EIS 533

AB018627

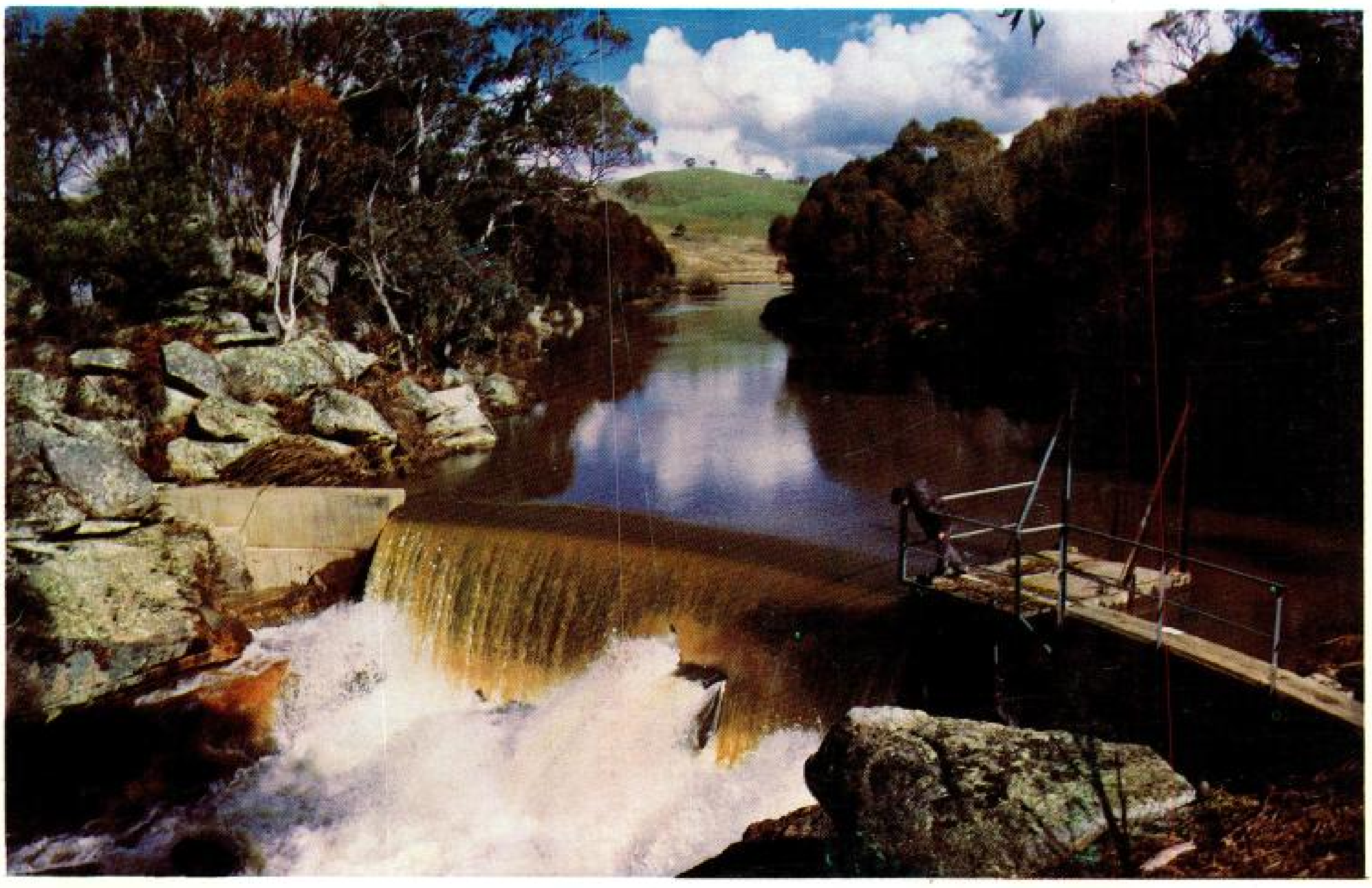
Environmental impact statement for the Wallamaine Colliery Coal Handling and Loading Facility at Morisset, NSW

PUBLIC WORKS

FISH RIVER WATER SUPPLY UNDERTAKING

DUCKMALOI WATER CLARIFICATION PLANT

ENVIRONMENTAL IMPACT ASSESMENT



environmental management

FISH RIVER WATER SUPPLY UNDERTAKING

DUCKMALOI WATER CLARIFICATION PLANT

ENVIRONMENTAL IMPACT ASSESSMENT

November 1988

prepared by

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Cover Photograph: Duckmaloi Weir eight days after the flood of August, 1986. The poor quality of the water is evident. Note the height of the floodwaters as indicated by the bushes flattened on the left of the photo.

FOREWORD

During the drought of 1978-83, one of the worst recorded in the Upper Macquarie Valley, the Fish River Water Supply Undertaking was unable to deliver the agreed allocations to its customers. Subsequent examinations found that the system did not perform as expected, because water quality constraints prevented water being drawn from Duckmaloi Weir as originally intended.

Given that demands on the scheme are continuing to grow, it is necessary to determine the most suitable means to overcome the shortcomings which have been exposed.

This Environmental Impact Assessment (EIA) describes the various alternatives which have been considered, and then assesses in detail the environmental effects and safeguards for the preferred option.

The report was prepared by Environmental Management, in association with officers from the Water Supply Branch and the Western Regional Office of the Public Works Department. Dr. David Goldney of Mitchell College of Advanced Education studied the platypus colony in the Duckmaloi River, while the aquatic ecosystems and water quality characteristics were investigated by W.S. Rooney and Associates, with assistance from the Fisheries Division of the Department of Agriculture. The archaeological investigation was undertaken by Brayshaw McDonald Pty.Ltd.

The assistance of all the above officers and consultants, particularly the contributions to the investigations of others in the team, is gratefully acknowledged.

For further information on this EIA, please contact the Fish River Water Supply Undertaking, c/o the Regional Manager, Public Works Department, 140 William St., Bathurst, 2795 (Tel. 063-334-222).

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LIST OF ABBREVIATIONS

AHD	Australian Height Datum
BOD	Biological Oxygen Demand
BPT	Break-Pressure Tank
COD	Chemical Oxygen Demand
DO	Dissolved oxygen
DWR	Department of Water Resources
ECNSW	Electricity Commission of NSW
EIA	Environmental Impact Assessment
EPA	Environmental Planning and Assessment (Act)
FRWS	Fish River Water Supply
GLCC	Greater Lithgow City Council
HDWB	Hunter District Water Board
km	kilometre
MAF	Mean annual flow
MAQ	Minimum Annual Quantity
ML	million litres
ML/a	million litres per annum
MW	megawatts
MWh	megawatt-hours
NPWS	National Parks and Wildlife Service
OSC	Oberon Shire Council
pH	index of alkalinity
PWD	Public Works Department
SCS	Soil Conservation Service
WB	Water Board
WCP	Water Clarification Plant
WFAS	Wentworth Falls Angling Society

SUMMARY

The Fish River Water Supply (FRWS) is a self-financing trading undertaking of the NSW Government. The Scheme was started in 1943 as part of the war effort, and was intended to supply water to the factories and coalfields around Lithgow and to the oil-shale works at Glen Davis. However, nowadays it supplies most of its water to Wallerawang Power Station, and urban areas in the Upper Blue Mountains, Greater Lithgow and Oberon.

Its major sources of supply are the Fish and Duckmaloi Rivers, in the headwaters of the Upper Macquarie Valley. Until recently, the Scheme had been assessed to be able to provide a supply of 14,200 ML/a with a reasonable degree of assurance (this is known as the "safe or secure yield"), and the FRWS Undertaking had entered into agreements to supply a minimum of 14,250 ML/a to its customers.

During the Drought of 1978-83, which was the worst on record, the water supply system was not able to deliver to its customers the quantities of water which had been agreed would be supplied, and severe restrictions on water consumption had to be imposed.

It was found that the system had not performed as expected because of constraints on the quality of water which could be supplied. At present, water is not taken from Duckmaloi Weir when flow in the stream exceeds about 6 ML/day, because the water quality is often too poor at high flows. This prevented water being drawn from the Duckmaloi Weir as originally intended, so that the secure yield of the FRWS was only 11,700 ML/a, a shortfall of 2,550 ML/a.

In order to bring the safe yield back up to near 14,250 ML/a, it is proposed to build a water clarification plant to treat the water from Duckmaloi Weir. The major environmental issues to be addressed concern the allocation of water from Duckmaloi River, rather than the effects of the water clarification plant itself. These issues are:-

- the need for this proposal;
- the transfer of water from west of the Great Dividing Range to the east;
- the effect of the extraction of water on the platypus which inhabit the Duckmaloi River;
- the effect of the extraction of water on the trout and native fish downstream of the weir.

Why More Water Is Needed

The Fish River Water Supply Scheme obtains its water from a storage dam on the Fish River at Oberon, and a small pipehead weir on the Duckmaloi River.

The Duckmaloi River is a tributary of the Fish River, which becomes the Macquarie River when joined by the Campbell River further downstream. The Scheme has four major consumers:

- Oberon Shire Council (OSC)
- Greater Lithgow City Council (GLCC)
- Electricity Commission of N.S.W. (ECNSW)
- the Water Board (WB).

There are approximately 300 minor consumers, mainly rural landholders whose properties adjoin the Scheme's pipelines.

The sources of supply are set out in Table S.1.

TABLE S.1. SOURCES OF WATER FOR FRWS

SOURCE	STORAGE CAPACITY (ML)	SAFE YIELD (ML/a)	CATCHMENT (km^2)	MEAN INFLOW (ML/a)
Oberon Dam	45,400	11,600	141	18,600
Rydal Storage	360	negligible	1	negligible
Duckmaloi Weir	20	100* (2,600)+	110	21,500
Totals	45,780	11,700 (14,200)	252	40,100

* Contributory yield when operated in conjunction with Oberon Dam and subject to water quality constraints.

\+ Duckmaloi contributory yield if it is assumed that water quality constraints are removed.

As part of the agreement between the FRWS and its major consumers, each major consumer undertakes to make minimum annual payments based on a certain minimum annual quantity (MAQ), even if a lesser volume is used. The current MAQs, totalling 14,250 ML/a, are set out in Table S.2, together with predicted demands to 1994.

TABLE S.2. FISH RIVER - SHORT-TERM ANNUAL DEMANDS (ML/a)

TOWNS	MAQ	1988	1994
Oberon	264	450	600
Greater Lithgow	2,092	2,100	2,100
The Water Board	3,650	3,650	3,650
Minor consumers	60	200	200
ECNSW	8,184	4,000	8,184
Total	14,250	10,400	14,734

During the drought of 1978-83, Oberon Dam was emptying rapidly, and restrictions had to be applied in 1980 and then more severely in 1981. This resulted in intense communal pressure to upgrade the Fish River Scheme's capacity to supply water.

Since the drought, restrictions have been removed, but the consumption of water from the Fish River Scheme has remained significantly less than the total MAQ. This is because the major consumers have each taken steps to reduce their dependence on the Fish River Scheme by obtaining water from other sources, using their own sources more effectively or reducing consumption. It also reflects the fact that during these non-drought years, supplies from these other sources are higher than can be expected in drier times.

The **Electricity Commission** takes water from the Fish River Scheme for its boilers in Wallerawang Power Station and for domestic uses. It seeks water from these sources in preference to water from the Coxs River, because of its higher quality. The alternative would be to treat water from the Coxs River at considerable expense.

At present, although the Commission is entitled to **8,184 ML/a** from the Fish River Scheme, it has managed to limit its consumption to an average of 4,000 ML/a over the past 5 years. However, once Mt. Piper Power Station is fully commissioned in 1994, the ECNSW will once more be drawing its full allocation of water from the Fish River Water Supply.

The **Water Board** has forecast that there will be little growth in demand in the **Upper Blue Mountains** in the next 20 years, and that it will be able to meet these demands from its local supplies, together with its current allocation of **3,650 ML/a** from the Fish River Scheme.

Much of **Greater Lithgow City Council's** water supply comes from its local sources and the Clarence Colliery. However, this latter source of water cannot be relied on in the long term. It is therefore necessary to take immediate steps to upgrade the security of Lithgow's present allocation of **2,092 ML/a** from the Fish River Scheme.

Oberon, the only major consumer of the Fish River Scheme on the western side of the Great Dividing Range, relies solely on Oberon Dam for its water supply. It has consumed more than its MAQ of **264 ML/a** in most years since 1964. The demand for water is expected to increase because of the present expansion of Oberon's timber industry, and it seems reasonable to assume that a consumption of up to 600 ML/a should be allowed for.

The **minor consumers** are either rural landholders whose properties adjoin the pipelines, or inhabitants of the villages of Rydal and Cullen Bullen. A few are coal mines which take water from the Fish River Scheme for domestic consumption, and some are local schools. Although the minimum allowance for these minor consumers totals only **60 ML/a**, this has been exceeded in every year since 1964. The total amount consumed has often been more than half of what was used by Oberon in the same year: last year this proportion was 62%. Options for reducing demand are being reviewed, with the goal of limiting consumption by the minor consumers to around 200 ML/a.

From now on, the maximum amount supplied to the major consumers will rarely be more than the total MAQ. When the storage behind Oberon Dam is below top water level, the Administrator of the FRWS will endeavour to ensure supplies are limited to the total MAQ (except in emergencies). This would be necessary to avoid unacceptably high restrictions being applied in future, should the system be entering a critical drought period. In the knowledge of these operating procedures, major consumers will be adapting their operations and usage of alternative water supplies such that it will similarly be unlikely that more than total MAQs will be used during wet years, when Oberon Dam is full.

Overall therefore, although the major consumers have been given extra water when they requested it in the past, it is thought there will be few situations when they will use more than the Scheme's total MAQ in the future.

The present demands of the various consumers, and their estimated requirements in 1994 are set out in Table S.2. It can be seen that while the current safe yield of the FRWS (11,700 ML/a) should normally suffice at present, it will not be adequate in four years' time. Furthermore, even if the Fish River Scheme still had a safe yield of 14,200 ML/a as had previously been thought, it would not quite meet the demands forecast for 1994, largely because of demands in excess of MAQ by minor consumers and Oberon, which is on the western side of the Great Dividing Range.

Options for addressing deficiencies

Various non-structural and structural options have been considered. These are:-

Non-structural

- **Doing nothing.** The consequences would be: severe restrictions during the next lengthy period of low rainfall; intensified political pressure to improve the supply; the major consumers would be forced to seek immediate alternative sources of supply, probably at very high cost and with uncertain environmental effects; and the aquatic ecosystems in the Duckmaloi River would become severely stressed, with adverse impacts on the platypus and trout populations in the River.

- **Introducing pricing policies which discourage excessive consumption.** There are two aspects of this: revising the method of charging the major consumers, to encourage them to adopt measures to reduce demand; and revising the tariffs actually charged to the end users of the water, to encourage them to keep their own consumptions low, by having them pay more directly for their consumption. The first of these strategies is currently being investigated. The second should be effective in reducing the demands in Oberon and of the minor consumers, and could result in a reduction in demand of **80 ML/a.**

- **Reducing domestic consumption through leak detection, and metering.** Most residences of Lithgow and 20% of the Upper Blue Mountains are not metered. It is estimated that if Greater Lithgow City Council metered all its consumers, there could be a reduction of 20% in demand, thereby reducing consumption by **700 ML/a.** Because the consumption in the Upper Blue Mountains (200 kL/a per dwelling) is already well below the current domestic allowance in the Sydney metropolitan area (300 kL/a), metering of the remaining 20% of customers in the Upper Blue Mountains would not reduce demand by any appreciable amount.

  Leak detection and reduction has already resulted in a saving of consumption of 50 ML/a in Oberon. It is thought that another **10 ML/a** might be saved in this way in the villages of Rydal and Cullen Bullen. At this stage, leak detection programmes in Greater Lithgow and the Upper Blue Mountains do not appear warranted.

- **Developing a Catchment Management Plan for the Duckmaloi and Fish Rivers.** If the access of stock to the Duckmaloi River upstream of Duckmaloi Weir could be prevented, the quality of water flowing into the weir would be improved, and more water could be extracted from the Duckmaloi River without treatment. However, this would take a long time to implement, and the increased supply would not be expected to be available by 1994. The environmental impacts downstream of Duckmaloi Weir would be the same as for the preferred option discussed below (constructing a water clarification plant).

  An even longer-term option for catchment management might be to replace pines in the catchment with eucalypts, thereby possibly increasing the yield of the Upper Macquarie Catchment significantly.

In all, it is considered that by 1994, demand could be reduced by **790 ML/a** through non-structural measures.

<u>Structural</u>

- **Recycling water.** Recycling sewage effluent at Oberon may reduce its demand by about 50 ML/a. Significant effluent recycling within the Blue Mountains is uneconomic because of the location of treatment works, the type of terrain and the minimal amount of non-domestic consumption in the area.

Effluent from the sewage treatment plants at Lithgow and Wallerawang already discharge into Farmers Creek and the Coxs River, respectively. Consequently, the treated sewage already constitutes part of the yield of the Electricity Commission's Coxs River water supply scheme. Thus, a recycling scheme is already in operation for these urban areas, and any action by the Fish River Scheme to utilise the effluents would result in the ECNSW having to build additional storages to compensate for the loss in yield. The direct cost of recycling effluent in Lithgow could be up to $6 million, almost 50% more than the cost of the preferred option (water clarification plant). When the costs to the ECNSW to build compensatory storage are added to this, it is clear that recycling of water is not a viable option for Lithgow, and by extension, Wallerawang.

In summary, it is estimated that demand from the Fish River Scheme might be economically reduced by **50 ML/a** through recycling. While this could be a useful means of reducing Oberon's demand on this Scheme, recycling would not be an important strategy for satisfying all the demands in 1994.

. **Constructing a weir on the Coxs River.** This option has the advantage that it relies on an eastern flowing waterway to provide the additional yield for the FRWS. A storage of 500 ML would be required, with a pump and pipeline to supply up to 12 ML/day to Lithgow and the Electricity Commission at Wallerawang.

Its disadvantages are that it would be considerably more expensive than the preferred option in both inital capital cost and on-going operating costs; full treatment of the water would be required; the yield of the Water Board's Warragamba Dam Catchment would be reduced; and the weir would have significant impacts on the in-stream environment.

. **Arranging for joint use of the Fish River Scheme and the storages of the Electricity Commission.** The Electricity Commission is proposing to construct a large dam on Thompsons Creek near Wallerawang to provide the bulk of water requirements for its Mt. Piper Power Station. The dam would be filled principally by pumping water from the Commission's existing Lyell Dam on the Coxs River.

Joint operation of storages would necessitate an increase in the size of the dam's storage from 35,000 ML to 43,000 ML. The FRWS would draw a supply from either Thompsons Creek Dam or Lyell Dam.

Disadvantages of this option are similar to those for the Coxs River Weir: high inital and on-going costs, the need for full water treatment, and a reduction in Warragamba Dam's yield. A more serious disadvantage is that if the FRWS drawoff were from Thompsons Creek Dam, power boating and body-contact recreation might have to cease on Lake Lyell. If drawoff were only from Lake Lyell, only the activities on this storage would be affected.

- **Constructing a pipeline from Duckmaloi Weir to the upper reaches of Lake Oberon.** This proposal provides for turbid water from the Duckmaloi to be pumped across to Oberon Dam, allowing the sediment and algae to settle out in the lake before being drawn off into the pipeline network. The operation of this system would have adverse impacts on the ecosystems in the weir. The intermittent pumping would result in sharp fluctuations in water level which would reduce the biological productivity of the weir. This would occur particularly in the shallow areas and along the foreshores, since much of the benthic habitats (living areas of the bottom-dwelling animals) would be regularly uncovered, and allowed to dry out. This diminution of food sources would reduce the capacity of the pond behind the weir to carry the present populations of platypus and trout.

  Furthermore, this fluctuation in water level could cause the flow downstream to vary between zero and full inflow within a day, and this would greatly stress the downstream aquatic ecosystems, including the trout and platypus.

- **Building a water clarification plant (preferred option).** This option involves partially treating the water from Duckmaloi Weir, bringing it to the same quality or better than that obtained from Oberon Dam. This treatment will allow the Duckmaloi source to be used more frequently than at present, by removing the constraint of unacceptable water quality. The clarification plant would be located at the Duckmaloi Break-pressure Tank site where it could also be used to treat water from Lake Oberon. Supply to the plant would be through the existing pipeline from the weir at its gravity-flow capacity of 33 ML/day.

  The proposal would provide the scheme with an additional yield of 2,200 ML/a which is less than the required increase of 2,500 ML/a. Nevertheless, the proposal offers the cheapest solution and represents a resonable compromise between consumer and environmental needs: the safe yield will be sufficiently high to meet most demands, whilst the amount of water released downstream will be sufficient to ensure environmental impacts are acceptable.

  The major potential impacts of the proposal are the transfer of additional water from west of the Great Dividing Range to the east, the effect on the platypus in and downstream of Duckmaloi Weir, and the effect on trout in the River.

As indicated in Table S.3, the water clarification plant is the structural option which would be the quickest to implement and cheapest overall. Its environmental effects would be less than those of interconnecting with the ECNSW water supply system, or consructing a separate weir on the Coxs River. This therefore has been chosen as the preferred option.

TABLE S.3. COMPARISON OF STRUCTURAL OPTIONS

	Coxs River Weir	Transfer Pipeline	Clarification Plant (preferred option)	Interconnect with Elcom	Recycling at Lithgow
Time to implement	5 years	18 months	18 months	3 years	5 years
Capital Cost	$15 million	$4.5 million	$4.0 million	$15 million	>$6 million
Additional Yield (ML/a)	2,500	2,500	2,200	2,500	2,400
Important Environmental Effects	Inundation. Changed aquatic env. Pipeline. Reduces Warragamba yield. May cause some restrictions in power boating on Lake Lyell. Access Roads.	W-E flows. Platypus. Trout. Fluctuations of weir level and river downstream. Possible archaeological areas	W-E flows. Platypus. Trout.	Loss of recreation on Lake Lyell storage. Reduced Warragamba yield.	Reduces yield of Elcom storages

Evaluation of the Preferred Option

It is proposed that the WCP will have the capacity to treat 40 ML/day, which is roughly the average daily demand of the Scheme's customers on the eastern side of the Great Dividing Range.

The currently allowed mode of extraction, where the riparian releases need be no more than 2 ML/day in summer and 0.5 ML/day in winter, would have caused very severe impacts on the aquatic environment in the past. The availability of food sources for the trout and platypus would have diminished, some downstream pools would have frequently become stagnant, and the number of platypus and trout between the weir and McKeons Creek would have decreased.

The average daily flow of Duckmaloi River at the weir is about 59 ML, and it is normally assumed that a minimal flow of 30% of this is needed to maintain the aquatic ecosystems in a satisfactory condition. A minimal flow of 10% or (5.9 ML/day) is usually taken as being merely sufficient to keep aquatic ecosystems in a poor or degraded condition. However, it has been determined by extensive studies at the site that, provided the flows will not drop below 6 ML/day, this should be sufficient to maintain the aquatic ecosystems downstream of the weir in a satisfactory condition.

The proposed operating procedures will thus allow at least 6 ML/day to flow downstream, unless the inflow is already less than this. In this way, this should ensure that the aquatic ecosystems are not overstressed because of the extraction of water for the Fish River Scheme.

Although the river is often flowing at less than 6 ML/day because of natural variations in water flow, this does not cause any significant disturbances to the aquatic ecosystems. These low flows are only reached over a long period, and the aquatic fauna would have time to adapt. If however, the flows were to drop below 6 ML/day during the normal extraction procedures, this would put these species under excessive stress, since the flows would be fluctuating between high and low values over only a few hours, and the larvae, invertebrates and fish would not be able to cope easily. Nevertheless, it has also been found in the Drought Simulation Study that if the flow drops to 3½ ML/day for only a few hours, the aquatic ecosystems should not be unduly stressed.

The extraction of water from the Duckmaloi would also reduce the load on Oberon Dam, and permit an increase in the amount released downstream during periods of high rainfall. This would benefit the aquatic ecosystems downstream of Oberon Dam to a small extent.

