height) will be tagged at each site using plastic cable ties and labels. Thus a total of 100 colonies will be tagged in the Doubtful Sound system and 40 in the reference fiord. At each site, the shallowest colonies observed will be tagged. Once a year in February the height of each colony will be measured using a flexible tape, following the curves of the major branch axis, and distinguishing features of each colony will be recorded (eg, general appearance or "health", presence of encrusting organisms, presence of symbiotic snake stars). A video image of each colony will also be recorded.

The outcome of black coral monitoring will be a long-term database on the status of a large number of individual black coral colonies in both the Doubtful Sound system and the reference fiord that can be related to the physical aspects of the LSL.

2.2.6 Synoptic survey of pelagic primary production

The spatial variability of chlorophyll a levels between the surface and 50 m depth will be assessed in conjunction with the servicing of the moored instruments using a pigment sensor mounted on a CTD at the same sites to be used for the synoptic survey of physical characteristics of the LSL (see section 2.1.4).

The outcome of the synoptic surveys of chlorophyll a will be a long-term series of seasonal overviews of pelagic primary production in the Doubtful Sound system and the entire reference fiord that can be related to physical aspects of the LSL.

2.2.7 Post-storm survey

In conjunction with the post-storm surveys of the LSL (see section 2.1.5), a representative sample of the tagged black coral colonies in the Doubtful Sound system will be examined, noting information on their general appearance and recording a video image of each colony. In addition, incidental information will be gathered on other coral colonies observed during the course of this work, as well as on the distribution and health of other representative biota.

The outcome of post-storm surveys of biota will be a database leading to a better understanding of the influence of major storm events on the health and distribution of black corals and other organisms.

2.2.8 Controlled transplantation and laboratory experiment

Two representative species of the stenohaline fiord rock wall community (the brachiopods *Magasella sanguinea* and *Neothyris lenticularis*) will be exposed to fluctuations in the LSL by controlled transplantation at four sites in Doubtful Sound. Paired sites (one on either side of the fiord) will be located as close as possible to moored instrument arrays so that the data from the arrays can be used to determine the salinities to which the experimental animals were exposed. Individuals of each species will be placed in a random stratified design down the rock wall at each site at depths from 0-20m. Individuals will also be placed back at the depth from which they were collected as controls. The transplanted animals will be monitored after 2, 4, 12, 25 and 56 weeks. It is expected that those individuals transplanted to the shallowest depths will survive for only a short period of time whereas the length of survival of those at deeper depths will depend on the frequency of LSL incursions to those depths. A companion laboratory experiment will control for the possible confounding effects of depth with salinity. Individuals of the same two species will be subjected to a range of salinity regimes in the laboratory and their survival monitored. Survival in full-strength seawater will mean that depth *per se* has no effect. The salinities at which death occurs in the laboratory will be correlated with data from the field experiments and moored instruments.

3.0 Reporting and Analysis

An annual report will be prepared each year. This report will present the data collected as part of the monitoring programme and a summary of the results in achieving the objectives of the programme.

At the end of the first year of the programme, a power analysis will be undertaken to determine the sensitivity of the biological monitoring work then completed. The results of the power analysis, together with any suggestions for modifications or refinement of the work, if any seem necessary, will be reported to the Department of Conservation and ECNZ. If agreement is not reached on the significance of the power analysis and the utility of the suggestions made for change, a report to the Waiau working party will be made so that the Regional Council can consider the need for any change or variation in consent conditions.

The first two annual reports will concentrate on presenting the data gathered and relevant observations. The third and subsequent reports will present the data and provide sound interpretation. The results of the controlled transplantation and laboratory experiments will be presented in the second annual report.

Data from physical monitoring will be used to formulate an empirically derived relationship between rainfall, Power Station discharge and depth and mean salinity of the LSL in the Doubtful Sound system and the reference fiord.

For each video image obtained during intertidal and subtidal monitoring the number of species and the percent coverage of dominant species will be determined. Species abundance and species diversity within each depth stratum will be calculated and patterns of species diversity contoured and related to information on the physical nature of the LSL. A time series of observations and video images obtained from black coral monitoring will be assembled and any changes in the status and health of black coral colonies related to changes in the physical nature of the LSL.

All data and images will be quality controlled and archived permanently on computer or video tape in the Department of Marine Science to allow for future analysis and, in the case of images, direct visual comparisons.

Assessment of Effects on the Environment



The next generation – Upper Waiau River

ID: 3102 Cat: Consents ECNZ
Title: Manapouri Power Scheme Assessment of Effects on the Environment

ELECTRICITY CORPORATION OF NEW ZEALAND LIMITED

Consents ECNZ