The peak rate of transfer of water from west of the Great Dividing Range to the east is unlikely to exceed current allocations of 14,000 ML/a, and it is expected that the highest flow of 15,000 ML/a in 1979 will not be repeated. However, while there would be no increase in transfers under normal conditions, the proposed works would result in an extra 1,700 ML/a being transferred during droughts. This may occur about 5% of the time. The mean annual flow of the Macquarie Valley at Bathurst is 320,000 ML with a minimum flow of 12,000 ML/a being recorded in 1940, before Chifley Dam was constructed. Chifley Dam regulates flows in the river for Bathurst Water Supply. The infrequent increased transfer of water from the FRWS will therefore have only a minimal effect on the flow of water at Bathurst, and further downstream at Burrendong Dam and the Macquarie Marshes.

The preferred proposal also has the advantage of providing additional water of better quality and from a higher elevation than available from the Coxs River. In this way, energy resources used for treating and pumping are kept low, whereas with the alternative of the Coxs River weir for example, the use of chemical and electrical resources would be much higher.

There are some small benefits to the Coxs Valley with the extra flow obtained from the FRWS, but their overall impacts are not judged to be significant.

The proposed works will have no effect on the terrestial ecosystems surrounding the Duckmaloi River. At the site of the Water Clarification Plant (WCP), some trees will be removed but consideration will be given to including **Eucalyptus pulveralenta** (a species with a restricted and reduced range) in the extensive landscaping which will be carried out to minimise the structure's visual impact. Apart from the operator's cottage, the plant will be visible from only three rural dwellings, and these are more than 1 km away.

Two sludge lagoons will be located 0.5 km to the west of the plant on cleared pasture land. These lagoons are low, unobtrusive structures similar to farm dams, to which sludge is transferred by underground pipe during the water treatment process. No odour is expected from the sludge. The clear discharge from the lagoons will flow to the Fish River under licence conditions specified by the State Pollution Control Commission.

There will be increased noise, dust and traffic during construction of the WCP and lagoons, although impacts on the environment will be minimal. The construction period will be about 16 months. No archaeological material has been found at or near the site.

Once the plant is commissioned, operational noise will be low, being less than 5 dB(A) above the acceptable base level at the nearest dwelling. Increased traffic movements will be negligible.

On balance, since the increase in the amount of water being transferred from west to east will be infrequent and small; since the proposed operating procedures will improve the habitat of the platypus and trout within the Duckmaloi River; and since alternative means of satisfying demand are more costly, use more resources, could have greater environmental impacts, or carry the risk of not meeting the needs of consumers, it is judged that the proposed augmentation should proceed, with the environmental safeguards listed below.

1. The water level behind the weir will not be allowed to drop below the crest.

2. Flows over the weir will not be deliberately allowed to drop below 6 ML/day, except in an emergency, and then only according to guidelines laid down by an aquatic ecologist. If the flow remains below 6 ML/day for more than 24 hours, the advice of an aquatic ecologist will be sought on the minimum flow to be temporarily released to help restore the environmental health of the river.

3. The quality of the water in and downstream of the weir will be monitored regularly, to ensure that an adequate supply of food for the platypus and trout is able to be maintained.

4. If the weir needs to be emptied for maintenance work, it will not be for longer than 24 hours. It will be undertaken in consultation with a wildlife ecologist and an aquatic ecologist. Notification will also be given to the Central Acclimatisation Society, should they wish to take extra steps to preserve the fish in the pond.

5. If the pond formed by the weir needs to be excavated to remove deposited sediment, care will be taken to ensure that sufficient benthos remains as a food source for the platypus and trout.

6. Both the health of the riverine environment, and the security of the platypus colony will be monitored for at least two years, and perhaps in more unusual circumstances, such as during periods of low flow.

1. INTRODUCTION

The Fish River Water Supply (FRWS) is a self-financing trading undertaking of the NSW Government, and operates under the direction of an Administrator who is the Director of the Public Works Department.

The Scheme was started in 1943 as part of the war effort, and supplied water to the factories and coalfields around Lithgow and to the oil shale works at Glen Davis. Nowadays, it supplies most of its water to Wallerawang Power Station, and urban areas in the Upper Blue Mountains, Greater Lithgow and Oberon.

The FRWS is essentially a bulk water supply authority, providing water to four major consumers: Oberon Shire Council, the Council of the City of Greater Lithgow, the Electricity Commission of N.S.W. at Wallerawang, and the Water Board (for its customers in the Blue Mountains).

Its major sources of supply are catchments of the Upper Macquarie Valley. Until recently, the Scheme had been assessed to be able to provide a supply of 14,200 ML/a with a reasonable degree of assurance (this is known as the "safe or secure yield"), and the FRWS Undertaking had entered into agreements to supply a minimum of 14,250 ML/a to its customers.

During the Drought of 1978-83, which was the worst on record, the water supply system was not able to deliver the agreed allocations to its customers, and severe restrictions on water consumption had to be imposed.

It was found that the system had not performed as expected because of constraints on the quality of water which could be supplied. This prevented water being drawn from the Duckmaloi Weir as originally intended, so that the secure yield of the FRWS was only 11,700 ML/a, a shortfall of 2,550 ML/a.

In the early stage of the investigations, it was realised that the preferred proposal would be based on an increased utilisation of Duckmaloi Weir. The major environmental issues to be addressed were therefore identified as concerning the allocation of water from Duckmaloi River rather than the effects of the works themselves. These major issues are:-

- the need for this proposal;
- the transfer of water from west of the Great Dividing Range to the east;
- the effect of the extraction of water on the platypus which inhabit the Duckmaloi River;
- the effect of the extraction of water on the trout and native fish downstream of the weir.

Chapter 2 explains why it is necessary to be able to supply more water than is available at present, while the options for addressing this need (including the option of doing nothing) are presented in Chapter 3. The proposed work and its environmental effects are then set out in Chapter 4. As much as possible, the technical information has been put into the Appendices.

2. WHY MORE WATER IS NEEDED

2.1. The Capacity of the Fish River Water Supply

The Fish River Water Supply Scheme obtains its water from a storage dam on the Fish River at Oberon, and a small pipehead weir on the Duckmaloi River approximately 8 km south-east of Oberon. The Duckmaloi River is a tributary of the Fish River, which becomes the Macquarie River when joined by the Campbell River further downstream. The Scheme has four major consumers:

* Oberon Shire Council (OSC)
* Greater Lithgow City Council (GLCC)
* Electricity Commission of N.S.W. (ECNSW)
* the Water Board (WB).

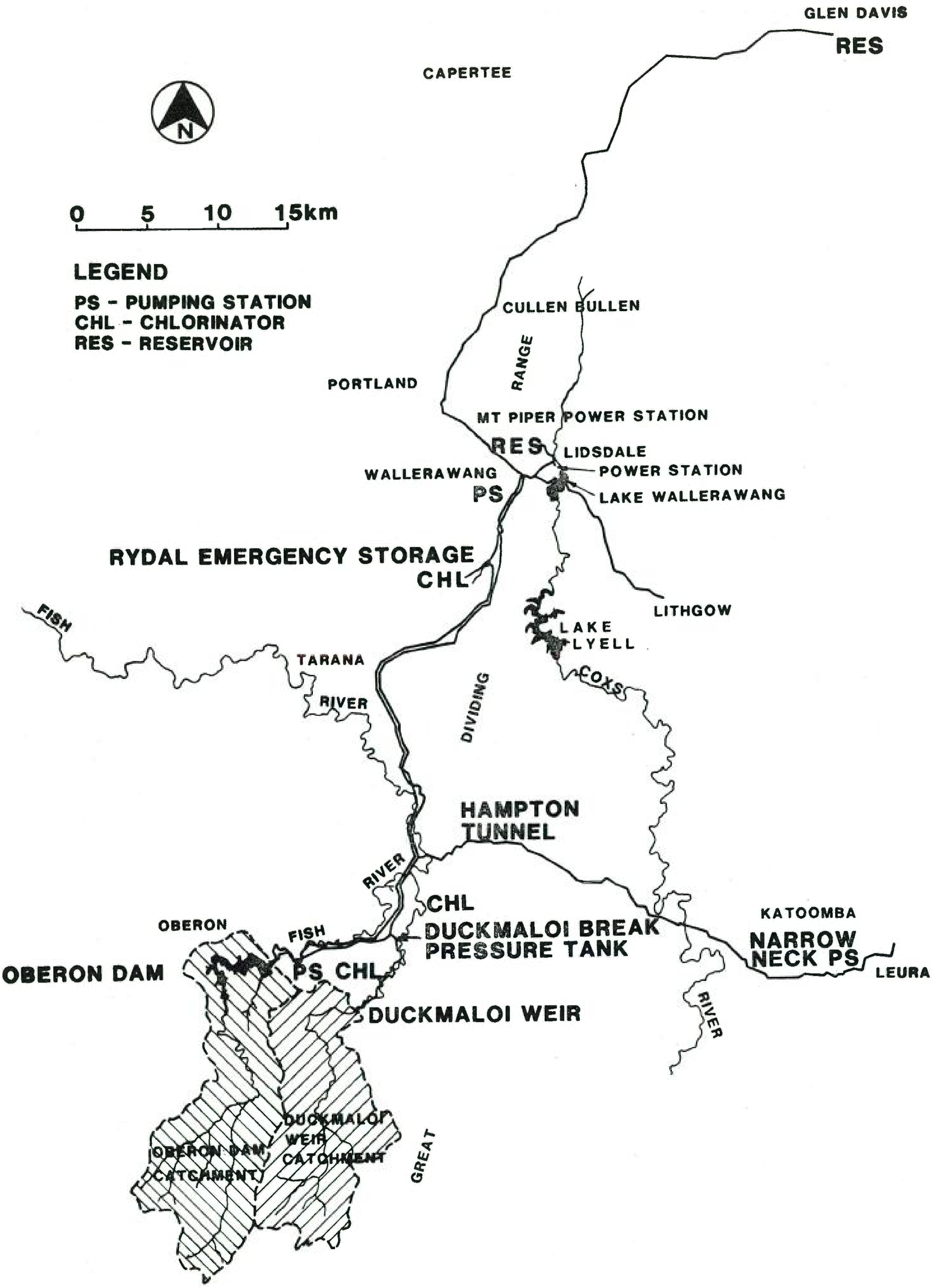
There are approximately 300 minor consumers, mainly rural landholders whose properties adjoin the Scheme's pipelines.

2.1.1. Components of Scheme

The components of the Fish River Water Supply Scheme are depicted in Figure 1. Waters from both Oberon Dam (Photo 1) and Duckmaloi Weir gravitate to the Duckmaloi Break-Pressure Tank (BPT) (Photo 2), which is used to control the pressure in the downstream section of the system. After leaving the BPT, most of the water is piped to Wallerawang. From there, supplies are distributed to Wallerawang Power Station, Portland, Cullen Bullen, Glen Davis, Lidsdale and Lithgow. An offtake, 6 km downstream of the BPT, provides water to the Water Board's Upper Blue Mountains System at Leura.

While the water supply for Oberon is pumped from the pipeline just downstream of the Dam, all other consumers are fed by gravity. However, supplies to Portland, Lithgow and Leura are occasionally boosted by pumping. Water supplies are untreated except for disinfection by chlorination at Oberon Dam, Duckmaloi BPT and at Rydal Storage. This latter storage is a small impoundment at Rydal which acts as an emergency supply for Wallerawang Power Station should there be a pipeline failure upstream.

The capacities and estimated yields of each of the main sources of supply are summarised in Table 1.



COMPONENTS OF FISH RIVER WATER SUPPLY
FIGURE 1

TABLE 1. SOURCES OF WATER FOR FRWS

SOURCE	STORAGE CAPACITY (ML)	SAFE YIELD# (ML/a)	CATCHMENT (km^2)	MEAN INFLOW (ML/a)
Oberon Dam	45,400	11,600	141	18,600
Rydal Storage	360	negligible	1	negligible
Duckmaloi Weir	20	100* (2,600)+	110	21,500
Totals	45,780	11,700 (14,200)	252	40,100

See Section 2.1.2 for discussion of the concept of "safe yield".

* Contributory yield when operated in conjunction with Oberon Dam and subject to water quality constraints.

\+ Duckmaloi contributory yield if it is assumed that water quality constraints are removed.

The full storage level of **Oberon Dam** is 1067 m AHD. The behaviour of the storage since 1963 is shown in Figure 2.

The crest of the **pipehead weir on the Duckmaloi River** is at an elevation of 1057 m AHD. The weir is a small concrete arch structure with a spillway whose crest is stepped, the lowest part being 12 m long (Photo 3). The weir holds back a small pondage of 20 ML (Fig. 3), which could be drawn off by the pipeline to the Duckmaloi BPT in about 15 hours.

The pipeline travels from the Duckmaloi Weir, along the Duckmaloi Valley for about 6 km, then rises up to the Duckmaloi BPT, located on a spur between the Fish and Duckmaloi Valleys (Fig. 4). At the BPT, the waters from Oberon Dam and Duckmaloi Weir are mixed before being piped to Wallerawang and the Blue Mountains.

2.1.2. Security of supply

In order to be able to guarantee a minimum annual supply of water, it is common practice to calculate what is known as a "safe (or secure) yield". This can be roughly defined as the amount of water which can be supplied annually with reasonable reliability: that is, restrictions would be necessary only infrequently. For details on the procedures used by the PWD and ECNSW for calculating safe yield, see Appendix A. Before the last drought, the safe yield for the Fish River Scheme had been assessed at about 14,200 ML/a, and this was the quantity of water recognised as being available to the Scheme's customers from these sources in the Upper Macquarie Catchment.

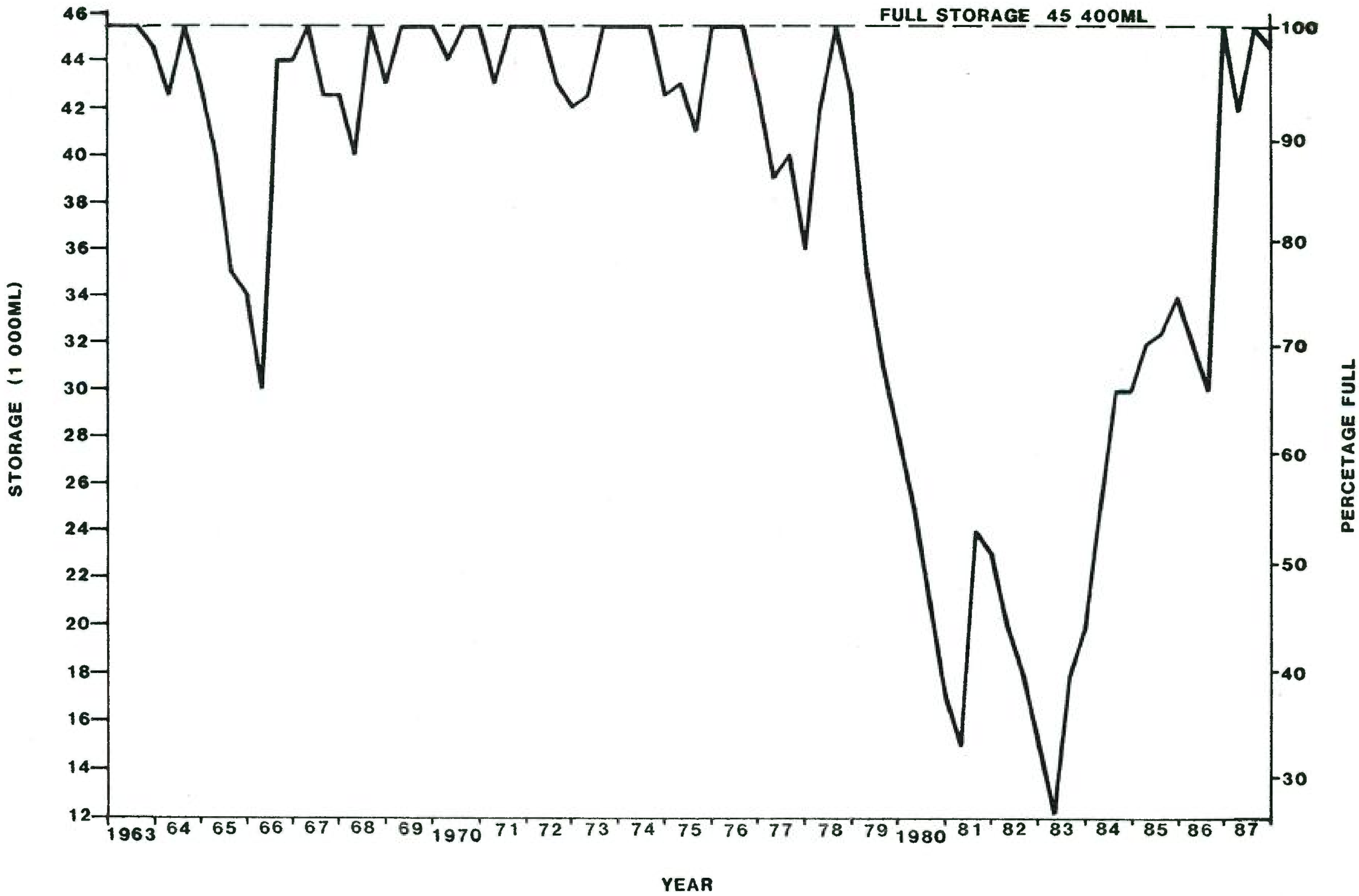


FIGURE 2

OBERON DAM STORAGE BEHAVIOUR SINCE 1963

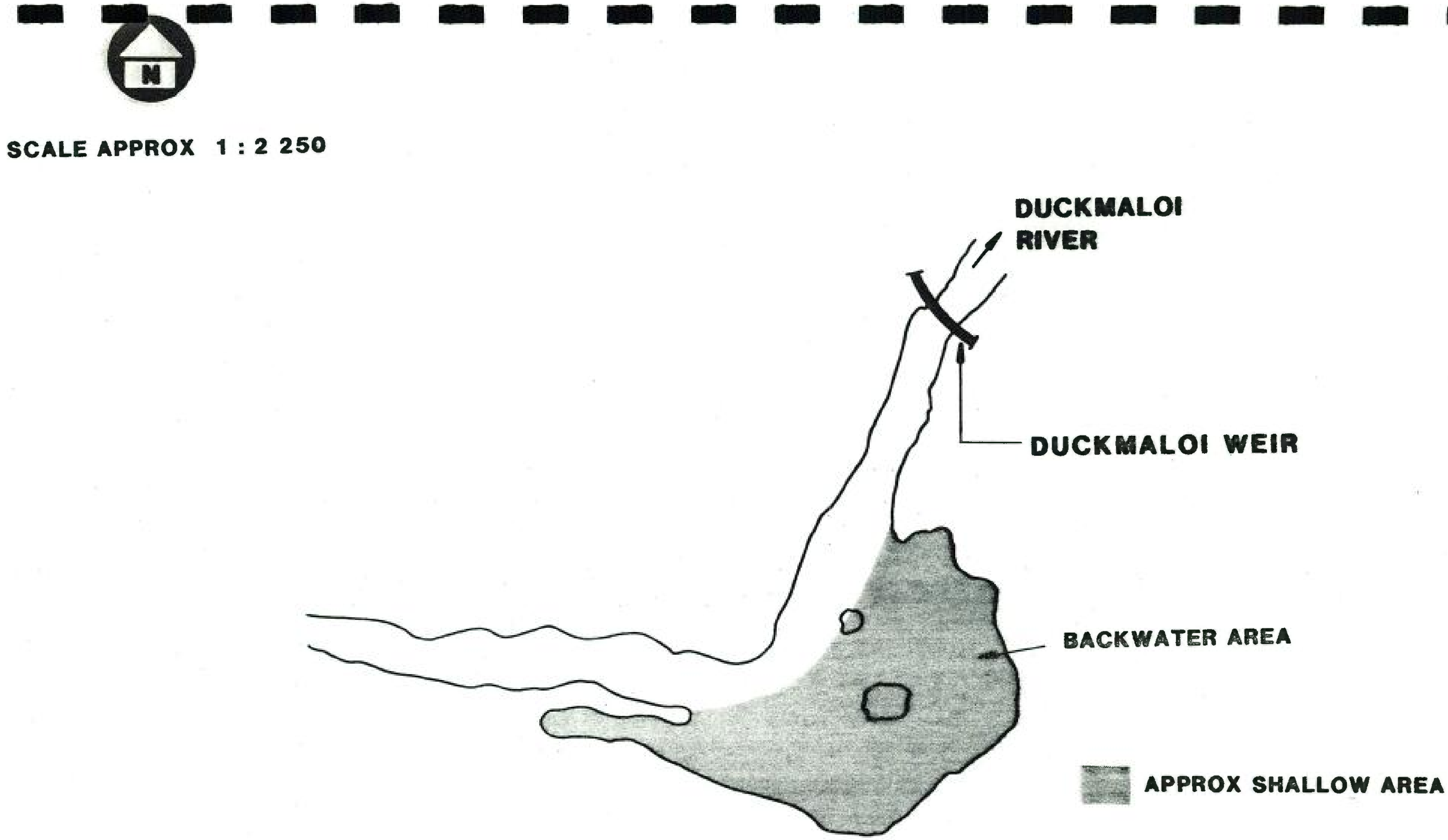
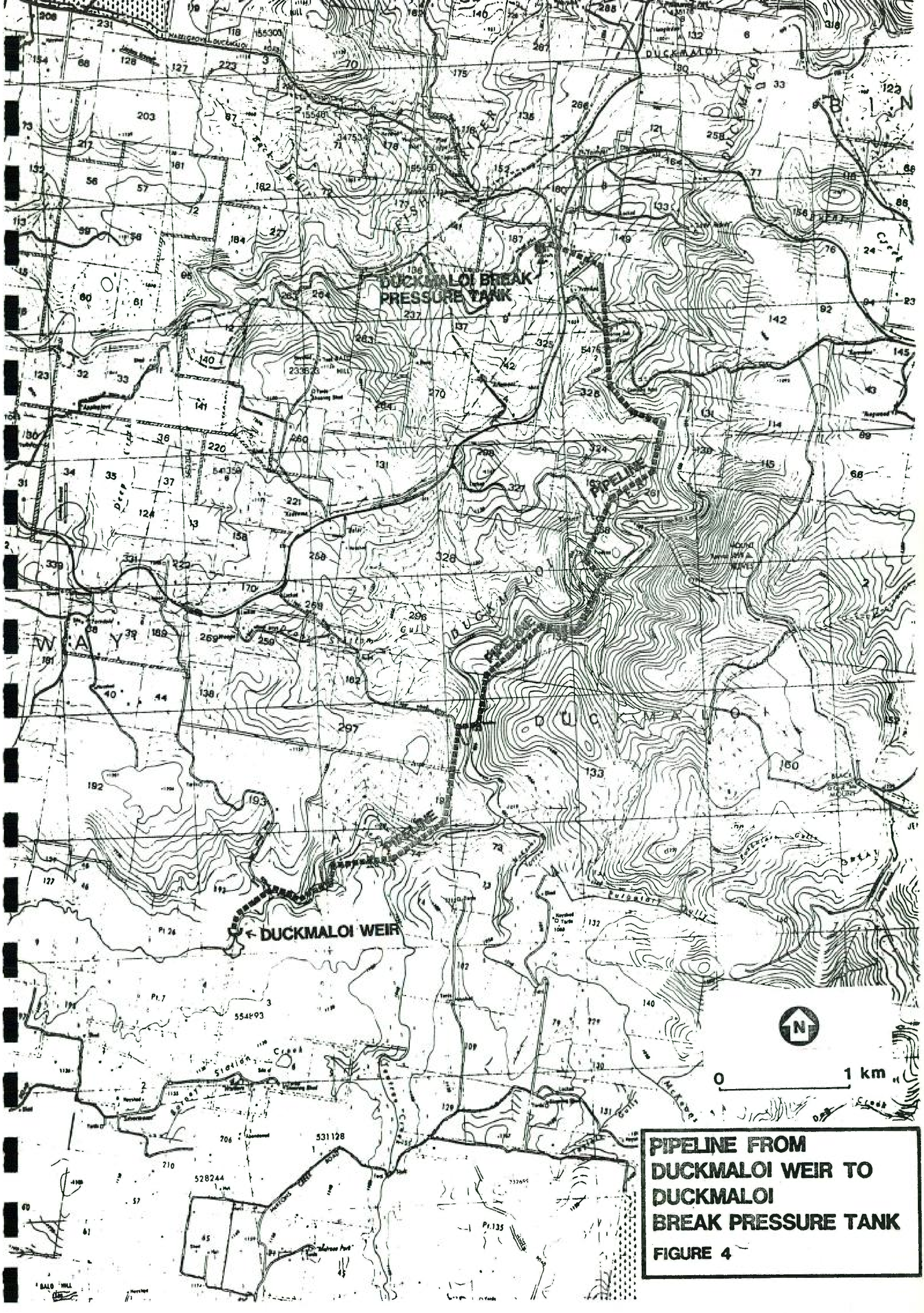


FIGURE 3

LAYOUT OF DUCKMALOI WEIR



PIPELINE FROM DUCKMALOI WEIR TO DUCKMALOI BREAK PRESSURE TANK

FIGURE 4

As part of the agreement between the FRWS and its major consumers, each major consumer undertakes to make minimum annual payments for which they are allocated a minimum annual quantity (MAQ) of water. They pay this minimum amount even if a lesser volume is used. The current MAQs, totalling 14,250 ML/a, in accordance with the Scheme's assumed safe yield, at the time, are set out in Table 2.

TABLE 2. MINIMUM ANNUAL QUANTITIES FOR CONSUMERS

Consumer	MAQ (ML/a)
Electricity Commission	8,184
The Water Board	3,650
Greater Lithgow City Council	2,092
Oberon Shire Council	264
Minor consumers	60
Total	14,250

Details of the consumption by each customer of the FRWS since 1946 are set out in Appendix B. Up to 1978, Oberon Dam was full or nearly full (see also Figure 2), and water was supplied to the major consumers as required. In 1979, the first full year of the recent drought, a total of 15,386 ML was supplied. By the middle of 1980, the dam was less than half full, and dropped to one-third full by early 1981. The dam fell to its lowest level (28% full) in 1983.

From 1980, most of the major consumers agreed to restrict their consumptions to less than their respective MAQs to allow the storage at Oberon Dam to recover. Although restrictions had been applied by the major urban consumers in 1980, it was found necessary to tighten them further in 1981. The need for these restrictions resulted in intense communal pressure to upgrade the capacity of the Fish River Scheme to supply water.

Restrictions were gradually eased as the dam recovered, but consumption has remained significantly less than the total MAQ for a number of reasons. The completion of the Lyell Dam on the Coxs River in 1983 enabled the **Electricity Commission** to confine its demands on the Fish River Scheme to essentially its requirements for its boilers and for domestic use; **Lithgow's** water supply was augmented by the construction of a pipeline to transfer water between Clarence Colliery and Farmers Creek Dam; and the **Water Board** constructed an emergency system to pump water from Emu Plains to the Upper Blue Mountains. (See Section 2.2, p. 10 below.) Finally, the major consumers have been gradually adjusting their operating procedures to reduce their dependence on the Fish River Scheme.

Even so, water demands in the region have been steadily increasing, and a new drought would see major and minor consumers once more calling fully upon their agreed allocations from the Fish River Scheme. Unless steps are taken to restore the Scheme's capacity to what was intended when Duckmaloi Weir was built, in 1963, the amounts supplied to the Scheme's customers would have to be severely restricted once more.

2.1.3. The capacity of Duckmaloi Weir

The inability of the Scheme to provide an adequate supply has arisen because the quality of the water in the Duckmaloi River has often been so poor that it has not been able to be used as originally intended.

Water in Duckmaloi Weir is frequently below the Health Department's "Desirable Criteria" for potable water (Appendix C). This problem is encountered mainly after rainfall, when flows in the Duckmaloi become coloured and highly turbid (Photo 4) and during summer when there are algal blooms in the weir. (The water quality in the Duckmaloi River is discussed in Section 4.3.4.2 (p. 43)). To minimise water quality problems, draw-off from the weir is restricted to periods of low flow in the river (nominally less than 6 ML/day). Since the riparian releases must be no less than 2 ML/day in summer and 0.5 ML/day in winter, the opportunities for actually using water from the Duckmaloi are very few, and consequently the weir is not being fully utilized as a source of supply.

2.2. Complementary Sources of Water

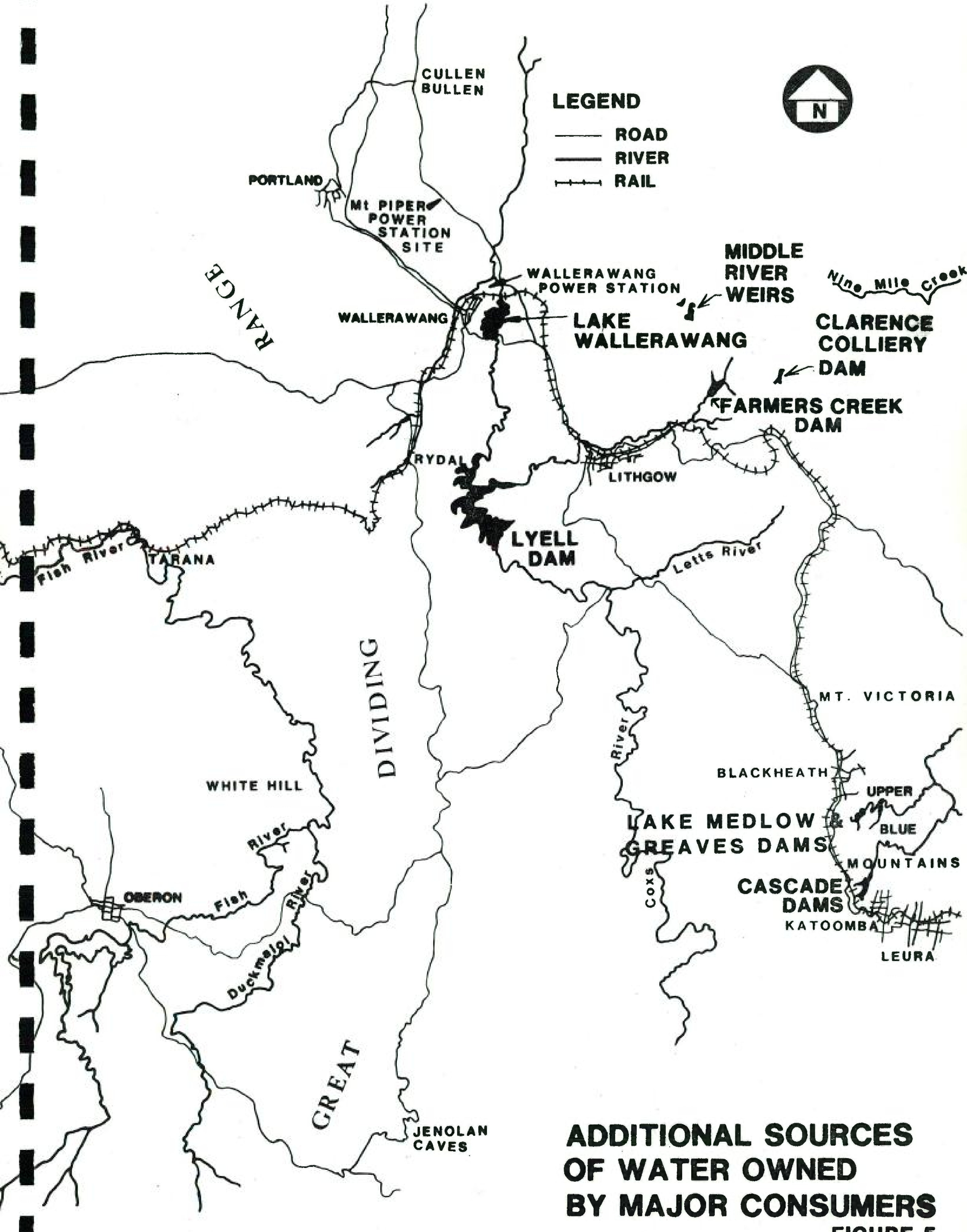
As indicated in Section **2.1.2** above (p.9), the **Greater Lithgow City Council, ECNSW** and **Water Board** also operate and maintain water supplies of their own (Fig. 5). Additional supplies to **Lithgow** come from Farmers Creek Dam, the Middle River Weirs and Clarence Colliery Dam. Cooling water for **Wallerawang Power Station** is drawn from two storages on the Coxs River, Lake Lyell and Lake Wallerawang, and the **Water Board** has storages in the Blue Mountains.

The only source of water for Oberon, Wallerawang, Portland, Lidsdale, Rydal, Cullen Bullen and Glen Davis is the **Fish River Scheme.**

The storages owned by **Greater Lithgow City Council** are very small, and during periods of drought, make only a small contribution to the urban water supply. The safe yield of Farmers Creek Dam and the Middle River Weirs is around 600 ML/a, about one-sixth of the demand of Greater Lithgow. However, with the supply from Clarence Colliery, normally over half the demand can be supplied from sources other than the FRWS.

Once the new **Mt. Piper Power Station** is commissioned (see Section 2.3.1, p.13), the storages of the **ECNSW,** at Lyell and Wallerawang Dams, will be fully committed to supplying water for purposes other than domestic and boiler make-up at Mt Piper and the Wallerawang Power Station. These latter uses will continue to require the higher quality Fish River water.

Lake Medlow and Greaves Dams primarily supply water to Blackheath, Mount Victoria, Shipley and Medlow Bath in **the Upper Blue Mountains.** However, Greaves Dam is also pumped to Upper Cascade Dam, and to a lesser extent, Middle Cascade Dam to supplement supplies to the Linden-Katoomba Area. It would not be economical or practical to augment these Upper Blue Mountains storages to any extent, as their catchments are only between 2 and 5 km^2.



ADDITIONAL SOURCES OF WATER OWNED BY MAJOR CONSUMERS

FIGURE 5

The Lower Blue Mountains receives its water supply from the Water Board's system at Emu Plains when local supplies are insufficient to meet demands. During the drought, because local storages and Oberon Dam were low, the **Water Board** extended this supply to the Upper Blue Mountains as a temporary measure. This was a costly and unreliable expedient, which can only be regarded as being a viable option in emergencies. The cost of the water supplied through this emergency scheme was $1.30/kL, whereas water from the Fish River Scheme cost 23¢/kL at the time.

Details of the complementary sources of water are briefly detailed in Table 3.

TABLE 3. COMPLEMENTARY SOURCES OF WATER

SCHEME	SOURCE	STORAGE CAPACITY (ML)	SAFE YIELD (ML)
Lithgow Water Supply	Farmers Creek Dam	450	400
	*Clarence Colliery	70	1,825
	Middle River Weirs	9	200
ECNSW Water Supply	Lake Wallerawang	4,300	13,000 (combined)
	Lake Lyell	26,000	
Water Board Storages in Upper Blue Mountains	Lower Cascade Dam	340	1,200 (combined)
	Middle Cascade Dam	156	
	Upper Cascade Dam	1,810	
	Lake Medlow Dam	300	2,700 (combined)
	Greaves Creek Dam	310	
	TOTAL ANNUAL YIELD		# roughly 20,000

* The supply from Clarence Colliery, which is presently excess to the mine's requirements, is not assured.

The methods of calculating safe yield vary between authorities (see Appendix A). Hence the calculated safe yields of all the storages cannot, strictly speaking, be added. The total is given here simply to indicate the order of magnitude of the available alternative supplies.

2.3. Present and Future Demands

2.3.1. Electricity Commission

The ECNSW is the main consumer of water within the study area. Presently, water from the Fish River Scheme is used for domestic purposes and boiler make-up at Wallerawang Power Station. The remaining supplies, mainly for cooling water, come from the Commission's storages on the Coxs River, held by Wallerawang and Lyell Dams. The Electricity Commission seeks a continuing supply from the Fish River Scheme, since this water is of higher quality than that available from the Coxs River.

Although the Electricity Commission is entitled to a minimum of 8,184 ML/a, it has rarely taken this much (Appendix B). Moreover, from 1980 to late 1986, it succeeded in substantially reducing its use of Fish River water, in order to conserve storage in Oberon Dam during the drought.

This lower consumption has not been without extra costs to the Electricity Commission. For example, during 1981-3, additional water was obtained by pumping from abandoned coal mines, quarries and ash disposal ponds. In addition, power generation was restricted from December, 1982 to January, 1983, when Lake Oberon had only about 30% of full storage capacity, in order to have sufficient water for power generation during periods of peak demand in winter.

As it happened, the peak demand for water for electricity was less than it might have been. Cracks to turbine blades in the Station's Unit No. 7 (with capacity 500 MW), entailed about 20 months of downtime for repairs and 18 months of operation at half capacity during the period 1981-4. Furthermore, by 1983, the Electricity Commission had sufficient excess generating capacity in its system to permit reductions in generation by its less efficient plant, and to allow repairs to plants such as at Wallerawang.

In general, through careful management, the Electricity Commission has been able to reduce its present requirements for water from the Fish River Scheme to approximately 4,000 ML/a.

A new power station is under construction at Mount Piper. The station may ultimately comprise four generating units, but only Units 1 and 2 are being built in the first stage. Units 3 and 4 will probably not be required before the year 2006. Unit 1 is scheduled to be commissioned during 1993 and Unit 2 is expected to be in use a year later. This will progressively increase the demand for high quality water to about 8,400 ML/a, which is more than the 8,184 ML/a provided by the agreement with the FRWS.

Part of the excess demand is expected to be reduced by decommissioning some of the older power generating units at Wallerawang Power Station and by using treated water from the Coxs River wherever possible. Moreover, the Electricity Commission has advised that a small reduction in supply could be tolerated for short periods in some circumstances. Even so, it can be seen that by 1994, the Commission will be looking to the FRWS to provide for most of the time the 8,184 ML/a, which has been its accepted allocation, and upon which it has been planning its future operations.

In addition to the extra demand generated for water for the boilers, the first stage of Mt. Piper Power Station will increase the ECNSW's need for cooling water by 15,000 ML/a. This issue is being addressed separately by the Commission and is discussed further in Section 3.2.2.3 (p.26).

2.3.2. Urban areas

The major urban areas are the City of the Blue Mountains, the City of Greater Lithgow and Oberon.

2.3.2.1. Blue Mountains

Under the agreement with the FRWS, the **Blue Mountains** is allocated **3,650 ML/a,** although in the second half of the 1970s, it regularly took more than this amount. In 1981, the Water Board assumed responsibility for the Blue Mountains' water supply.

Consumption of water from the Fish River Scheme subsequently dropped sharply as the Board maximised drawoffs from its local storages and established its emergency supply from the Lower Blue Mountains. (See Section 2.2, p.10.)

The Water Board has forecast that there will be little growth in demand in the Upper Blue Mountains in the next 20 years, and that it will be able to meet these demands from its local supplies together with its current allocation of 3,650 ML/a from the Fish River Scheme.

2.3.2.2. Greater Lithgow

The MAQ for **Greater Lithgow,** which includes Lithgow, Portland, Wallerawang and Glen Davis, is **2092 ML/a.** However, the amount supplied has often been far greater than this. In 1979, about 140% of MAQ was used by Council. Since the end of the drought, the quantity has dropped to between 60 and 70% of MAQ, since greater supplies have been available from Council's storages.

The total consumptions within Greater Lithgow were 3,400 ML in 1986 and 3,480 ML in 1987, of which 1,467 and 1,205 ML were supplied from the Fish River Scheme, respectively. These total consumptions are significantly less than the 4,260 ML, which the PWD has recently assessed as the current annual water requirement. It is possible that this results from the wet weather which has been experienced over this period.

Recent developments in the coal industry would indicate that, in the short term at least, there is unlikely to be any significant growth in population or water demands. The PWD predicts that in the longer term, there could be a maximum increase in demand of about 10% by the year 2006, on the assumption that the population will have grown by 0.6% by then. Most of this increase in population is expected to have taken place by 1994, in conjuction with the commissioning of Mt. Piper Power Station.

Since the supply from Clarence Colliery cannot be relied on, it is necessary to ensure that the allocation of 2,092 ML/a from the Fish River Scheme will be available when needed.

2.3.2.3. Oberon

The township of **Oberon** is the only major consumer of the Fish River Scheme which is on the western side of the Great Dividing Range. It relies solely on Oberon Dam for its water supply, and has consumed more than its MAQ of **264 ML/a** in most years since 1964. Its consumptions in 1986 and 1987 were 418 and 428 ML, respectively. During the second half of 1987, a programme for reducing leakage was undertaken, and this appears to have reduced overall demand by about 50 ML/a.

Even though the population of Oberon has been virtually static in recent years, there has been a small increase in the number of dwellings, and this should lead to a somewhat greater domestic consumption. As well, the timber industry is also expanding at the present time, and it seems reasonable to assume that a consumption of up to 600 ML/a should be allowed for.

2.3.2.4. Minor consumers

Most of the **minor consumers** are either rural landholders whose properties adjoin the pipelines, or inhabitants of the villages of Rydal and Cullen Bullen. A few are coal mines which take water from the Fish River Scheme for domestic consumption and some are local schools. About half of the minor consumers use more than their minimum allowance of 200 kL/a, and of these, a small number use well in excess of the allowance. For the 300 minor consumers, this nominal allowance of 200 kL/a amounts to 60 ML/a, and this has been exceeded in every year since 1964. The total amount consumed has often exceeded half of what was used by Oberon in the same year: last year this proportion was 62%.

The supply to the minor consumers is currently being reviewed. Some options under consideration for reducing demand are: negotiating with the coal companies to ensure that their domestic consumption is used prudently; checking for leakages; and increasing the tariff for excess consumption. The goal is to reduce the demands of the minor consumers to around 200 ML/a.

<u>2.3.3. Overall demand</u>

From now on, the maximum amount supplied to the major consumers will rarely be more than the total MAQ. When the storage behind Oberon Dam is below top water level, the Administrator of the FRWS will endeavour to ensure supplies are limited to total MAQ (except in emergencies). This would be necessary to avoid unacceptably high restrictions being applied in future should the system be entering a critical drought period. In order to achieve this limitation on supplies, the Scheme's pricing and allocation policy will have to be altered to accommodate consumptions in excess of their current MAQs by Oberon and minor consumers. In the knowledge of these operating procedures, major consumers will be adapting their operations and usage of alternative water supplies so that, it will similarly be unlikely that more than total MAQs will be used during wet years, when Oberon Dam is full.

Overall therefore, although the major consumers have been given extra water when they requested it in the past, it is thought there should be few situations when they will use more than the Scheme's total MAQ in the future.

The present demands of the various consumers, and their estimated requirements in 1994 are set out in Table 4. It can be seen that while the current safe yield of the FRWS (11,700 ML/a) should normally suffice at present, it will not be adequate in four years' time. Furthermore, even if the Fish River Scheme still had a safe yield of 14,200 ML/a as had previously been thought, it would not quite meet the demands forecast for 1994, largely because of demands in excess of MAQ by minor consumers and Oberon which is on the western side of the Great Dividing Range.

TABLE 4. FISH RIVER - SHORT-TERM ANNUAL DEMANDS (ML/a)

TOWNS	MAQ	1988	1994
Oberon	264	450	600
Greater Lithgow	2,092	2,100	2,100
Blue Mountains	3,650	3,650	3,650
Minor consumers	60	200	200
ECNSW	8,184	4,000	8,184
Total	14,250	10,400	14,734

2.4. Summary

Prior to the 1978/83 drought, and since completion of the Duckmaloi Weir in 1963, the Fish River scheme had a "safe yield" of approximately 14,000 ML/a. Agreements had accordingly been made with consumers to supply a total of 14,250 ML/a and this is represents an acknowledged and accepted drawoff from the Scheme's Fish River and Duckmaloi River catchments in the Upper Macquarie Valley.

The definition of "safe yield" assumes that in periods of drought, allocations to consumers would be restricted to 80% of nominal allocations. However, it became apparent during the recent drought that even with 20% restrictions, the FRWS headworks are insufficient to meet demands. In fact, subsequent yield analyses have found that the scheme's safe yield is actually in the order of 11,700 ML/a, largely because Duckmaloi water is frequently of unsuitable quality and is therefore underutilised.

The need for major consumers to apply severe water restrictions during the drought resulted in intense communal pressure to upgrade the capacity of the Fish River Scheme.

Major consumers, other than Oberon Shire Council, have their own sources of water which are used in preference to the Scheme's water. In the non-drought years presently being experienced, this is resulting in low demands being made on the scheme. This is despite financial arrangements which require consumers to pay for their full allocations.

Low demands at present are also a reflection of the steps taken by the Electricity Commission to reduce its present requirements from the Scheme through operational changes at Wallerawang Power Station.

Whilst the current safe yield of the FRWS should normally suffice at present, this will not be the case from 1994. By then, ECNSW will require its full allocation following completion of Mt Piper Power Station. It is estimated that demands on the Scheme could then be up to 14,570 ML/a, depending on availablility of water from consumers' own sources. The increase of 500 ML/a above the present total allocation of 14,250 ML/a is largely because of the additional water requirements of Oberon township (336 ML/a above its present allocation of 264 ML/a). The remaining increase comes from consumptions by minor consumers located alongside the Scheme's pipelines.

3. OPTIONS FOR ADDRESSING DEFICIENCIES

3.1. Consequences of Doing Nothing

One of the options for responding to the shortfall in supply is to do nothing, and let events take their own course. There would probably be few consequences until the next lengthy period of low rainfall, when severe restrictions would once again have to be applied. Communal pressures to improve the supply would be repeated and intensified, and the major consumers might be forced to re-establish expensive arrangements for emergency supplies.

3.1.1. Effect on Consumers

The safe yield of Oberon Dam together with Duckmaloi Weir has been calculated at 11,700 ML/a, about 2,550 ML/a or 18% short of the total MAQ, which the Administrator of the FRWS has undertaken to supply.

If the Administrator attempted to proceed without augmenting the capacity of the FRWS, it is estimated that **restrictions** would have to be applied on average **once every 5 years**, and they would last for about **33-50% of the time.**

A few members of the community might compensate to some extent by installing bores as has happened in a similar situation in Perth (Armanasco, 1986) or by installing rainwater tanks. However, the scope for adjustment to such restrictions is limited, since some 57% of the water is used by the Electricity Commission, whose requirement would not be easily reduced. (See Section 2.3.1, p.13 above.)

Unless the Electricity Commission is able to reduce its power generation substantially, it would follow that the brunt of the restrictions will fall on the urban consumers. They could thus see their "secure" supply fall frequently from 6,066 ML/a to around 3,300 ML/a, a reduction of about 45%. This would be unacceptable to most consumers.

In addition, the major consumers have planned their capital works programmes based on the assurance that the FRWS would be able to supply the respective MAQs, and the Administrator therefore has a responsibility to make good that assurance.

Furthermore, if the secure supply was reduced, the major consumers would be forced to seek alternative sources, all of which would be at at increased economic cost. (The environmental costs of the several schemes are unknown at this stage.) This would probably be accompanied by a greater fragmentation of responsibility for the management of the water resources of the region, with its attendant dangers of greater inefficiencies.

3.1.2. Effect on the Duckmaloi River

In times of drought, the FRWS would be under pressure to supply as much water as possible from Oberon Dam and to extract as much as possible from the Duckmaloi River.

Since it would be likely that the aquatic ecosystems in the Duckmaloi would already be severely stressed because of the low flows in the river, any further extractions (limited only by the need to provide the minimal riparian releases outlined in Section 2.1.3, p.10) would have severe ecological consequences.

3.1.3. Summary

It can be seen that the strategy of doing nothing would result in establishment of expensive emergency supplies, action by the major consumers to establish alternative sources of supply, and, as occurred during the last drought, strong communal pressure for action to increase the capacity of the Fish River Scheme. During droughts, there could also be severe environmental impact on the Duckmaloi River.

3.2. Options for Satisfying the Demand

There are several structural and non-structural options for satisfying part or all of the extra demands. As will be discussed below, several could be undertaken together. (The term "structural option" refers to strategies requiring some kind of construction for improving the water supply. "Non-structural options" refers to strategies which do not need construction works.)

The **non-structural** options are:-

- revising the agreements with the major consumers, to allow transfers of allocations between consumers;
- reducing domestic consumption through leak detection, metering and pricing policies;
- developing a Catchment Management Plan for the Duckmaloi and Fish Rivers.

The **structural** options for satisfying demands are:-

- recycling water from sewage treatment plants;
- constructing a weir on the Coxs River;

- arranging for joint use of the Fish River Scheme and the storages of the Electricity Commission;

- constructing a pipeline from Duckmaloi Weir to the upper reaches of Lake Oberon, so that turbid water from the Duckmaloi can be pumped across, allowing the sediment and algae to settle out in the lake before being drawn off into the pipeline network;

- building a clarification tank at Duckmaloi Break-Pressure Tank to bring the quality of water from the Duckmaloi River up to at least the standard of the water from Oberon Dam. This is the preferred option.

3.2.1. Non-structural approaches

The non-structural options listed above are under consideration or are being implemented by the FRWS in collaboration with its major consumers. While the benefits of some of these strategies will start to become apparent in the short term, the full implementation and benefits of many of them will not be realised for many years. It will be seen therefore, that there is still a need for a structural augmentation to the capacity of the FRWS.

3.2.1.1. Transfer of allocations

The **Water Board** has urged the Administrator of the FRWS to adopt a more flexible approach to charging, whereby a transfer of allocations between consumers would be permitted, and major consumers would pay for their share of total consumption, irrespective of the MAQs which they have agreed to. For example, in cold, wet winters, when urban consumers would have lower demands than usual, the ECNSW may have a demand for power generation which was greater than normal. In this way, the major consumers could have a greater incentive to reduce their demands.

3.2.1.2. Leak detection

As mentioned in Section **2.3.2.3**, a leak detection programme has reduced demands in **Oberon** by about 50 ML/a. However, little could be saved by a leak detection programme in Greater Lithgow or the Blue Mountains (Appendix G). It is possible that such a programme could be of value in the villages of Rydal and Cullen Bullen, but the savings would appear unlikely to exceed 10 ML/a. Hence the overall reduction in demand through leak detection might be limited to about 10 ML/a.

3.2.1.3. Metering

Many studies, both in Australia and elsewhere, have shown that once meters are installed, the consumption of water can reduce by 20-40% (Appendix G).

The **Greater Lithgow City Council** has meters only on its large consumers - flats, hotels, motels, mines etc. With so much of Lithgow not metered, one might conclude that its urban demand could be reduced if meters would be installed. If a minimum of 20% reduction in consumption through metering is assumed, this could represent a saving of at least **700 ML/a** for the Fish River Scheme.

About 20% of the consumers in the **Blue Mountains** are not metered, but as explained in Appendix G, it is extremely unlikely that metering of these properties would reduce demand by any detectable amount.

All other consumers are metered.

It can be seen that in the short to medium term, demand could be reduced by **700 ML/a** if all properties within the FRWS area were metered.

3.2.1.4. Pricing

The major consumers are charged for their respective minimum annual quantities, at the same rate as for excess water (currently about 25¢/kL). In principle, these organisations should have some financial incentive to conserve water by seeking to avoid additional costs through the excess charges. However, as set out in Section 2.3.3 (p.15) above, the amount supplied to the major consumers will rarely exceed their respective MAQs, and at present therefore, there is little financial incentive for them to reduce their demands. Should, for example, MAQs be set at say three-quarters of expected demand, and charges for extra water be at a higher unit rate than for the MAQs, this could provide some incentive for the major consumers to take steps to limit their demands.

There are many methods of charging which can be explored along these lines, and these are being investigated by the FRWS Undertaking, in collaboration with the major consumers. They would provide an important incentive to the major consumers to take other steps, such as those discussed in this Section (3.2.1), to manage demands.

One step the major consumers could take is in the area of their own pricing policies. The **National Parks Association** (Appendix H) has urged that the principle of paying for use should be applied to urban water users to encourage careful use.

Although the **Water Board** is moving towards a policy of paying for use, it will be some time before this would have any appreciable effect on consumption in the Blue Mountains, since the average consumption is 200 kL/a per household while the current allowance is 300 kL/a.

There would be little point in raising the tariffs charged by the **Greater Lithgow City Council**, since the tariffs are already very high (75¢/kL for excess water for its domestic consumers, $1.00/kL for its commercial customers, and $1.30/kL for its industrial consumers). Most of the savings would come when the houses are metered, and this has been addressed in Section 3.2.1.3 above.

There are moves to amend the Local Government Act to allow tariffs to be structured along lines which promote the concept of paying for use, yet preserve desirable elements of cross-subsidisation. If tariffs were structured in this way, and **Oberon Shire Council** increased certain tariffs to promote the idea of paying for use, it is reasonable to assume a lessening of Oberon's demand of perhaps 10%, or **60 ML/a** in the long term.

The Scheme's **minor consumers** have a minimum allowance of 200 kL/a each. However, some consumers draw a supply considerably in excess of this, so that the average consumption is 800 kL/a, more than twice the average consumption of the urban consumers supplied by the Fish River Scheme. If the rate for excess water were increased, this might reduce demand by perhaps 10%, or **20 ML/a.** (See also Section 2.3.2.4, p.15.)

In summary, the total savings through increased tariffs might be about **80 ML/a.**

3.2.1.5. Catchment management plan

The **Nature Conservation Council** and the **Total Environment Centre** have advocated that a catchment management plan be prepared (Appendix G). As it is, one is already being prepared by the Public Works Department.

Under the Fish River Water Supply Administration Act, 1945-1960, the Governor can make regulations to protect any stream or watercourse in any catchment area of the FRWS.

As outlined in Section 4.3.4.2 below, the information collected so far on the water quality of the Duckmaloi indicates that the problem of poor quality water results partly from the inflow of nutrients from the farms into the watercourses, and the willows growing along the banks.

It might be concluded from this that if the access of sheep and cattle to the Duckmaloi and its major tributaries could be restricted, and the willows replaced with natives such as casuarinas, the quality of the water at the weir would improve significantly. With a high quality of water flowing through Duckmaloi Weir, water could be extracted from the river when it is running at higher flows than is permissible at present (ie. above 6 ML/day). In this way, the safe yield of the FRWS could be increased.

If the maximum flow at which water could be extracted without treatment were increased from 6 ML/day to say, 20 ML/day, the safe yield could be increased to 13,300 ML/a (Appendix E). The environmental impacts would be much the same as for the preferred option, the water clarification plant, and these will be outlined in Section 3.2.2.5. (p.27).

In addition, about one-third of the Fish and Duckmaloi Catchments are covered with pine forests, and it appears from catchment studies at nearby Lidsdale (Smith and others, 1974) that the yield of catchments with eucalypts can be significantly greater than with pines. Although further studies in this area are being carried out by others, it could be concluded that, if there were to be a gradual conversion of pine plantations to eucalypts, an increase in catchment yields could be expected.

The Administrator of the FRWS has power to bring about some improvements in the quality of the water flowing into Duckmaloi Weir by imposing restrictions on the access of stock to the waterways, but this could entail a significant cost in compensation. Likewise, the conversion from pines to eucalypt forests would also entail significant compensation.

Both measures would take a long time to implement, and inasmuch as there is a need to guarantee an adequate safe yield in the immediate future, the improvements from close catchment management controls have to be regarded as uncertain and not sufficiently beneficial in the short term.

3.2.1.6. Summary

From Table 4 (p.16), it can be seen that until 1994, the demand on the Fish River Scheme is liable to be approximately 12,000-12,500 ML/a. It is considered that the total annual demand could be reduced by perhaps **790 ML** through leak detection, metering and tariff restructuring within the **next four years.** This would not be sufficient on its own to satisfy the demand which is expected for water from the Fish River Scheme by 1994.

A catchment management plan could improve the quality of the water flowing into Duckmaloi Weir to a sufficient extent to allow an increased amount of water to be extracted, perhaps to **13,300 ML/a.** In the long run, if pine plantations in the Upper Macquarie Valley are replanted with eucalypts, the yields from the Duckmaloi and Fish Catchments might increase to an extent sufficient to satisfy demand. Nevertheless, catchment management requires a long-term effort, and the catchments could not be improved sufficiently to bring about the significant increase in yield needed by 1994.

It follows that while non-structural strategies can make a useful contribution to reducing overall demand, they are not sufficient in themselves to satisfy the shortfall in supply.

3.2.2. Structural Options

A comparison of the structural options is given in Table 5, page 30.

3.2.2.1. Recycling water

Recycled effluent from sewage treatment works can be utilised for watering lawns and recreational areas; for a limited number of purposes in agriculture; for cooling water, coal washing and dust suppression in the coal industry; and for car washing, fire control, toilet flushing and airconditioning in residential areas.

Within the area supplied by the Fish River Scheme, there are sewage treatment plants at Wallerawang, Lithgow, Oberon and in the Blue Mountains.

The Blue Mountains plants are generally located considerable distances below urban areas: any recycling of effluent would involve expensive pumping, and the nature of the terrain would also entail costly pipework. These high costs make recycling schemes uneconomic in this area, particularly as non-domestic consumption is minimal.

The new timber works being built at Oberon could possibly use recycled water. The additional demand is estimated at 50-100 ML/a for the mill and associated industrial development. If, say, 75% of the industrial requirements for water could be satisfied by treated effluent, this might reduce demand by about **50 ML/a.**

Effluent from the sewage treatment plants at Lithgow and Wallerawang already discharge into Farmers Creek and the Coxs River, respectively. Consequently, the treated sewage already constitutes part of the yield of the Electricity Commission's Coxs River water supply scheme. The Commission's capital works have been planned on the assumption that these discharges will continue. Thus, a recycling scheme is already in operation for these urban areas, and any action by the Fish River Scheme to utilise the effluents would result in the ECNSW having to build additional storages to compensate for the loss in yield.

Nevertheless, the direct cost of recycling effluent in Lithgow could be up to $6 million, almost 50% more than the cost of the preferred option (Section 3.2.2.5, p.27). When the costs of the ECNSW to build compensatory storage are added to this, it is clear that recycling of water is not a viable option for Lithgow, and by extension, Wallerawang.

In summary, it is estimated that demand from the Fish River Scheme might be economically reduced by **50 ML/a** through recycling. While this could be a useful means of reducing Oberon's demand on the Scheme, recycling would not be an important strategy for satisfying all the demands in 1994.

3.2.2.2. Coxs River Weir

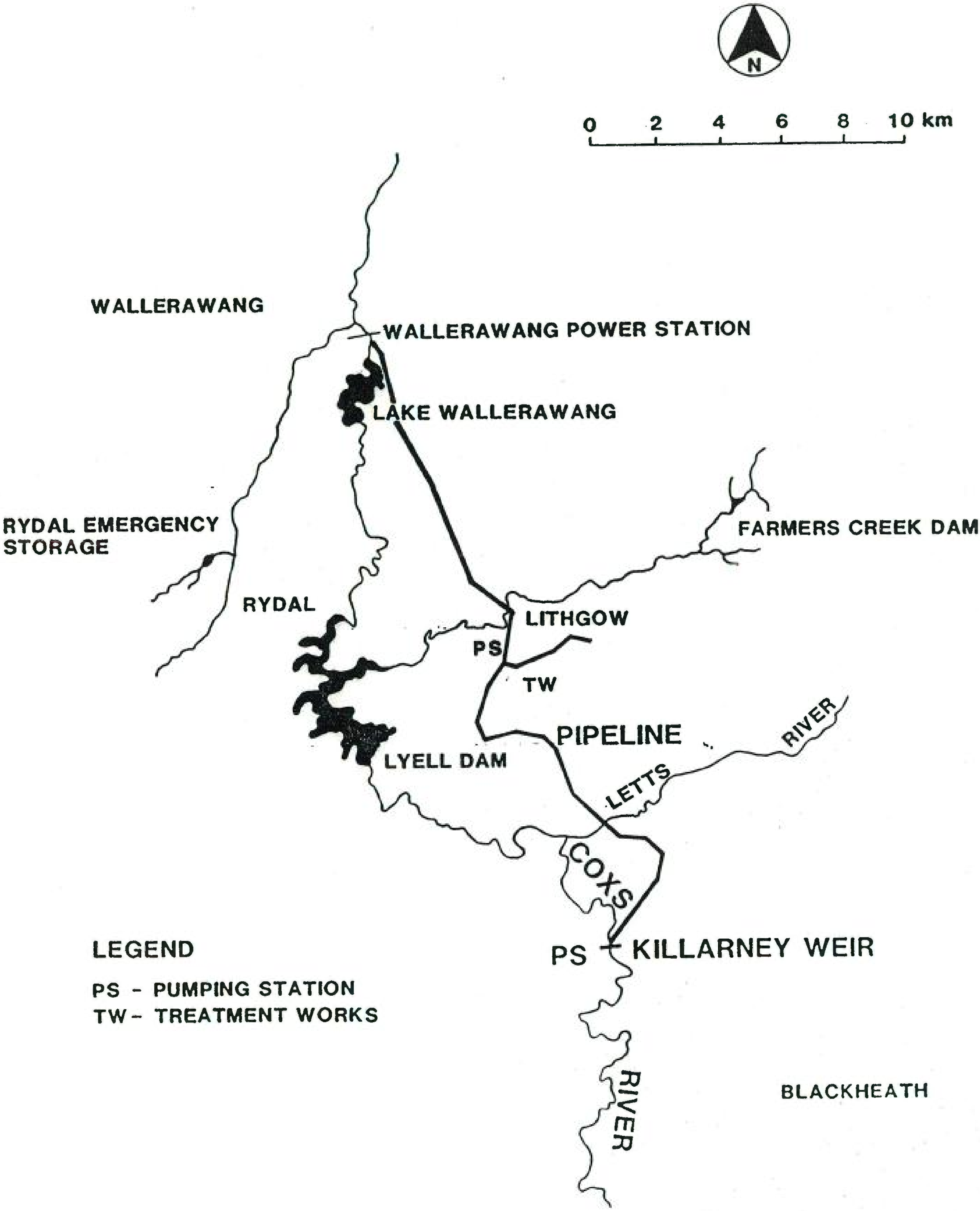
The capacity of the FRWS could be increased by building a weir on the Coxs River with a pipeline to Lithgow and to the Electricity Commission at Wallerawang (Fig. 6). Full treatment of the water would be required. Whilst the weir could be built to satisfy the Scheme's medium- to long-term demands, it need only have a storage of 500 ML at this time, to provide the additional yield of 2,500 ML/a required to meet the Fish River Scheme's current commitments. The pipeline to Lithgow would need to be able to supply at least 12 ML/day.

This option has the advantage that it relies on an eastern flowing stream to provide the additional yield for the Scheme. **Bathurst City Council** (Appendix H) has expressed concern with the diversion of westward-flowing water to the east, and with the effect that this has on Bathurst's water supply.

The Coxs Weir alternative has several drawbacks. It is considerably more expensive than the preferred option in initial capital cost; it would require continual pumping; the quality of the water obtained would be such as to require full treatment; and extraction of water from the Coxs River will reduce the yield of the Water Board's catchment for Warragamba Dam. This last impact will increase the Board's reliance on its more expensive sources in the Shoalhaven System.

On the matter of water quality, further studies would be required to resolve whether sufficient treatment could be carried out to render the water suitable for domestic consumption. This is because Lake Lyell, which is only 10 km upstream of the Killarney site (assuming that was the chosen site), supports full recreational activities, including power boating.

There would also be significant environmental effects resulting from the change in the upstream aquatic ecosystem from lotic (running water) to lentic (still water) and a variation in the downstream flow conditions.



WORKS REQUIRED FOR WEIR ON COXS RIVER
FIGURE 6

3.2.2.3. Joint use of ECNSW storages and Fish River Scheme

A further option, which is in fact a variation on the Coxs River Weir proposal, is to combine the operations of the Electricity Commission's Coxs River System and the Fish River System. Both systems require development at present and economies may be achieved by the joint use of storages.

The Commission has resolved that its preferred option for meeting additional cooling water requirements for Mt Piper Power Station is to construct a dam on Thompsons Creek near Wallerawang. This dam would be filled principally by pumping from the Commission's existing Lyell Dam on the Coxs River.

Joint operation of storages would require a larger dam on Thompsons Creek to allow for drawoff by the Fish Scheme. In effect, upgrading of the Coxs River System would be designed to provide the additional yields sought by both ECNSW and FRWS. The FRWS drawoff could be either from Lyell Dam or from Thompsons Creek Dam.

A dam storage in the order of 35,000 ML is required by ECNSW to provide its total yield requirement of 21,000 ML/a. This brings the Coxs River system close to its economic limit, if not beyond it, and there would be a need to increase the dam storage by 10,000 ML to achieve the additional 2,500 ML/a yield for the FRWS. Moreover, it would not be economically feasible to increase the storage capacity of Thompsons Creek Dam 45,000 ML. Since this option is not economical, the environmental impact of this increased storage requirement has not been addressed.

Drawbacks of this option are similar to those for the Coxs River Weir proposal: high initial cost; continual high pumping cost to either Lithgow or Thompsons Creek Dam; full water treatment; and reduction in Warragamba Dam's yield. A more significant drawback in this instance however, is that since the FRWS drawoff is for domestic consumption, power boating and body-contact recreation may have to cease on Lake Lyell.

3.2.2.4. Transfer from Duckmaloi Weir to Lake Oberon

A scheme which would increase the safe yield of the Fish River Scheme to 14,200 ML/a, would be to transfer water from the **Duckmaloi Weir** to the headwaters of **Lake Oberon.** Because the transferred water would remain in storage for an appreciable period, the sediment would settle out, the excess nutrients could be taken up by organisms in the lake, and most algal blooms would die off before being drawn into the pipelines to the consumers.

The operation of this system would have some adverse impact on the ecosystems in the weir. The pumps would extract water, until the water level in the weir lowered to perhaps half a metre below the crest. They would then cut off and allow the level to rise to the crest once more. These sharp fluctuations in water level would reduce the biological productivity of the weir, particularly in the shallow areas and along the foreshores, since much of the benthic habitats (living areas of the bottom-dwelling animals) would be regularly uncovered, and allowed to dry out. This diminution of food sources would reduce the capacity of the pond behind the weir to carry the present populations of platypus and trout. Furthermore, this fluctuation in water level could cause the flow downstream to vary between zero and full inflow daily, and as will be shown in Section 4.3.4 (p.43), this would greatly stress the downstream aquatic ecosystems.

Alternatively, the weir could be raised by 0.5 m, and the water could be allowed to rise and fall only between the new top water level and the old one. This would result in extra land being inundated, and because of the frequent wetting and drying, this new land could be converted into a highly productive swamp. On the other hand, the productivity in the area covered by the present storage would decrease, since the amount of sunlight penetrating to the bottom would be reduced, and the very productive shoreline (described in Appendix I) would be disturbed. Overall therefore, it would appear that the aquatic productivity could be slightly reduced, while the area of swampland would increase. This would reduce the amount of food available for the platypus and trout, but increase the amount of habitat available for waterbirds and other users of swamps.

The transfer pipeline would be laid as shown in Figure 7, and in itself would have little environmental impact, since few if any trees would be removed along the route, and little erosion would be caused. The country through which the pipeline would pass is mostly cleared grazing land.

A balance tank would be built in a copse of trees near the top of the ridge between Duckmaloi River and Fish River. This copse is mainly **Eucalyptus fastigata** (Brown Barrel) interspersed with a few individuals of **E. dalrympleana** (Mountain Gum). The main understory nowadays is grass, most of the shrubs having apparently been eaten by the stock. Two trees would have to be removed to allow the balance tank to be built.

Because the pipeline passes close to the banks of the Duckmaloi River, it is quite possible that archaeological artifacts could be encountered, since such areas could have provided suitable sites for permanent or temporary camping by aborigines. However, since it is not proposed to proceed with this option, no archaeological survey has been undertaken.

The other environmental impacts of this option would be much the same as those of the preferred option to be outlined below.

3.2.2.5. Duckmaloi Clarification Plant (the preferred option)

An alternative to the transfer scheme is to treat the water from Duckmaloi Weir, bringing it to at least the same quality as that obtained from Oberon Dam. At present, when flow in the Duckmaloi River is in excess of about 6 ML/d, the water is generally unacceptably coloured and turbid. If this quality problem can be overcome, the Duckmaloi Weir source can be used as originally intended, thereby easing the supply problems experienced by the present scheme during periods of drought. In effect, the plant would allow water to be taken from the weir over a greater range of river flows than is currently possible.

The water would be treated in a Water Clarification Plant (WCP), located at the site of the Duckmaloi Break-pressure Tank. At this location, it could also be used to treat water from Lake Oberon, if necessary.

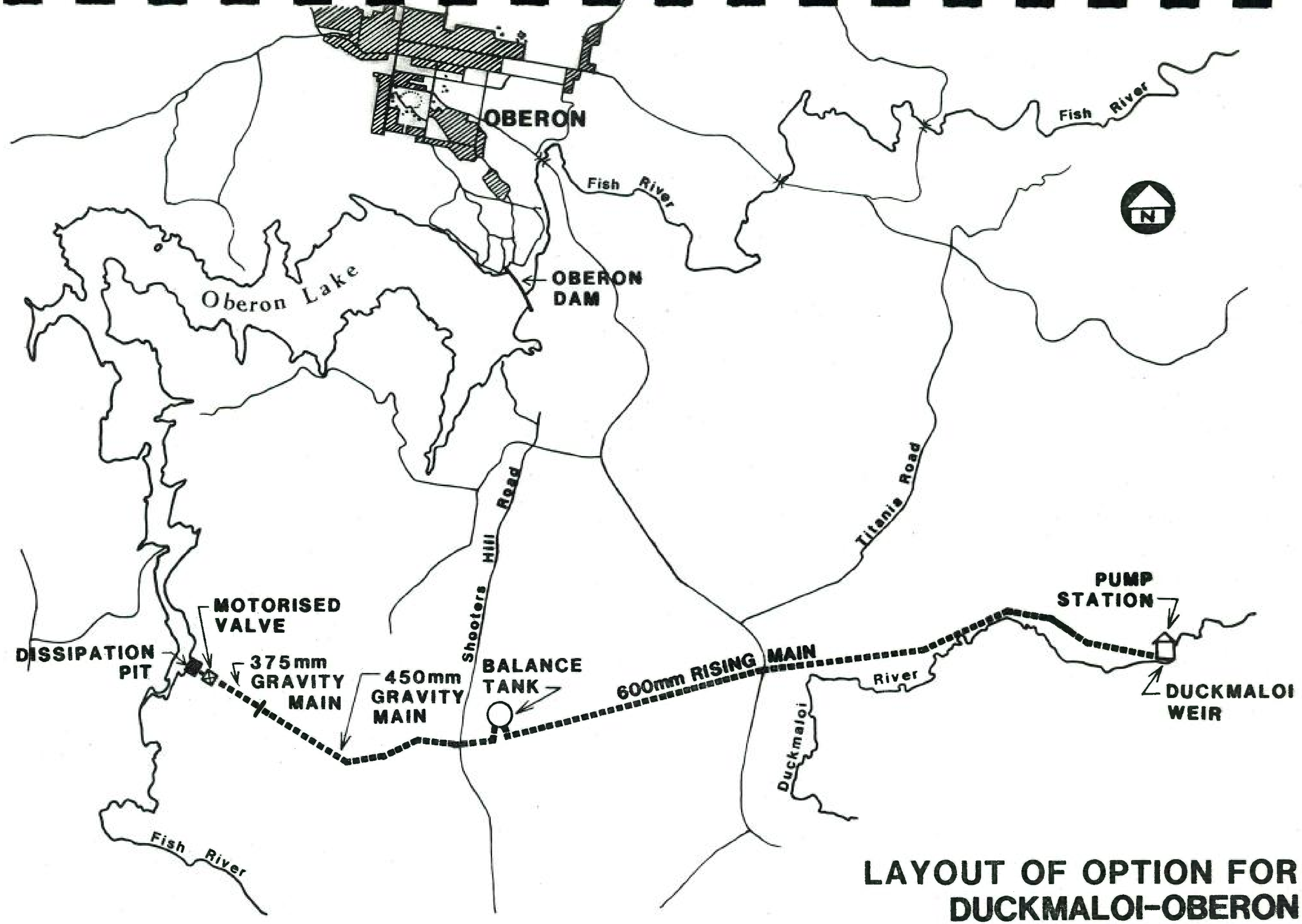


FIGURE 7

LAYOUT OF OPTION FOR DUCKMALOI-OBERON TRANSFER PIPELINE

It is proposed that the WCP will have the capacity to treat 40 ML/day, which is roughly the average daily demand of the Scheme's customers on the eastern side of the Great Dividing Range. Supply to the plant from the weir will be by gravity through the existing pipeline at its capacity of 33 ML/day. The balance of consumer demands will be met from Oberon Dam. Further details of the WCP are given in Appendix F.

The WCP would benefit the operation of the Fish River Scheme as a whole, since it would enable water quality to be kept more uniform than at present, and would also have a small benefit through reducing the accumulation of sediment in the pipes downstream of the Duckmaloi Break-Pressure Tank.

As discussed in Chapter 4, the major potential impacts of this are: the transfer of additional water from west of the Great Dividing Range to the east; the effect on the platypus in and downstream of Duckmaloi Weir; and the effect on the trout in Duckmaloi River, which has been quoted as the best trout stream in the Central Western Region of N.S.W. No significant environmental impacts would arise from construction or operation of the WCP itself.

The additional yield available to the Scheme through this option is constrained by releases from the weir needed to minimise downstream environmental impacts. Studies carried out for the proposal indicate there should be releases of at least 6 ML/day when there is extraction of water from the weir. These releases are considerably more than the 2 ML/day and 0.5 ML/day currently adopted, and will restrict the yield of the Scheme to 13,900 ML/a rather than the 14,250 ML/a actually sought. Nevertheless, the lower yield is accepted as a reasonable compromise: the safe yield is sufficiently high to meet most demands, yet the amount of water released downstream will be sufficient to ensure that the environmental impacts are acceptable.

3.2.2.6. Summary

As indicated in Table 5, the water clarification plant would be the structural option which should be the quickest and cheapest overall. Its financial costs and environmental effects would be less than that of interconnecting with the ECNSW water supply system, and would be somewhat less than those of recycling effluent from Lithgow, building a weir on the Coxs River, or a transfer scheme to Lake Oberon. This therefore has been chosen as the preferred option, and is discussed in detail in Chapter 4.

TABLE 5. COMPARISON OF STRUCTURAL OPTIONS

	Coxs River Weir	Transfer Pipeline	Clarification Plant (preferred option)	Interconnect with Elcom	Recycling at Lithgow
Time to implement	5 years	18 months	18 months	3 years	5 years
Capital Cost	$15 million	$4.5 million	$4.0 million	$15 million	>$6 million
Additional Yield (ML/a)	2,500	2,500	2,200	2,500	2,400
Important Environmental Effects	Inundation. Changed aquatic env. Pipeline. Reduces Warragamba yield. May cause some restrictions in power boating on Lake Lyell. Access Roads.	W-E flows. Platypus. Trout. Fluctuations of weir level and river downstream. Possible archaeological areas	W-E flows. Platypus. Trout.	Loss of recreation on Lake Lyell storage. Reduced Warragamba yield.	Reduces yield of Elcom storages

4. EVALUATION OF PREFERRED OPTION

The preferred option for satisfying the need to increase the yield of the Fish River Scheme is judged to be that of augmenting the supply with additional water from the Duckmaloi River. In this chapter, the environmental impacts of this option are assessed.

4.1. Proposed Works

It is proposed to build a water clarification plant (WCP), with a capacity to treat 40 ML of water per day, near Duckmaloi BPT (Photo 2) to allow water to be taken from Duckmaloi Weir over a greater range of river flows than is possible at present. Water from the Weir would be supplied by gravity to the plant through the existing 7km long pipeline which runs from the weir to the BPT. At the plant, the water would be clarified to reduce its turbidity to less than 3 turbidity units, its colour to less than 15 colour units, and its iron to less than 0.3 mg/L. If necessary, water from Oberon Dam could be clarified similarly, since the pipework at the site will be such as to allow water from both sources to be treated.

The rate at which water will be drawn from Duckmaloi Weir will normally vary between 7 and 33 ML/day. The upper bound is determined by the capacity of the pipeline, and the lower bound is deemed to be the minimum at which it will be economical to operate the plant. Under normal operating conditions, the weir pool will remain full.

Further details of the water clarification plant layout, treatment processes and proposed operating procedures are given in Appendix F.

4.2 Public Comment

A list of organisations who were contacted during the preparation of this EIA is given in Appendix H, together with summaries of their responses. The concerns expressed by these groups have been addressed throughout this report.

4.3. Environmental Effects

4.3.1. Hydrological Effects

Drawoffs from the weir are presently restricted to periods when river flow is less than 6 ML/day, because the water quality deteriorates above that. As well as this, riparian releases are the lesser of inflow or 2 ML/day during September to April and 0.5 ML/day during May to August. Augmentation of the Scheme will allow for releases of 6 ML/day or inflow, whichever is the lesser. Because the minimum drawoff rate will be 7 ML/day, the Duckmaloi Weir source will only be used when inflow is greater than 13 ML/day.

Figure 8 shows the flows which would have occurred downstream of the Weir during the last 96 years for two situations: with the weir being operated as at present, and with the Fish River Scheme augmented with the WCP. Figure 9 provides more detail of the lower flows under these two situations. These graphs have been prepared using a hydrological model of the Fish River Scheme, which is described in Appendix E.

Figure 10 shows the corresponding flow-duration curves. (A flow-duration curve is a graph showing the estimated proportion of the time that a given flow is equalled or exceeded. It helps to provide an appreciation of how often there are high and low flows in the river. For most Australian rivers, it is important for the riverine ecosystems that the flows are variable, since different flows are needed for different stages of the life cycles of the aquatic species.)

It can be seen that while the frequency of higher flows is reduced, the frequency of low flows is maintained.

Figure 11 shows the comparable flow-duration curve at the confluence of Duckmaloi River with McKeons Creek, 3 km downstream of the weir. The impact the augmentation will have on the quantity and variability of flow is clearly significantly less than at the weir (Figure 10).

Figure 12 show the spills that would have occurred over Oberon Dam during the last 96 years, with and without the augmentation. It can be seen that the aquatic environment downstream of the dam would have been enhanced with the extra supplies being taken from the Duckmaloi River, since the dam would spill more frequently. This would improve the downstream habitats for both native and exotic fish to a small extent.

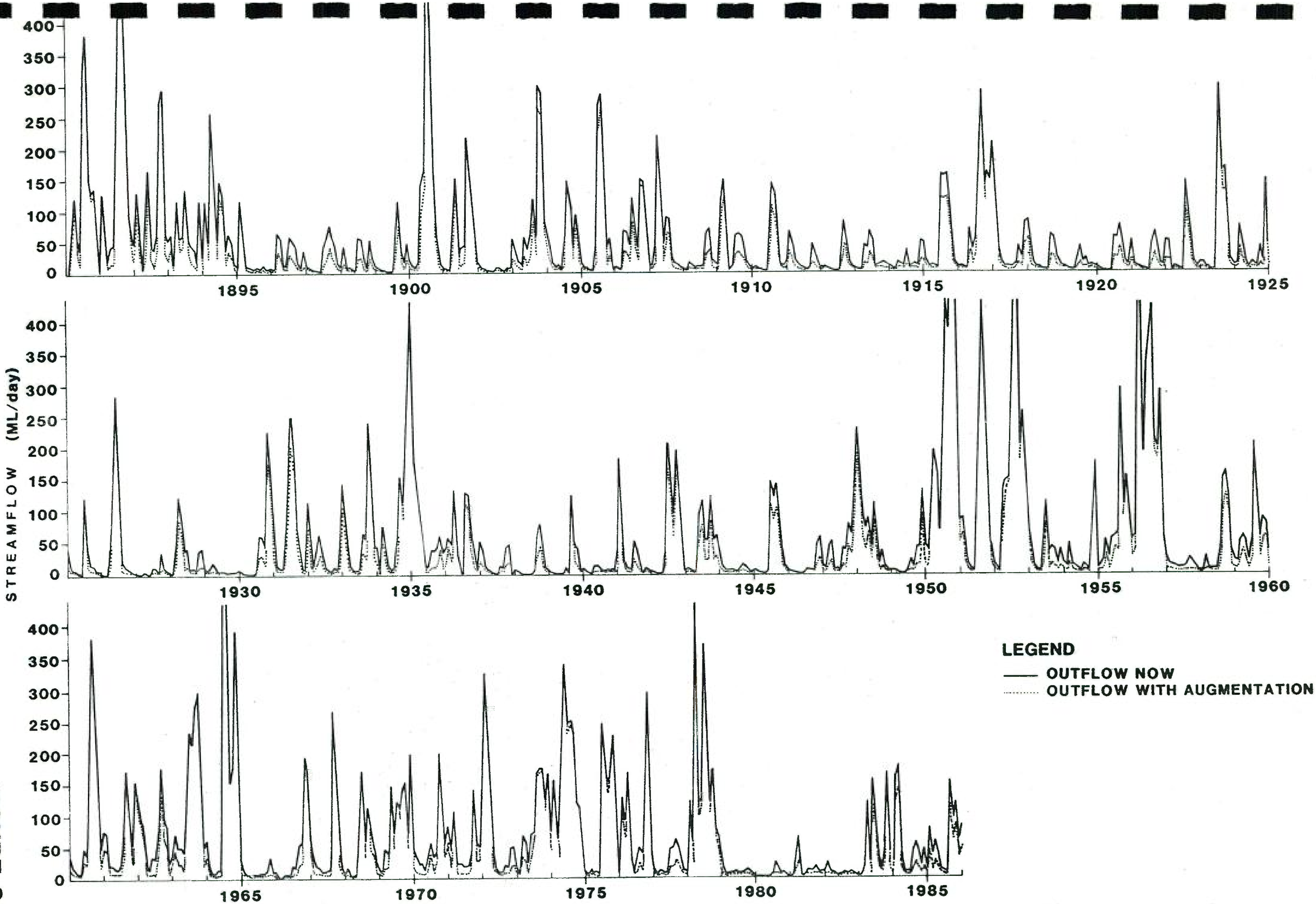


FIGURE 8

SYNTHESISED STREAMFLOW AT DUCKMALOI WEIR

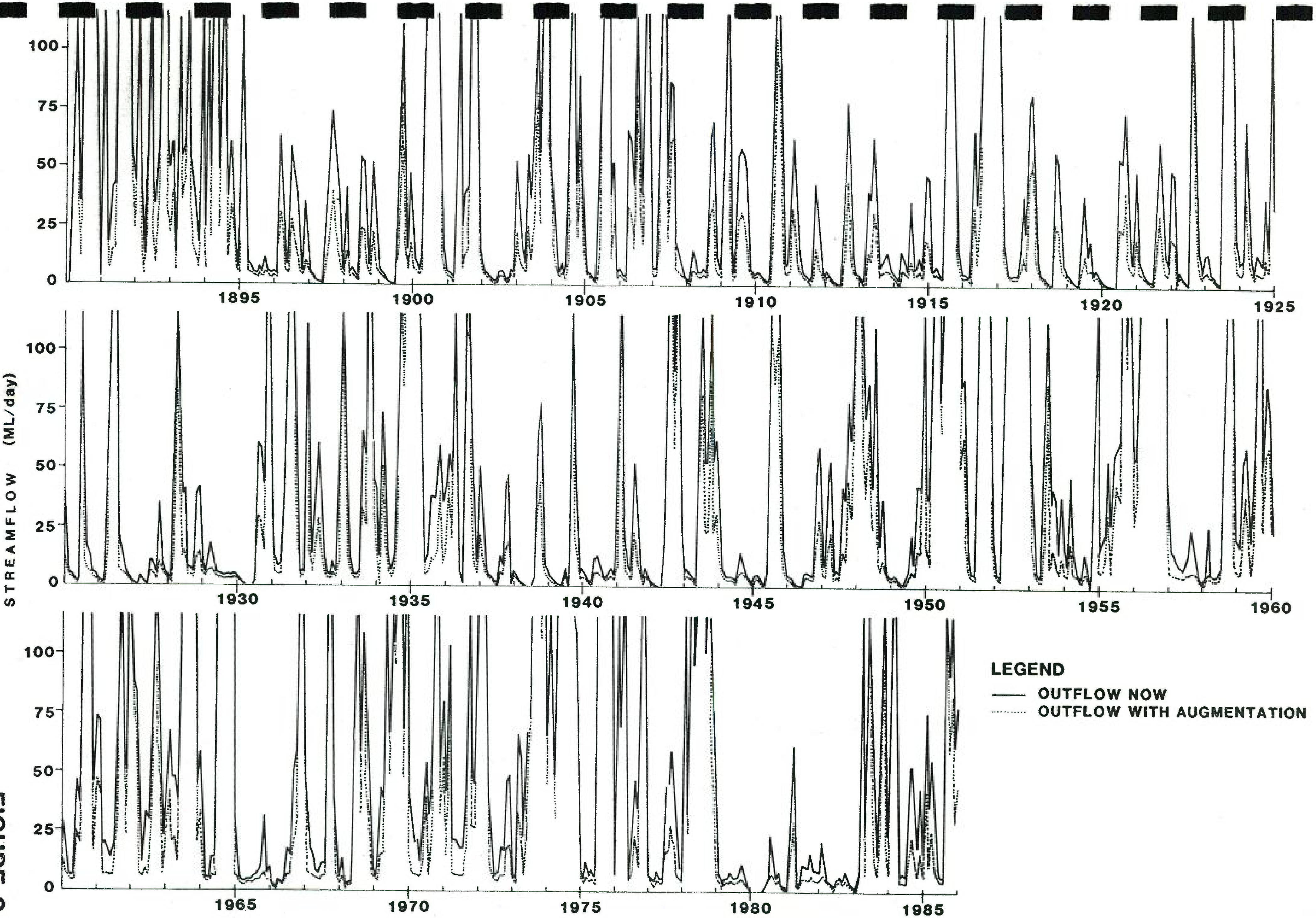


FIGURE 9

SYNTHESISED STREAMFLOW AT DUCKMALOI WEIR SHOWING DETAILS OF LOW FLOWS

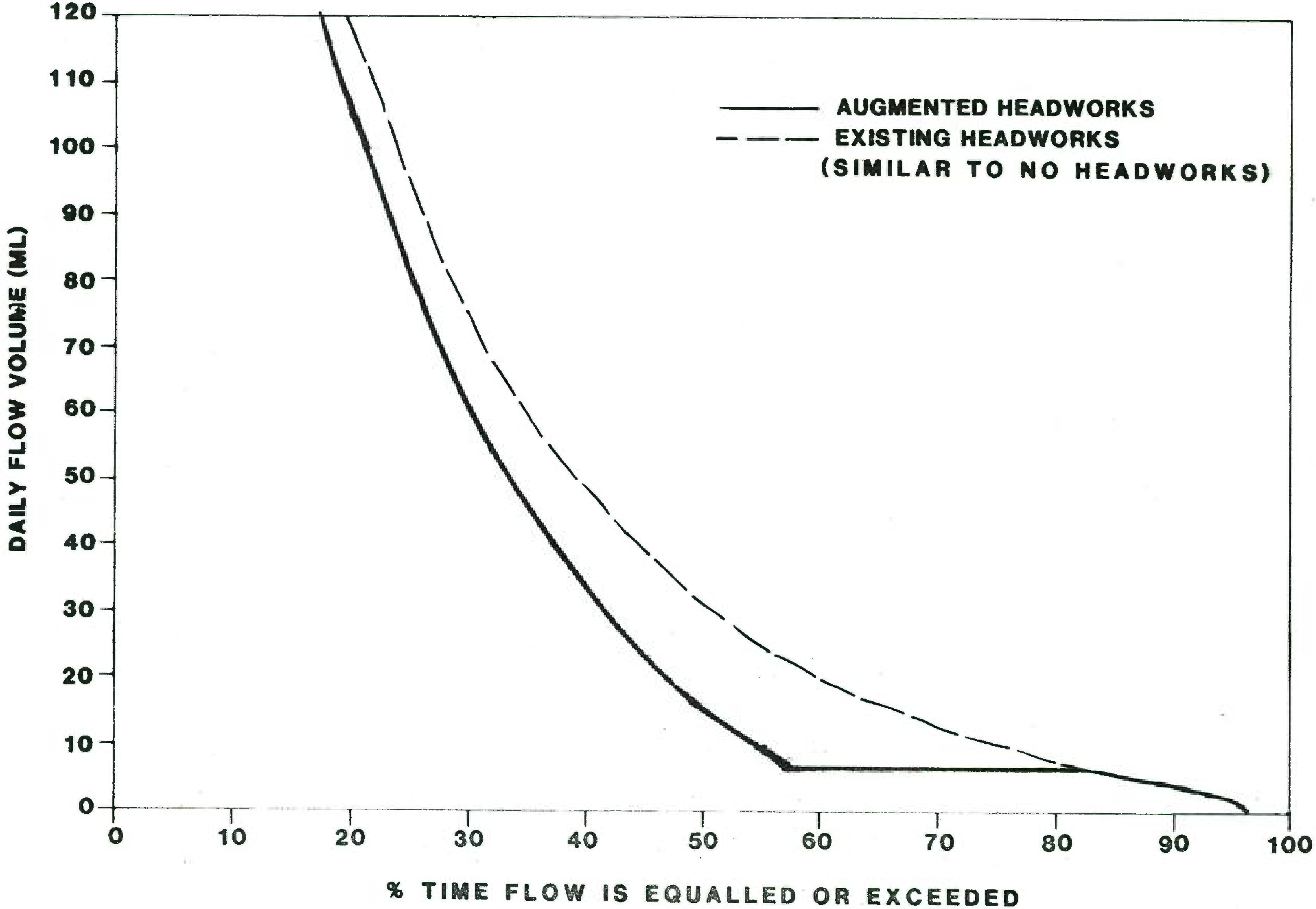


FIGURE 10

DAILY FLOW DURATION CURVE AT DUCKMALOI WEIR

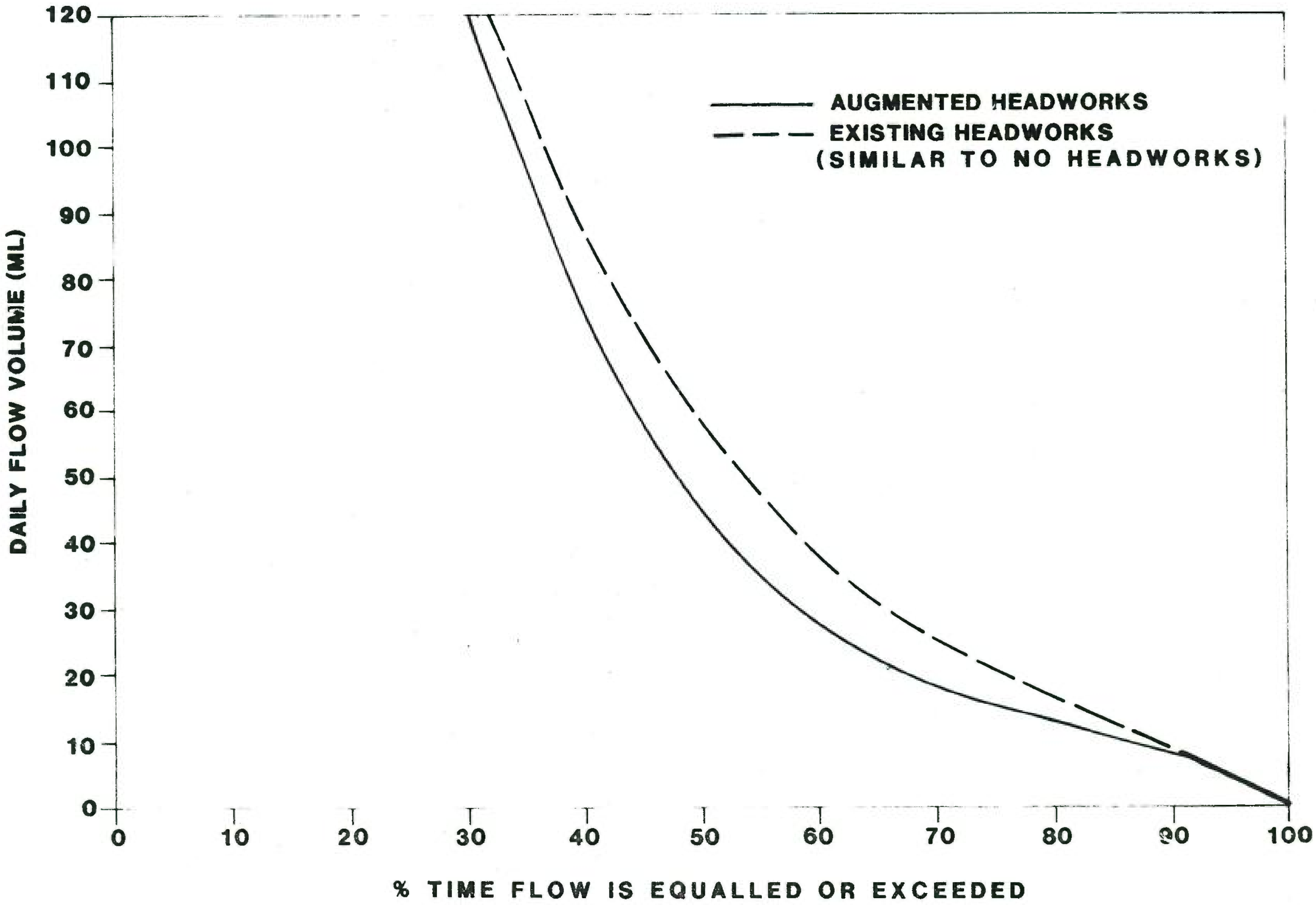


FIGURE 11

DAILY FLOW DURATION CURVE AT JUNCTION OF DUCKMALOI RIVER & McKEONS CREEK

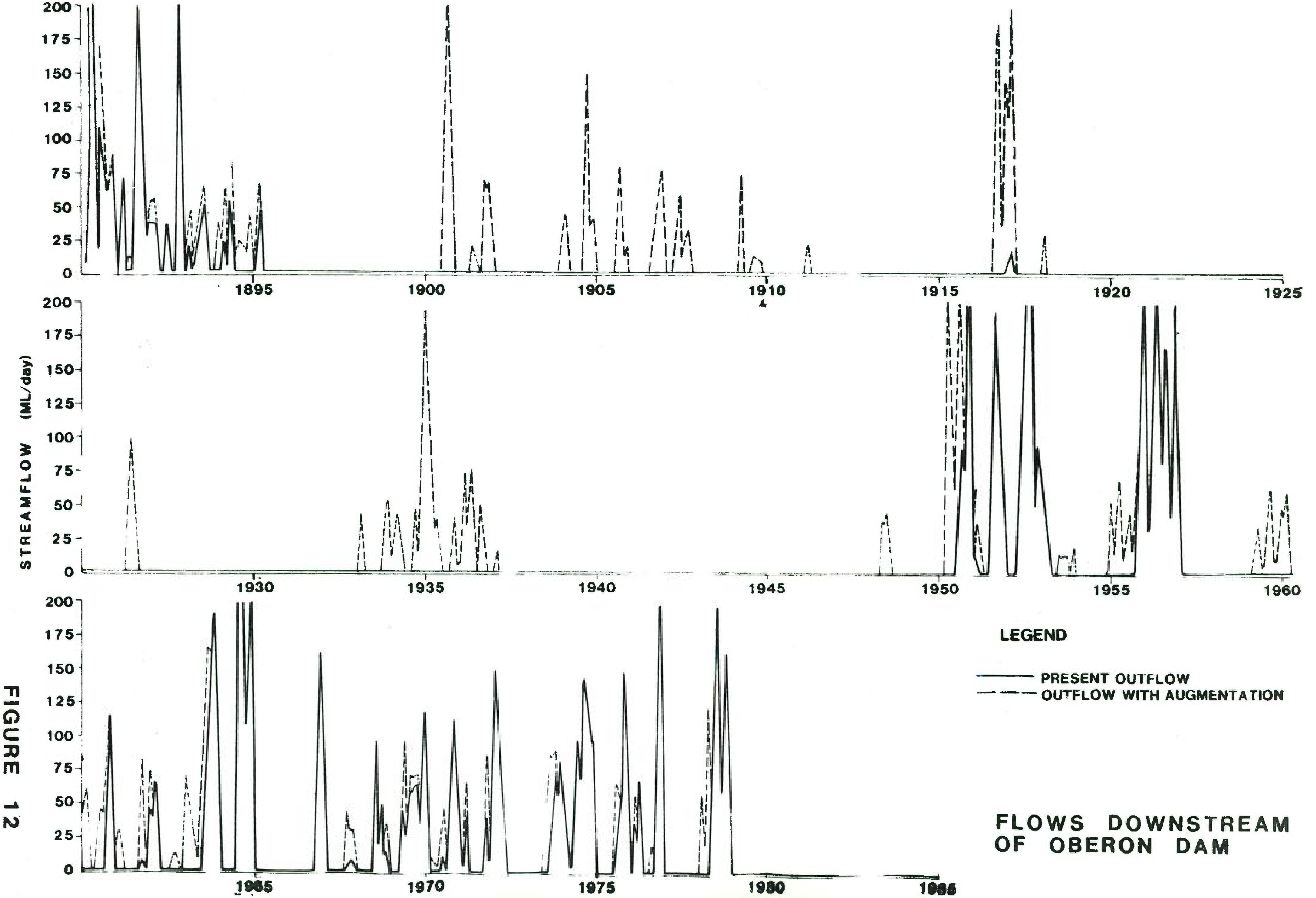


FIGURE 12

FLOWS DOWNSTREAM OF OBERON DAM

4.3.2. Impacts west of the Great Dividing Range

4.3.2.1. Opposition to transferring water eastwards

The issue of transfer of westward-flowing waters to the east of the Great Dividing Range has been one of significance to residents of the Macquarie Valley since Oberon Dam was built (Appendix J OF MCAE, 1977). The **Bathurst City Council** has expressed opposition to any scheme for transferring additional water eastwards, as have the **Central Acclimatisation Society,** the **Friends of the Macquarie,** the **National Parks Association,** the **Nature Conservation Council** and the **Wentworth Falls Angling Society** (Appendix H).

4.3.2.2. Quantities transferred from west to east

Under normal conditions, the proposed works will not increase the quantity of water transferred to the eastern consumers (the Electricity Commission, Greater Lithgow and the Water Board). In fact, a more rigid operating policy has been developed whereby consumers are optimising the use of local sources in preference to calling upon Fish River water in the first instance. Under this arrangement, the situation which arose in the late 1970's when consumptions were in excess of allocations should now not recur.

The proposal will however, have an impact on tranfers which occur during severe drought conditions. The purpose of the proposal is to increase the safe yield of the system so that consumer demands can be reasonably met during prolonged dry spells. At present, the safe yield is assessed at 11,700 ML/a, which implies that under drought conditions only 9,400 ML/a (approximately 80% of 11,700 ML/a - refer to Appendix A) would be available for consumption if failure of the water supply were to be avoided. Augmentation of the scheme will increase its yield to 13,900 ML/a, thereby providing 11,100 ML/a for consumption during drought periods. The additional 1,700 ML/a represents the increased transfer to the east during this period.

In considering the significance of this increased transfer, it should be noted that the definition of safe yield includes the criterion that restrictions should not be in force more than 5% of the time.

4.3.2.3. Bathurst Water Supply

Bathurst obtains its water (about 9,000 ML/a) mostly by pumping from the Macquarie River, which commences at the junction of the Fish and Campbells Rivers. The Campbells River is regulated by Ben Chifley Dam (16,000 ML storage), which is the only other storage in the Upper Macquarie Valley. The dam's main function is to ensure that Bathurst obtains sufficient water from the Macquarie River for urban consumption.

As discussed in Section 4.3.2.2. (p.38), the proposal for the Fish River Scheme will result in an additional 1,700 ML/a being extracted from the Upper Macquarie Catchment during drought conditions in that area. The mean annual flow of the Macquarie River at Bathurst is 320,000 ML with a minimum flow of 12,000 ML/a being recorded in 1940, before Chifley Dam was constructed. Any impact the additional extractions would have at Bathurst would be negligible in view of the in-stream losses which would occur during droughts, and the fact that flows are now regulated by releases from Chifley Dam so that the minimum flow at Bathurst should now be much higher.

During the 1978-83 Drought, up to half the releases from this dam were lost by the time the water reached Bathurst. Part of the cause could be the unauthorised extraction of water by some farmers whose properties adjoin the river. This problem is discussed in further detail in PWD (1985c), where it is suggested that this problem might be limited by a Volumetric Allocation Scheme.

4.3.2.4. Burrendong Dam

The next major storage downstream is Burrendong Dam, which has a capacity of 1,677,000 ML. This includes 489,000 ML for flood mitigation, leaving 1,188,000 ML for water conservation. The storage has a secure yield (that is, with an estimated 100% reliability) of 291,000 ML/a, and a yield of 490,000 ML/a with an operating reliability of 67%. (This storage is used predominantly for irrigation, for which a two-thirds reliability is considered an acceptable measure.) The annual demand for water is around 470,000 ML, mostly for irrigation. Burrendong Dam also receives water from a tributary, the Cudgegong River, which has Windemere Dam on its upper reaches. This has a storage of 368,000 ML and an average annual flow of 55,000 ML/a.

It can be seen that the extra 1,700 ML/a of water which would be transferred eastwards during droughts through augmenting the FRWS would hardly be significant. It amounts to a little more than half a day's average flow past Burrendong Dam. Even in dry years, the environmental effect of the extra 1,700 ML used to the east of the Great Dividing Range would not be noticeable.

4.3.2.5. Macquarie Marshes

In correspondence with the PWD concerning a proposal to build a dam on the Fish River at Tarana Gorge, the **National Parks Association** gave as one of its reasons for objecting to any further augmentation for the FRWS in the Macquarie Valley, the potential for further degradation of the Macquarie Marshes, which is downstream of Burrendong Dam (Appendix H).

A water management plan has been prepared for the Macquarie Marshes (DWR/NPWS, 1986). Under this plan, an annual allocation for wildlife of **50,000 ML** is made available from regulated flow when required, except in those years when the amount of water available for irrigation is less than 25% of the nominal allocation. Even so, an allocation will be made, if there has been none in the previous three years.

Under the guidelines, the National Parks and Wildlife Service (NPWS) may decide not to request an allocation if the Marshes are dry, since in this way it may be a closer simulation of natural conditions to leave the Marshes dry for a number of years. An allocation will mostly be requested if the Marshes have already been wetted by previous flows or rains.

In wet years, flows which are surplus to requirements for water supplies, stock and irrigation may also be directed to the Marshes.

When compared with Burrendong Dam's secure yield of nearly **300,000 ML/a,** and the allocation to the Marshes of 50,000 ML/a, the additional FRWS dry-year transfer of 1,700 ML/a would have a negligible effect on the availability of water for irrigation, and would not alter the amount of flow to the Macquarie Marshes, particularly given the way that water from Burrendong Dam is allotted.

4.3.2.6. Releases from Oberon Dam

It is interesting to note in this discussion that waters stored behind Oberon Dam were released downstream in 1965 and 1966 to augment the flows in the Lower Macquarie River. The Macquarie had had very low flows at Warren, and consequently the amount of water which was being diverted to Nyngan and Cobar along the Albert Priest Canal were being restricted. Because priority had to be given to domestic consumption, and Cobar's water storage was running low, there was a danger that little or no water would be available for the mines at Cobar.

Following representations from the Minister for Conservation to the Minister for Public Works, approval was given for 2,250 ML to be released downstream. There were further representations from local landowners in the Lower Macquarie, Gunningbar Creek as well as around Nyngan and Cobar, and a further approach by the Minister for Conservation. An additional 1,800 ML was allowed out of the dam a few months later, and again early the next year. In late 1972, preparations were being made for another release, before rains in early 1973 rendered this unnecessary.

These supplies from Oberon Dam to the Macquarie Valley have thus established a precedent, which in the right circumstances (eg. high rainfall at Oberon, low storage in Burrendong Dam) could be repeated.

4.3.2.7. Summary

Whilst the proposed works will reduce the overall quantity of water flowing downstream of the weir, the variability of flow will be largely maintained.

The impact of the works on westward flowing rivers will be minimal. Under normal conditions, there will be no increase in the quantity of water transferred to the east. Under drought conditions, an additional 1,700 ML/a could be transferred to consumers on the eastern side of the Great Dividing Range. This may occur 5% of the time. These additional transfers will have a negligible effect on flows and consumers in the Macquarie Valley.

4.3.3. Landscape, landuse and terrestrial ecology

4.3.3.1. Duckmaloi River area

The region is mainly cleared grazing land, one of the major exceptions being along the steep sections of the Duckmaloi River downstream of the weir.

The dominant species are:-

- . **Eucalyptus pauciflora** (Snow gum)
- . **Eucalyptus melliodora** (Yellow box)
- . **Eucalyptus stellulata** (Black sallee)

Along the river, particularly downstream of the weir, the dominant and often only species is **Salix alba** (Basket willow). Where willows do not dominate, the main species are **E. pauciflora** and **E. stellulata.**

Much of the understorey is covered by blackberry bushes, making much of the river difficult to approach. Soon after leaving the weir, the river enters a gorge, which supports a very thick gallery of willows, flanked on both sides by eucalypts higher up the banks. This gorge, although fenced and inaccessible to most people, does carry some sheep, which appear to drink from the river and eat the leaves of the lower branches of the willows.

The **Total Environment Centre** (Appendix H) has requested that account should be taken of any wild, scenic or recreational river values. Although providing an area for solitude, the river downstream of the weir could not be classed as wild. Furthermore, the area is not accessible to the public.

When the river emerges from the gorge further downstream, the banks are more accessible to stock, and much of it has been cleared. These lower sections of the river could also be more accessible to trout fishermen, provided they obtained the landowner's permission to enter.

The weir itself provides a local aesthetic enhancement to its surrounds. (See Photo J.1 of Appendix J.) Although there may be some unauthorised use of the weir for fishing, this is not permitted by the FRWS.

The major terrestrial animals which have been observed, or inferred from droppings, burrows and a previous survey (MCAE, 1977, App. F) are wombats, platypus along the river, echidnas (**Tachyglossus aculeatus**) and the Grey kangaroo (Macropus gigantus). Exotic mammals known to inhabit the area are rabbits, the domestic mouse (**Mus mus**) and the Black rat (**Rattus rattus**). The pastures adjoining the weir carry sheep, while sheep and cattle graze on properties bordering the river downstream.

The proposed WCP will have no effect on the terrestrial ecosystems surrounding the Duckmaloi River.

A number of waterbirds have been observed at Duckmaloi Weir in a previous survey (MCAE, 1977). Those species which are known to breed at the weir are the Black cormorant (**Phalocrocorax melanclencos**), the Little pied cormorant (**Phalocrocorax carbo**), the Eastern swamphen (**Porphyrio melanotus**), the White Coot (**Fulica atra**), the Dusky moorhen (**Gallinula tenebrosa**), and the Masked plover (**Vanellus miles**). Other species of waterbird which use Duckmaloi Weir as a staging place are the Black duck (Anas superciliosa), the Grey teal (Anas gibberfrons), the Chestnut teal (Anas costanea) and the Musk duck (Biziura labata). There is not expected to be any effect of the proposal on the waterbirds.

4.3.3.2. Water clarification plant site

The most suitable site for the water clarification plant itself is a copse of **Eucalyptus mannifera** (Red spotted gum) to the west of the existing BPT (Photo 5). Although the **National Trust** has commented that the works should be laid out in a manner which takes visual qualities into account, and which has a minimum impact on trees (Appendix H), it would be impractical to locate the WCP on the surrounding cleared land.

Firstly, the elevation of the plant is constrained: if it is too high, the rates of flow from Oberon Dam and Duckmaloi Weir will be reduced: the flow to the BPT site is by gravity, and the difference in elevation between the weir and the BPT is already limiting the capacity of the pipeline to carry water from the weir.

If the elevation of the plant is too low, the supplies to Lithgow and Leura would have to be pumped more frequently.

The plant is constrained to the east by the existing BPT, and although the site to the west is cleared, this would entail extra pipework having to be laid, extra earthworks, an additional length of access road, and extra land needing resumption, at a cost of some $100,000 to $150,000.

As the settling tanks of the WCP will not be covered, surrounding trees will have to be removed, to reduce the quantities of leaves falling in. The buildings will be architecturally designed, and once the works are built, the surrounds will be landscaped. Shrubs will be planted near the tanks, and trees will be planted further away. The opportunity will also be taken to landscape the area around the existing Break-pressure Tank.

Two species originally from this area have been notified as rare or endangered: **Lepidium hyssopifolium** (Leigh and others, 1984) and **Eucalyptus pulveralenta** (Silver-leaved mountain gum) (Rohan-Jones, NPWS, 1986, pers. comm.).

L. hyssopifolium is thought to be extinct in mainland Australia, while **E. pulveralenta** is a very localised tree, nowadays growing only in the Western Blue Mountains and the Bredbo-Snowy River Area (Costermans, 1983). Consideration will be given to using **E. pulveralenta** in the landscaping.

Apart from the operator's cottage, the site is visible from only three rural residences, and these are in excess of 1 km away.

The sludge lagoons will be located 0.5 km to the west of the plant on cleared pasture land.

The soils in the vicinity of the BPT have been provisionally classified as Red to Brown Duplex Soils (Murray and Hird, 1976). The erodibility and dispersibility of this type of soil is judged to be moderate.

The soils seen on the site appear to conform to this classification: steeply-sloping embankments on the site appear to be quite stable, even those without vegetative cover, and little evidence of erosion can be seen, even where sealed surfaces have resulted in appreciable concentrations of runoff. It is therefore judged that, provided suitable precautions along the lines outlined by the **Soil Conservation Service** are taken, there should be few problems with erosion during the construction of the WCP.

4.3.4. Aquatic ecology

4.3.4.1. Layout of river downstream of weir

The Duckmaloi River downstream of the weir meanders through undulating country for about 400 m, and then enters a fairly steep gorge about 500 m long, passing through a series of cascades and short pools. At the bottom of the gorge, the slope flattens, although the country on each side remains steep. (See Appendix I for more details.) The pools lengthen considerably, often being 200 m between riffles. About 1500 m downstream of the weir, the river meets Teatree Creek, and McKeons Creek another 1500 m later.

The combined catchment of these last two creeks is about half that of the Duckmaloi at the weir. The inflow from these two would therefore be roughly half that flowing into Duckmaloi Weir.

4.3.4.2. Water Quality and downstream releases

The measurements of water quality of the Duckmaloi suggest that the water is very soft, poorly buffered and therefore susceptible to **pH fluctuations.** The pH is approximately neutral to slightly basic, which is higher than one might expect. (The pH of rainwater is usually significantly less than 7.)

Nitrogen is predominantly in the reduced forms (ie. ammonia and organic nitrogen), suggesting a high oxygen demand on the system. This is confirmed by the results of measurement of Chemical Oxygen Demand (COD) which showed higher values than in Teatree or McKeons Creek.

The **COD** (Chemical Oxygen Demand) was higher about 6 km upstream of the weir than in the pool below the weir, indicating there is a large demand upstream of the weir. This is thought to be caused by animal faeces deposited when the animals are drinking or standing in the creek. Sheep and cattle are not restricted from the waterways, and their droppings can be seen along the banks both upstream and downstream of the weir. Although the weir is fenced off, the fence has come down in a few places, so that stock have access to the storage itself.

Tests of water quality in the Duckmaloi River (Appendix I) have indicated that the rate of sediment transport is low for flows at least up to 40 ML/day, and it is understood that the Soil Conservation Service regards the Duckmaloi Catchment as having far fewer problems of erosion than others in the district (Murray and Hird, 1976; C. Marshall, SCS, pers. comm., 1986).

Turbidity and non-filtrable residue are not excessively high during low-flow conditions. Much of the apparent turbidity and colour could be caused by a high density of red and brown algae and diatoms. Nevertheless, after a fresh in the river, the turbidity values become unacceptably high.

During a fresh there are also high levels of **E. coli** bacteria. Both the high turbidity and the E. coli would require that there be treatment before domestic consumption.

The results of a recent water sampling programme (Appendix I) show that the dissolved oxygen is moderately low in the river upstream of the weir, indicating that there is quite a large biological demand for oxygen. In the weir in summer, the concentration of dissolved oxygen drops during the night to just above the minimum tolerated by aquatic fauna.

The dense stands of willows in the river are also thought to contribute to a deterioration of water quality. The many leaves falling into the river from the willows, particularly in autumn, break down, releasing chemicals which colour the water.

The roots of the willows provide an important habitat for benthos. The roots form fibrous mats which extend over many of the riffles in the waterway (Photo 6), providing many well-aerated spaces for small organisms to shelter. The high respiration (ie. rate of breathing of organisms plus breakdown of organic detritus) of the pools carrying these willow-root mats was demonstrated when the flow ceased during the Drought Simulation Study (Appendix K). In one pool, the dissolved oxygen dropped from a reasonably high value to virtually zero within about 1 hour. That is, when there was little aerated water entering the pool, the existing organisms used up what was available very quickly. Consequently, the aeration of the water is judged to be crucial to maintaining the aquatic ecosystem, and this can only be provided by having sufficient flow over the riffles.

It might also be noted that the **Nature Conservation Council** points out that if too much water is drawn off from a nutrient-rich river like the Duckmaloi, there is some likelihood of there being eutrophic algal growth in the remaining waters (Appendix H).

The average daily flow of Duckmaloi River at the weir is about 59 ML, and it is normally assumed that a minimal flow of 30% of this is needed to maintain the aquatic ecosystems in a satisfactory condition (Tennant, 1976). A minimal flow of 10% or (5.9 ML/day) is usually taken as being merely sufficient to keep aquatic ecosystems in a poor or degraded condition. However, the aquatic ecologist has judged from the results of the Drought Simulation Study (Appendix K) that a minimum flow of 5 ML/day would be acceptable to maintain a healthy aquatic environment: to provide an extra factor of safety, he has recommended that the minimum flow should be 6 ML/day.

As part of the operating procedures for the proposed works, the aquatic habitat downstream of Duckmaloi Weir will thus be maintained by ensuring that the flow does not drop below 6 ML/day, except when natural flows are less than this or for short periods in an emergency.

Although the river is often flowing at less than 6 ML/day because of natural variations in water flow, this does not cause any significant disturbances to the aquatic ecosystems. These low flows are only reached over a relatively long period, and the aquatic fauna would have time to adapt. If however, the flows were to drop below 6 ML/day during the normal extraction procedures, this would put these species under large stress, since the flows would be fluctuating between high and low values over only a few hours, and the larve, invertebrates and fish would not be able to cope easily. Nevertheless, it has also been determined in the Drought Simulation Study that if the flow drops to 3½ ML/day for only a few hours, the aquatic ecosystems should not be unduly stressed.

He has also judged that flows as low as 3½ ML/day can be tolerated for short periods with only minor ecological damage.

These minimal flows are significantly less than those originally suggested by the **Fisheries Division Section of the Department of Agriculture.** Fisheries Division requested that the minimum flow be maintained at 11 ML/day or alternatively

5 ML/day during the period December-June and 20 ML/day from July to November, except when the inflow is less (Appendix H). The flow of 20 ML/day was to allow migration as a precursor to breeding. However, as the river between the weir and the junction with McKeons Creek does not contain any areas suitable for breeding, this higher flow is not needed.

The environmental effects of extracting water from Duckmaloi River are not expected to be significant downstream of the junction with McKeons Creek, since the flows from McKeons and Teatree Creeks will dampen the effects of extraction. Figure 11 indicates that the variability of flows below McKeons Creek will change, but not too severely.

The **Wentworth Falls Angling Society** has expressed its apprehension that demands for water from Duckmaloi Weir would be greatest during periods of low rainfall, and that this would be when any reduction in flow would cause the most damage (Appendix H).

It should be appreciated that the minimum flow which will be released over the weir would be substantially greater than what is allowed at present. The current minimum riparian releases are **2 ML/day** from September to April and **0.5 ML/day** from May to August. The minimum summer release is below the minimum of 3.5 ML/day that this study has found can be tolerated for short periods only and well below the 6 ML/day that would be acceptable for extended periods. Flows of 2 ML/day during summer, when the solubility of oxygen in the water is low, would cause pools to stagnate, fish to die and the food of the platypus living in these pools to decrease markedly.

Likewise during winter, it has been seen in field investigations that there would be hardly any aeration at flows of 0.5 ML/day, so that even though the solubility of oxygen in the water would be higher, the pools would be stagnating or drying up.

It is thought that when water has been extracted from Duckmaloi Weir in the past, particularly during periods of water shortages, adherence to these minimal riparian requirements would have caused severe ecological impacts. Adoption of this augmentation proposal will overcome these problems and satisfy the Angling Society's concerns.

4.3.4.3. Aquatic ecosystems in Duckmaloi River

(The platypus population is discussed in Section 4.3.5, p.47.)

The Duckmaloi River is a gazetted trout stream containing Brown trout (**Salmo trutta**) and Rainbow trout (**Salmo gairdneri**). Trout fingerlings are released into the Duckmaloi River by the **Oberon Branch** of the **Central Acclimatisation Society.**

The **Wentworth Falls Angling Society (WFAS)** has stated (Appendix H) that the Duckmaloi is the premier trout stream in the Central Tablelands, and is accessible at bridges about 8 km upstream of the weir and 11 km downstream, and at a recreation area about 8 km downstream. The **WFAS** claims that even during the last drought, the river had sufficient flow to allow the trout to spawn. This contrasts with the opinion of the **Fisheries Division** which considers that trout do not breed between the weir and Tarana. The aquatic ecologist (Appendix I) found no section of the river between the weir and the junction with McKeons Creek to have clean gravel suitable for spawning. However, McKeons Creek itself, which will not be affected by this proposal, was judged to have suitable clean gravel.

The WFAS states that the Brown trout in Duckmaloi River is self-generating, and is the major species caught below the weir. This is not the case between the weir and Teatree Creek: almost all the salmonids caught by electrofishing in the weir and the pools were Rainbow trout. Only two Brown trout were caught just upstream of Teatree Creek. It is understood that the Central Acclimatisation Society nowadays stocks the Duckmaloi River only with Rainbow trout.

The **Nature Conservation Council** has stated that any release rules ought not to favour the trout at the expense of the native fish (Appendix H). On the other hand, the WFAS has also offered the comment that the Duckmaloi River will not support a native fish population under current or reduced flows.

Besides the two species of trout, only one other species was found, the native galaxia **Galaxias olidus.** The greatest number of fish were galaxias, but the greatest biomass was trout. No other natives were found, even though Llewellyn (1983) had stated that there are another three species of native fish which would have been in the Upper Duckmaloi prior to alteration of habitat for the trout. These are the Freshwater Catfish **Tandanus tandanus,** the River Blackfish **Gadopsis marmoratus** and the Austalian smelt **Retropinna semoni.**

The diversity of fish is very low, as is the abundance (less than 0.65 fish/m^2) and the unit biomass (less than 6 gm/m^2). The greatest number of fish in the river downstream of the weir appears to occur in shallow, shaded pools and riffles, indicating that this type of habitat provided the best source of food and oxygen. This is supported by the sampling of benthic invertebrates, which clearly shows the greatest numbers and diversity of invertebrates occur within riffles over matted willow-root fibres. Deep rocky pools yielded the least number of invertebrate animals.

Large numbers of juvenile trout were also found in the shaded riffles and pools. However, the largest trout were caught in pools with good cover from logs and overhanging rocks.

The cascades of the gorge downstream of the weir provide valuable aeration and self-cleansing for water discharged from the weir. However, they also appear to act as a physical barrier to upstream migration of all fish during periods of low flow. Nevertheless, during floods, it is likely that fish could pass upstream through this area. Therefore regular flooding of the Duckmaloi is necessary to enable redistribution and migration between the sections of the river upstream and downstream of the gorge. Since the maximum rate at which water can be taken from the weir is 33 ML/day, and flood flows are very much larger than this, the proposed extraction would have almost no effect on the floods.

The weir itself has a different fauna than the downstream habitats, primarily because of the sand and mud substrate within the weir as opposed to clean rock or matted root fibres downstream. The riparian or shoreline vegetation around the weir provides excellent habitat for extremely high numbers of insects such as water-boatmen.

It is judged that the two most important localities for food are the shallow sections of the weir and the fast-flowing riffles in the stream itself. As discussed in Section 4.3.4.2 (p.43), it is considered that a flow of 6 ML/day will supply the riffles with sufficient flow to maintain their associated biota. Flows between $3\frac{1}{2}$-6 ML/day for no more than 24 hours should suffice for most organisms in these riffles to survive. However, such flows will not be induced deliberately, except in an emergency.

The demand for water within the FRWS Scheme can vary during the day. This will result in the demand for water from the water clarification plant sometimes changing within a few hours. When the river level is rising quickly, this should not cause any appreciable impacts on the riverine ecosystems. However, if the extraction causes the river level to fall rapidly, there is a danger that small animals inhabiting the edges of the waterways could become stranded and die, decreasing the amount of food available for the platypus and trout.

This rapid drawdown will be dampened to some extent by the weir: the flow over the weir has been observed to take two to four hours to stabilise after a sudden increase in the rate of extraction. Furthermore, each pool will lag in its response to the decrease in flow from the pool above it, so that downstream of the first few ponds, the reduction could occur over several more hours.

4.3.5. Platypus

Detailed studies have been carried out on the platypus population in Duckmaloi Weir. The National Parks and Wildlife Service has stated that the impact on this colony needs to be considered as part of the environmental studies (Appendix H). The results of these studies are set out in Appendix J and can be summarised as follows:-

1. The ecology of the Duckmaloi is well-suited to the platypus. The number of platypus known to have been in the weir at any particular time range from 6 to 20 individuals. (The actual population would probably be somewhat larger than this.) The population downstream of the weir to McKeons Creek is estimated to be between 10 and 30 animals.

2. Provided the weir is kept full, the food supply in the weir should be maintained.

3. Provided the water is released downstream at a rate which is sufficient for adequate food production in the pools between the weir and Teatree Creek, the platypus living downstream should not be significantly affected. (As outlined in Section 4.3.4 (p.43), the aquatic ecologist has determined the desirable minimum flow to maintain habitats and food production to be 6 ML/day.)

4. Platypus living downstream of the weir have been observed and recorded as moving up to the weir, and in times of low flow, would be able to take advantage of the reliable food supply there.

5. Once the water clarification plant is operating, the quantity of food in the riffles and pools just downstream of the weir will reduce. Consequently, the population of platypus in these pools will decrease slightly. It is judged that in the first instance, those platypus displaced because of the fluctuating river flows will move upstream to the weir. In the longer term, it is estimated that the overall population in this part of the river could stabilise at a slightly lower size than at present.

6. If the weir is to be emptied, it should be in the colder time of the year and outside the breeding season of the platypus. It should not be emptied for more than 24 hours, and the advice of a wildlife ecologist will be sought.

4.3.6. Water clarification plant

During construction of the water clarification plant, disturbance of existing vegetation and natural features will be kept to a minimum. However construction activities will create temporary adverse effects from dust, noise and increased traffic flow in the area. This will be limited to daylight hours and will be kept to a minimum. It is estimated that construction noise will not exceed the acceptable base level by more than 10 dB(A). The anticipated construction time for the plant is about 16 months.

Excess spoil from the earthworks at the treatment plant site will be spread on the site wherever possible. The remainder shall be carted away.

Once the plant is commissioned, operational noise will be low, being less than 5 dB(A) above the acceptable base level at the nearest dwelling. There will be increased traffic movements, but these will be minimal. Chemical supply trucks will be required to make deliveries to the plant about once a fortnight, and solidified sludge will be excavated and removed annually.

The potential for permanent visual impact will result primarily from introducing a public utility process into a natural landscape. The treatment plant will introduce elements which contrast strongly with the surrounding environment. However, the plant is visible from only three rural residences and extensive landscaping will be carried out to minimise the impact.

The sludge lagoons are low, unobtrusive structures, similar to farm dams. No odour is expected to be produced by the sludge. Clear supernatant liquid will be discharged from the lagoons into a minor creek which flows into the Fish River. This discharge will be in accordance with licence conditions to be specified by State Pollution Control Commission.

4.4. Archaeology

As set out in Appendix L, no archaeological material has been found at or near the site of the Water Clarification Plant.

4.5. Environmental Safeguards

4.5.1. Operation of the weir

A telemetry system will be installed to relay data on river flows from the weir to the WCP, so that the operation of the weir can adhere to the following procedures:-

1. If water is spilling over Oberon Dam, then normally all water will be taken from Oberon Dam. If the water is not spilling, demands will be

supplied initially from Duckmaloi Weir, with any balance being satisfied from Oberon Dam.

2. If Oberon Dam is not spilling, and inflows to Duckmaloi Weir are above 39 ML/day, 33 ML/day will be used, unless the demand on the Fish River Scheme is less than this. With these higher inflows, the flow over Duckmaloi Weir would then be above 6 ML/day.

3. With Oberon Dam not spilling, and inflows between 39 and 13 ML/day, the drawoff to the Duckmaloi WCP will be between 33 and 7 ML/day again allowing a flow over the weir of 6 ML/day.

4. Normally, no water will be drawn off when the river inflows are less than 13 ML/day.

5. If the plant is operating and the flow over the weir drops below 6 ML/day, an alarm will ring at the WCP. If the flow drops to 3.5 ML/day, the WCP will automatically shut down, so that the flow over the weir will equal the inflow.

6. Flows over the weir will not be deliberately allowed to drop below 6 ML/day, except in an emergency, and then only according to guidelines laid down by an aquatic ecologist. If the flow remains below 6 ML/day for more than 24 hours, the advice of an aquatic ecologist will be sought on the minimum flow to be temporarily released to help restore the environmental health of the river.

7. If the weir is to be emptied, it should be in the colder time of the year and outside the breeding season of the platypus. It should not be emptied for more than 24 hours, and the advice of a wildlife ecologist and an aquatic ecologist will be sought.

8. To facilitate operation of the system in accoradance with the above, the weir will be calibrated (ie. a relationship between water level and discharge will be established), and a continuous record will be kept of the flow over the weir.

4.5.2. Erosion

All earthworks for the WCP will be planned to mitigate erosion of any embankments or stockpiled soil. Restoration will be planned to ensure that there is little concentration of runoff.

4.5.3. Monitoring of operations

Over time, the storage behind the weir is expected to silt up gradually, and it may be deemed desirable to excavate some of this sediment to maintain adequate storage and/or to maintain a suitable habitat for the platypus and trout. Such an excavation would temporarily remove some of the sources of food. Accordingly, any dredging will be planned in collaboration with an aquatic ecologist, to ensure that sufficient benthos is retained to maintain the aquatic ecosystems. Notification will also be given to the Central Acclimatisation Society, should they wish to take extra steps to preserve the fish in the pond.

It is also pointed out that the criterla for releases downstream of the weir have only been determined by one set of experiments. In order to ensure that the aquatic ecosystems are maintained in practice, and that the colony of platyus will not be significantly affected, the effects of operation of the water clarification plant will be monitored for the first two years, and after that possibly in more exceptional circumstances, such as during a drought.

4.6. Energy Use

The water clarification plant will be treating approximately 4,000 ML/a. This would entail 100 days of operation for two modules or 200 days for one module, about 4,400 hours for the two modules. If the rated capacity of the motors is 50 kW in all, this would amount to roughly 220 MWh/a.

The construction of the water clarification plant is estimated to require 150 kL of fuel to be consumed. If the calorific value of the fuel is 11 kWh/L, this would result in a fuel consumption of 1,650 MWh.

If we assume the working life of the water clarification plant is 20 years, the total energy use would amount to roughly 4,000 MWh.

The scheme for transferring water from the Duckmaloi Weir to Oberon Dam would have required regular pumping, using 3,000 MWh/a over twenty years. This neglects the energy used for constructing the pumping station and laying the pipeline.

The alternative of building a weir on the Coxs River can only be calculated very approximately, since the best site would still have to be determined. Rough estimates of the pumping requirements indicate an energy expenditure of 5,500 MWh/a over 20 years. The energy to build the weir, the pipeline, and the water treatment plant would be additional to this.

The corresponding energy needed for pumping in the Thompsons Creek alternative would be roughly 3,000 MWh/a over 20 years.

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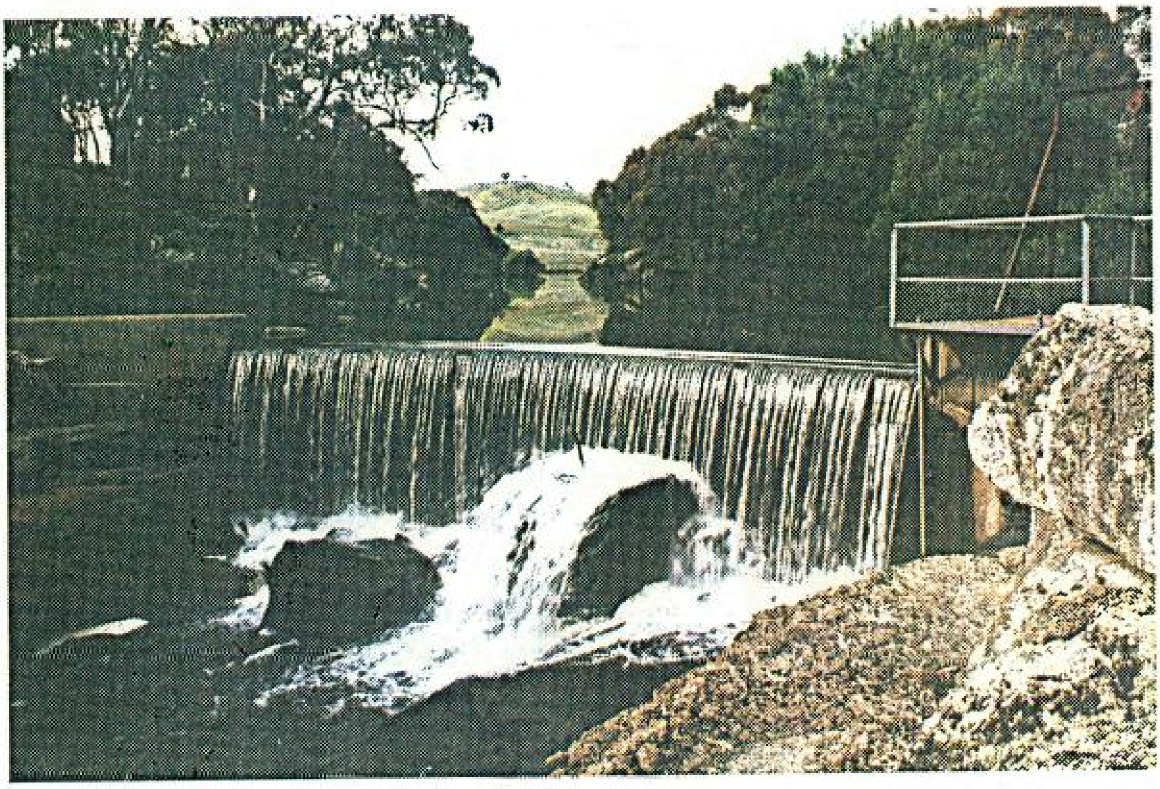
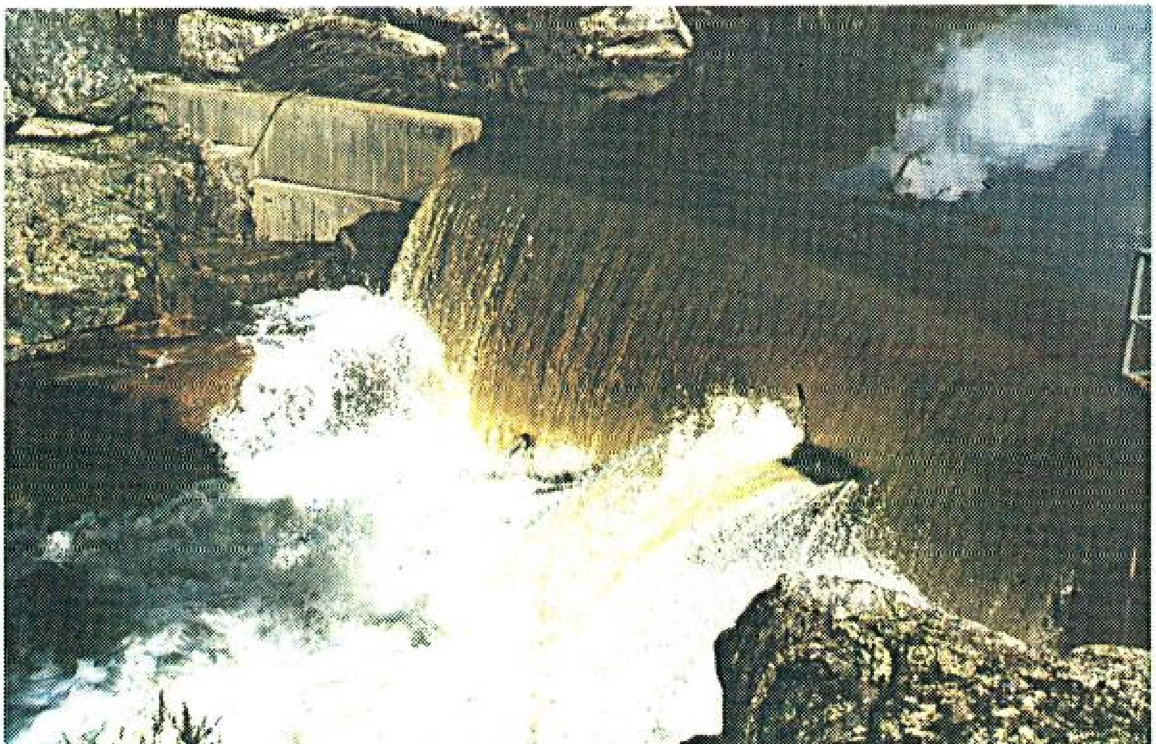
1. Oberon Dam.

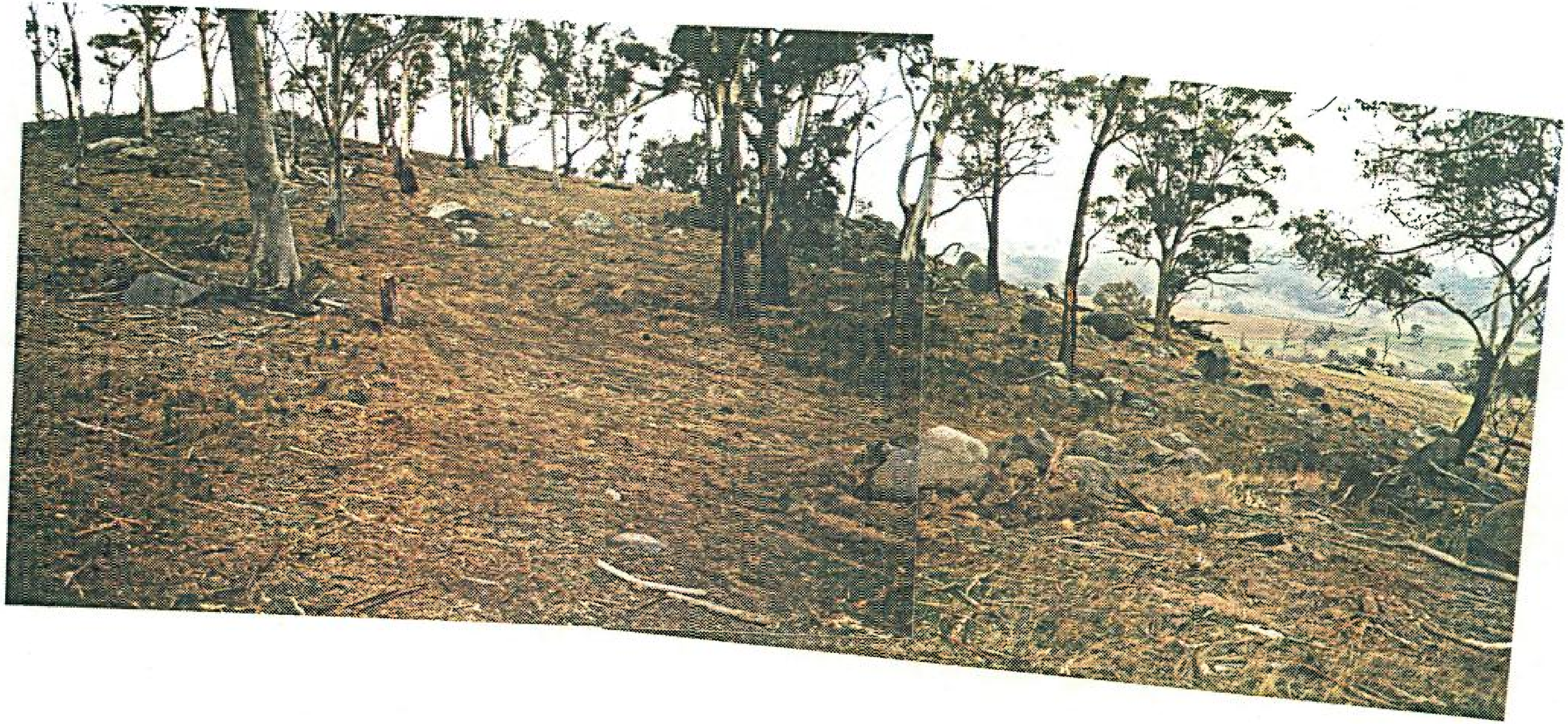
2. Duckmaloi Break-pressure Tank.



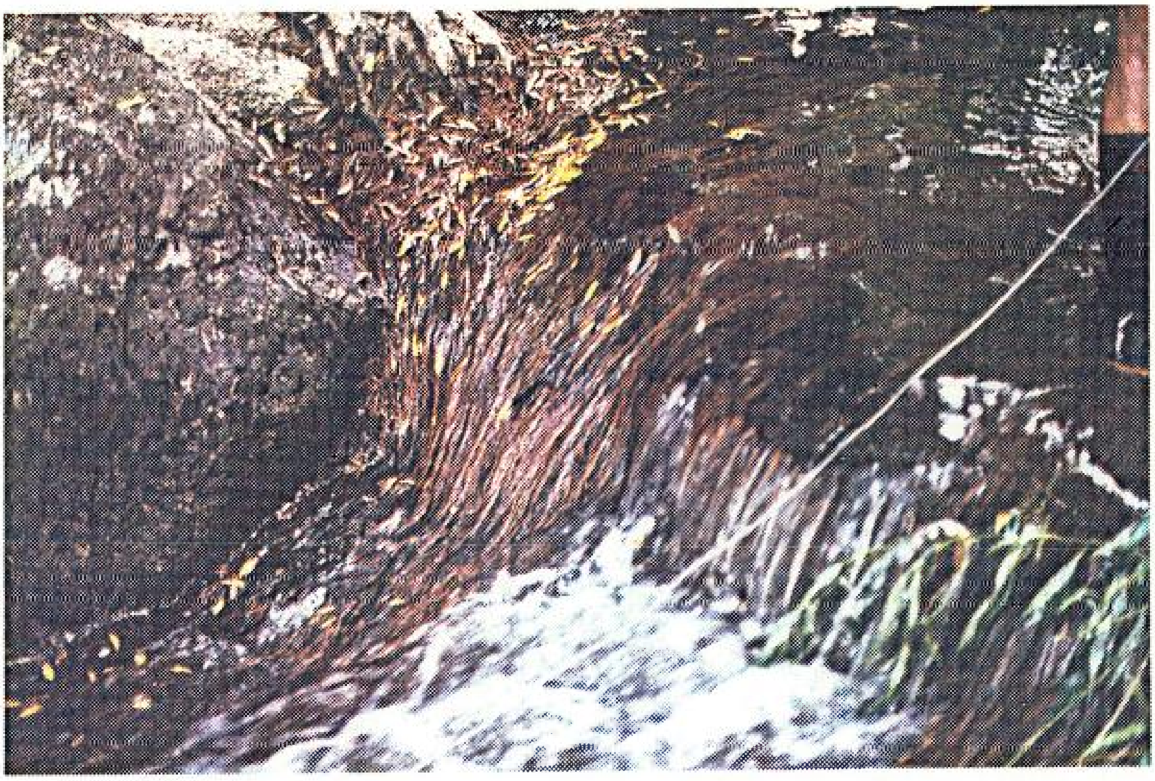
3. Duckmaloi Weir.



4. Coloured and turbid spilling water over Duckmaloi Weir.



5. Copse of trees at site of water clarification tank.



6. Fibrous roots of willows in Duckmaloi River.

APPENDIX A

CALCULATION OF SAFE YIELD OF STORAGES

A. CALCULATION OF SAFE YIELD OF STORAGES

A.1. Public Works

The Public Works Department has developed a set of guidelines for estimating the safe yield of a water supply system. The safe yield can be defined as the amount of water which can be supplied annually to consumers with a reasonable degree of assurance.

Four criteria, have been laid down to determine this safe yield.

1: The system should be able to meet all normal demands during the worst drought on record, assuming there are no water restrictions, and assuming the dam is full at the start of the drought.

2: Restrictions should not be in force more than 5% of the time.

3: Restrictions should not be applied more than an average of one year in ten.

4: If the worst drought on record recurred and commenced just when restrictions were applied, the system should be able to meet 80% of normal demands. The level at which restrictions are applied is taken as the lower of the two levels determined in Subcriteria 2 and 3.

A.2. Electricity Commission

The Commission determines its storages to be acceptably safe if they are designed to hold one year's supply after the critical drought. In this assessment, no allowance is made for inflow during the following year.

APPENDIX B

HISTORICAL USE OF WATER FROM

FISH RIVER WATER SUPPLY

B. HISTORICAL USE OF WATER FROM FISH RIVER WATER SUPPLY

The initial consumers of water from the Fish River Water Supply in the mid-1940s were the National Oil Co. which produced oil from oil shale at Glen Davis, the forerunners of Greater Lithgow City Council, and minor consumers adjoining the pipeline.

Oberon Shire joined the Scheme soon afterwards, but the National Oil Company ceased operation in the early 1950s. This left the Scheme with spare capacity, and this was made use of following the construction of Wallerawang Power Station.

The capacity of the scheme was increased in the early 1960s, by raising Oberon Dam and constructing Duckmaloi Weir. A pipeline was also built to Leura, and supply commenced to the Blue Mountains in the mid-1960s.

Table B.1 shows the quantities supplied each year by the FRWS, since it commenced operation.

TABLE B.1. CONSUMPTION SINCE 1946 (ML/a)

	ECNSW	WB	GLCC	OSC	Minor Consumers	National Oil Co.	Total
See Note	(1)	(2)	(3)		(4)		
MAQ	8184	3650	2092	264	60		14250
Year							
1946			71		2	747	820
1947			136		3	938	1077
1948			297	6	8	964	1269
1949			1214	39	27	996	2276
1950			1536	56	50	1112	2754
1951			1645	69	61	989	2764
1952			1692	94	35	691	2513
1953			2332	100	47	80	2559
1954			1861	111	60	0.1	2032
1955			1137	128	44		1309
1956			1247	150	35		1432
1957	321		1486	209	62		2078
1958	1299		1662	165	48		3174
1959	1146		1913	171	49		3279
1960	2306		1715	199	50		4270
1961	3943		2071	195	47		6256
1962	4019		1331	201	51		5602
1963	4118		1077	217	38		5450
1964	4162		2530	274	64		7030
1965	4381	1167	2130	304	74		8056
1966	4378	2749	1815	315	131		9388

TABLE B.1. CONSUMPTION SINCE 1946 (ML/a) (cont.)

Year	ECNSW	WB	GLCC	OSC	Minor Consumers	National Oil Co.	Total
1967	4342	2631	1948	293	106		9320
1968	4188	3586	2088	315	98		10275
1969	4308	3099	2065	334	81		9887
1970	4607	3112	1934	325	80		9978
1971	4944	3368	2057	330	71		10699
1972	4878	3454	2133	300	91		10765
1973	4391	3466	2034	356	125		10247
1974	3930	3465	2556	386	124		10459
1975	3884	3592	2116	350	180		10122
1976	5583	3919	2332	358	129		12321
1977	6583	4572	2261	374	165		13911
1978	8259	3844	2505	284	182		15073
1979	7887	3982	2928	381	208		15386
1980	7854	3943	2305	323	172		14597
1981	6521	942	1244	237	83		9027
1982	7007	774	2026	268	123		10198
1983	4346	432	1226	207	78		6305
1984	3044	71	1166	263	82		4626
1985	4897	354	1605	336	241		7433
1986	4162	1171	1467	418	177		7418
1987	3818	2487	1205	428	267		8206

1 Water was supplied to the Electricity Commission from 1957.

2 Water was supplied to the Blue Mountains from May, 1965. From July, 1981, the WB assumed responsibility for the supply of water to the Blue Mountains.

3 Blaxland Shire Council and Lithgow City Council amalgamated in 1979 to become Greater Lithgow City Council.

4 Each minor consumer has an MAQ of 200 kL. This makes the total MAQ for the 300 minor consumers 60 ML.

APPENDIX C

GUIDELINES FOR DRINKING WATER QUALITY

C. GUIDELINES FOR DRINKING WATER QUALITY

The Health Department of New South wales has adopted the guidelines of the National Health and Medical Research Council and the Australian Water Resources Council (NHMRC/AWRC) for drinking water quality. The criteria include limits on physical, chemical, radiological, microbiological and pesticidal contamination. The physical, chemical and microbiological criteria are summarised in Table C.1 below.

The "desirable current criteria" in the table are the suggested maximum levels which may be appropriate for drinking water under present Australian conditions. The "long-term objectives" indicate standards which should be aimed for in the longer term. The values "requiring health investigation" constitute levels at which the appropriate health authority should advise on action which may be needed to avoid a situation potentially hazardous to health.

The PWD regards the Desirable Current Criteria as minimal, and given the fact that water of this quality is not always considered to be satisfactory by consumers, would normally aim for supplies of a higher standard.

TABLE C.1. GUIDELINES FOR DRINKING WATER QUALITY

Characteristics	Desirable Current Criteria	Long-term Objectives	Requiring Health Invesigation
Physical	Maximum levels		
Colour units	50	5	
Turbidity units	25	5	
Odour	unobjectionable	unobjectionable	
Taste	unobjectionable	unobjectionable	
pH range	6.5 to 9.2	7.0 to 8.5	less than 6.5 or more than 9.2
Chemical (mg/L)	Maximum levels		if levels exceed
Total solids	1,500	500	
Calcium	200	75	
Chloride	600	200	
Copper	1.5	0.05	10
Total iron	1.0	0.1	
Magnesium	150	50	
Manganese	0.5	0.05	
Sulphate	400	200	
Zinc	15	10	15
Nitrate as N	10	10	10
Total hardness (CaCO3)	600	100	
Aggressive CO2	-	-	
Phenolics (as Phenol)	0.002	0.001	
MBAS	1.0	0.2	
Chromium	0.05	0.05	0.05
Cadmium	0.01	0.01	0.01
Cyanide	0.05	0.05	0.05
Arsenic	0.05	0.05	0.05
Barium	1.0	1.0	1.0
Lead	0.05	0.05	0.05
Silver	0.05	0.05	0.05
Mercury	0.001	0.001	0.001
Selenium	0.01	0.01	0.01
Microbiological			
Coliforms	10 per 100 ml	95% of samples contain no coliform; no sample more than 10 per 100 ml; coliform not detectable in 100 ml of any two consecutive samples.	if levels exceed 10 per 100 ml
E. coli	0 per 100 ml	0 per 100 ml	if exceed 0 per 100 ml.

APPENDIX D

LONG-TERM SOURCES OF WATER

D. LONG-TERM SOURCES OF WATER

In the long term, i.e. beyond the year 2005, extra resources in the region may need to be developed for Mount Piper Units 3 & 4, and for growth in the urban population.

Various potential sources of surface water, at sites on the Fish, Duckmaloi, Coxs and Lett Rivers (Fig. D.1) have previously been evaluated, together with the environmental effects which could be expected (PWD, 1985a). It was concluded that only the Fish and the Coxs River Systems had sufficient capacity to meet projected demands: dams on either the Duckmaloi or Lett Rivers, even in combination with each other, would eventually require additional augmentation from either the Coxs or Fish Rivers.

A dam on the Fish River near Tarana was found to be the most economic solution for the long-term needs of the region. However, it would result in the following significant environmental impacts.

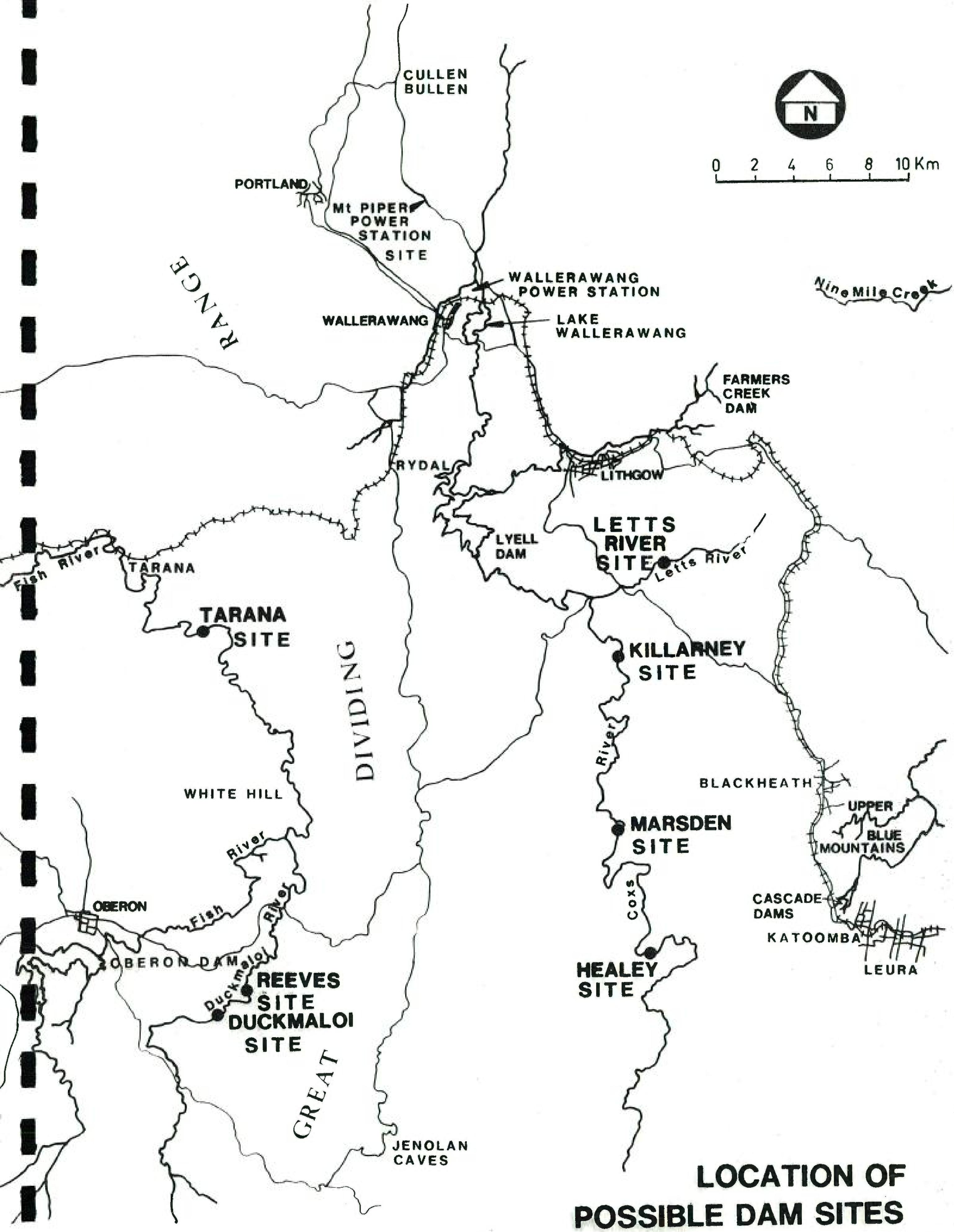
- It would inundate Tarana Gorge, an environmentally sensitive area.
- It would cause a reduction in water flows to the Macquarie Marshes.
- There would be less water available for other downstream users of the Macquarie River System than now.
- It would be a major diversion of westward-flowing water to the east of the Great Dividing Range.

It was therefore decided that any further detailed investigations should proceed on the premise that the Coxs Valley would be the main source for satisfying future regional demands.

It has been concluded that supplies cannot be obtained from groundwater in sufficient quantities or adequate qualities (PWD, 1985a) One source of groundwater, bores, would have very low yields, while water from abandoned mine workings, although potentially having adequate yield, would require uneconomic levels of treatment to meet desirable quality criteria.

A comprehensive catchment management plan could prove to be a cost-effective means of providing high-quality water to consumers in the Coxs Valley. Such a plan, if it incorporated constraints on landuse, should result in the level of pollution of the Coxs River being lessened. As the degree of pollution of the Coxs River declined, the proportion used by the Electricity Commission for boiler make-up water could be increased, reducing the demand on the supplies from the Macquarie Valley.

Nevertheless, it should be stressed that the development and implementation of a Total Catchment Management Plan would require a very long-term programme, and could only be regarded as complementary to other options.



LOCATION OF POSSIBLE DAM SITES

FIGURE D1

APPENDIX E

CLIMATE AND HYDROLOGY

E. CLIMATE AND HYDROLOGY

E.1. Climate

The mean daily maximum in January is 24.3°C with an 86- percentile of 29.6°C. These high temperatures persist from December to February.

The average rainfall at Oberon is 840 mm/a, which falls fairly evenly through the year. However, the rainfall in the Duckmaloi Valley appears to be much higher than in the Fish Valley, probably because of the orographic effect of the nearby Great Dividing Range (Fig. E.1).

E.2. Hydrology

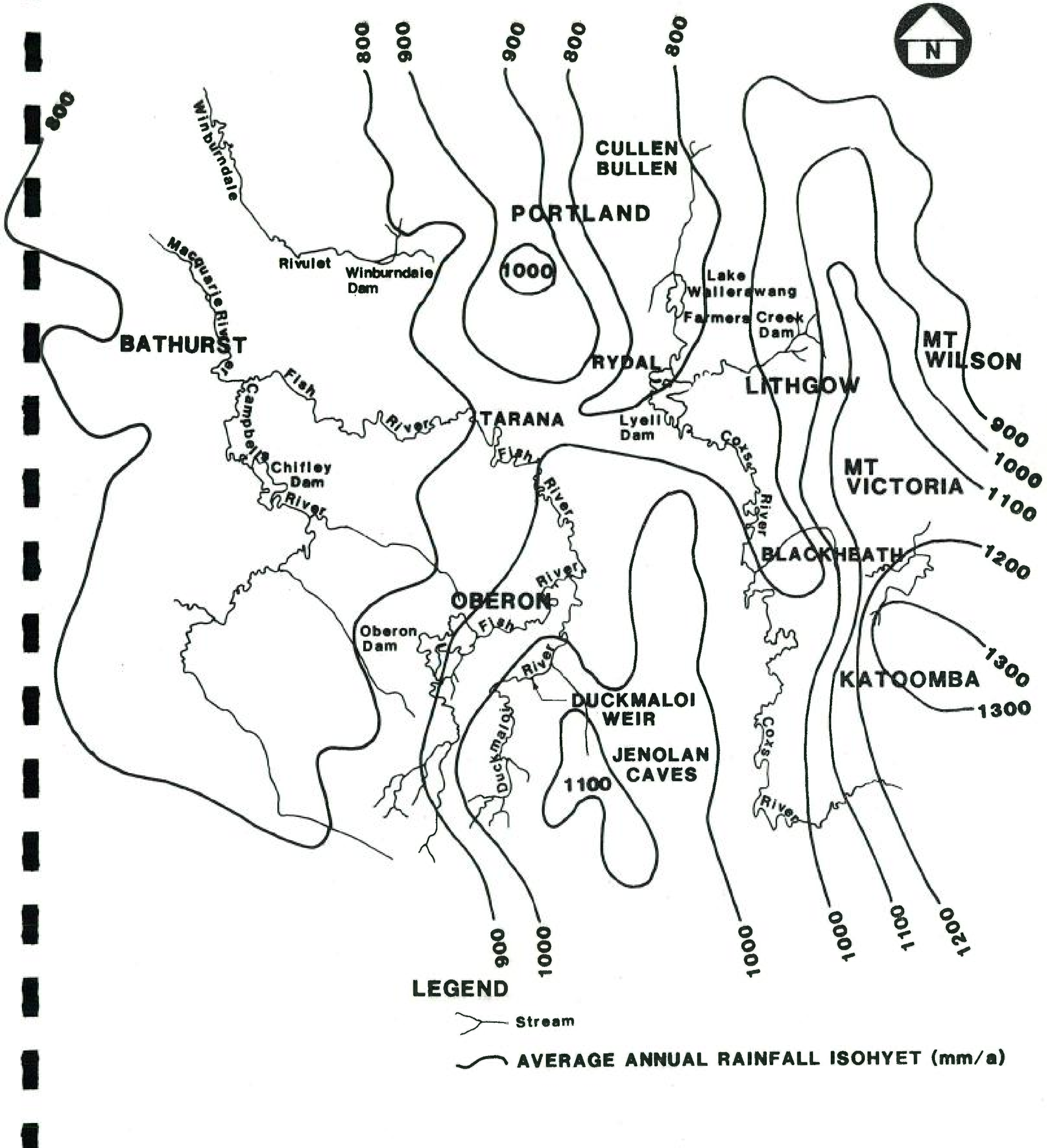
Although the catchment of Duckmaloi Weir (110 km^2) is about 20% less than that of Oberon Dam (140 km^2), its average annual flow is nearly as great (20,200 and 21,400 ML/a respectively), because it receives a higher rainfall.

It is understood that the Duckmaloi ceased to flow at one stage during the recent drought (J. Armstrong, pers. comm., 1986), whereas Teatree and McKeons Creek did not, even though they have smaller catchments. This could be related to the number of farm dams in the respective catchments.

A monthly streamflow record was synthesised for a 96-year period, correlating the flows at Duckmaloi River observed over the period 1954-1981 with rainfall records from 1890 to 1985 and with other climatic data, using a non-parametric regression analysis (PWD, 1985a, App. D).

Similarly, monthly flows on the Fish River were simulated by correlating the known flows at Oberon Dam from 1963 to 1983 with the rainfall at Oberon, and then synthesising the flows, using the 96 years of rainfall records.

The various proposals for augmenting the capacity were modelled mathematically to reflect the sizes of components, demands and methods of operation, and the behaviour of the weather over these 96 years. Because aquatic flora and fauna react to daily changes in the aquatic environment, known patterns of daily flow were used in the development of equations for monthly flows in the Duckmaloi River, to simulate the real situation as closely as possible.



AVERAGE ANNUAL RAINFALL

FIGURE E1

Using this set of models, the safe yield of the FRWS system was calculated for a range of operating rules, to assess the increase in security of supply with the augmented capacity. The results are shown in Table E.1.

TABLE E.1. SAFE YIELD OF FRWS FOR DIFFERENT OPERATING CONDITIONS

	Operating conditions	Safe yield (ML/a)
1.	Oberon Dam without Duckmaloi	11,600
2.	Existing system - Oberon Dam with Duckmaloi Weir suppling water when flow less than 6 ML/day, because of water quality constraints; riparian releases: 2 ML/day Sept.- April and 0.5 ML/day May-August.	11,700
3.	Oberon Dam with Duckmaloi Weir without water quality constraints, and current riparian releases 2 ML/day Sept.-April and 0.5 ML/day May-August.	14,200
4.	Oberon Dam with Duckmaloi Weir supplying water when flow less than 6 ML/day, but with no requirements for riparian releases.	14,700
5.	Oberon Dam with Duckmaloi Weir and WCP of capacity 40 ML/day, releasing flows not less than 5 ML/day or inflow, whichever is the lesser. Duckmaloi used only when inflow exceeds 13 ML/day.	14,000
6.	Preferred option - Oberon Dam with Duckmaloi Weir and WCP, releasing flows not less than 6 ML/day or inflow, whichever is the lesser. Duckmaloi used only when inflow is 13 ML/day or more.	13,900
7.	Oberon Dam with Duckmaloi Weir and WCP of capacity 20 ML/day, releasing flows not less than 5 ML/day or inflow, whichever is the lesser. Duckmaloi used only when inflow exceeds 13 ML/day.	13,300

APPENDIX F

DETAILS OF WATER CLARIFICATION PLANT

F. DETAILS OF WATER CLARIFICATION PLANT

At the plant, the water would be clarified to reduce its turbidity to less than 3 turbidity units, its colour to less than 15 colour units, and its iron to less than 0.3 mg/L. If necessary, water from Oberon Dam could be clarified similarly.

The plant layout is shown in Figures F.1 and F.2. It will consist of two concrete flocculation tanks, two concrete horizontal flow settling tanks (clarifiers), a clear water balance tank and architecturally designed control building. The plant will be designed to treat up to 40 ML/day, assuming it operates for an average of 22 hours a day (ie. 505 L/s). It will be built in essentially two modules, so that whenever the amount of water available from Duckmaloi Weir is less than 253 L/s (ie. 20 ML/day over 22 hours), only one module will be operating. In order to have these modules working efficiently, water will also be supplied to the WCP from Oberon Dam to bring the total flow up to the rated 505 or 253 L/s, depending on the number of modules operating.

The water will be first dosed with lime slurry in a rapid-mix tank to bring its pH to the optimum for flocculation, and then dosed with alum. Next, a polymer to speed up the settling of the flocs will be added. Following this, the flocculating water will enter one of two flocculation tanks, each with a retention time of 30 minutes. From there, the water will flow into a sedimentation basin and be detained for about 130 minutes. Additional lime will be added to reduce any corrosive tendencies of the clarified water. The clarified water will discharge into the 2.5 ML clearwater balance tank and be mixed with raw water from Oberon Dam if necessary to meet downstream demands.

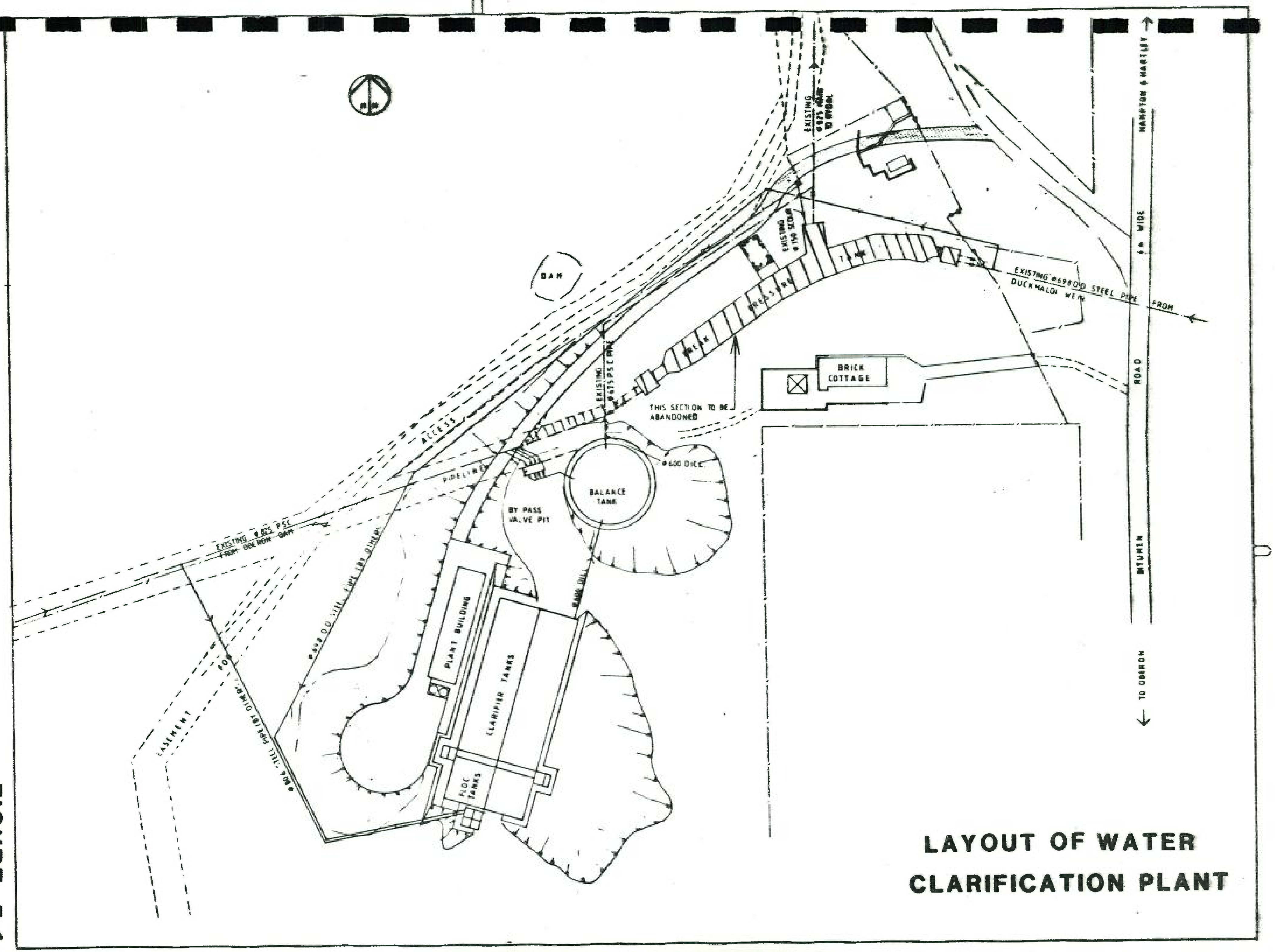
The sludge from the sedimentation tanks will be automatically discharged into one of two sludge lagoons to be constructed approximately 500 m to the west of the plant site. In these lagoons, the sludge will be allowed to settle out, leaving a clear supernatant liquid at the top. This liquid will be discharged to a minor creek which flows into the Fish River. The water discharged from the sludge lagoons will not have any adverse impact: its sediment and organic debris will have been removed, so that its quality will be better than that in the river. Approval to discharge this water will be sought from the State Pollution Control Commission. No problems with this approval are anticipated.

Once one sludge lagoon is sufficently full, it will be taken out of service and allowed to dry, while the other is used. Each lagoon will operate for about 12 months. Once dry, the solidified sludge will be excavated and can be either disposed of at a suitable site, used for fill, or as a road base.

The rate at which water will be drawn from Duckmaloi Weir will normally vary between 7 and 33 ML/day. The upper bound is determined by the capacity of the pipeline, and the lower bound is deemed to be the minimum at which it will be economical to operate the plant.

When the flow available from Duckmaloi Weir drops below 7 ML/day, the plant will be shut off, unless it is resolved to continue clarifying water from Oberon Dam.

The plant will be operated so that the discharge over Duckmaloi Weir does not drop below 6 ML/day. Should this discharge accidentally become less than this, an alarm will be activated. If the discharge falls further to less than 3.5 ML/day, the plant will shut down.



LAYOUT OF WATER CLARIFICATION PLANT

FIGURE F.1

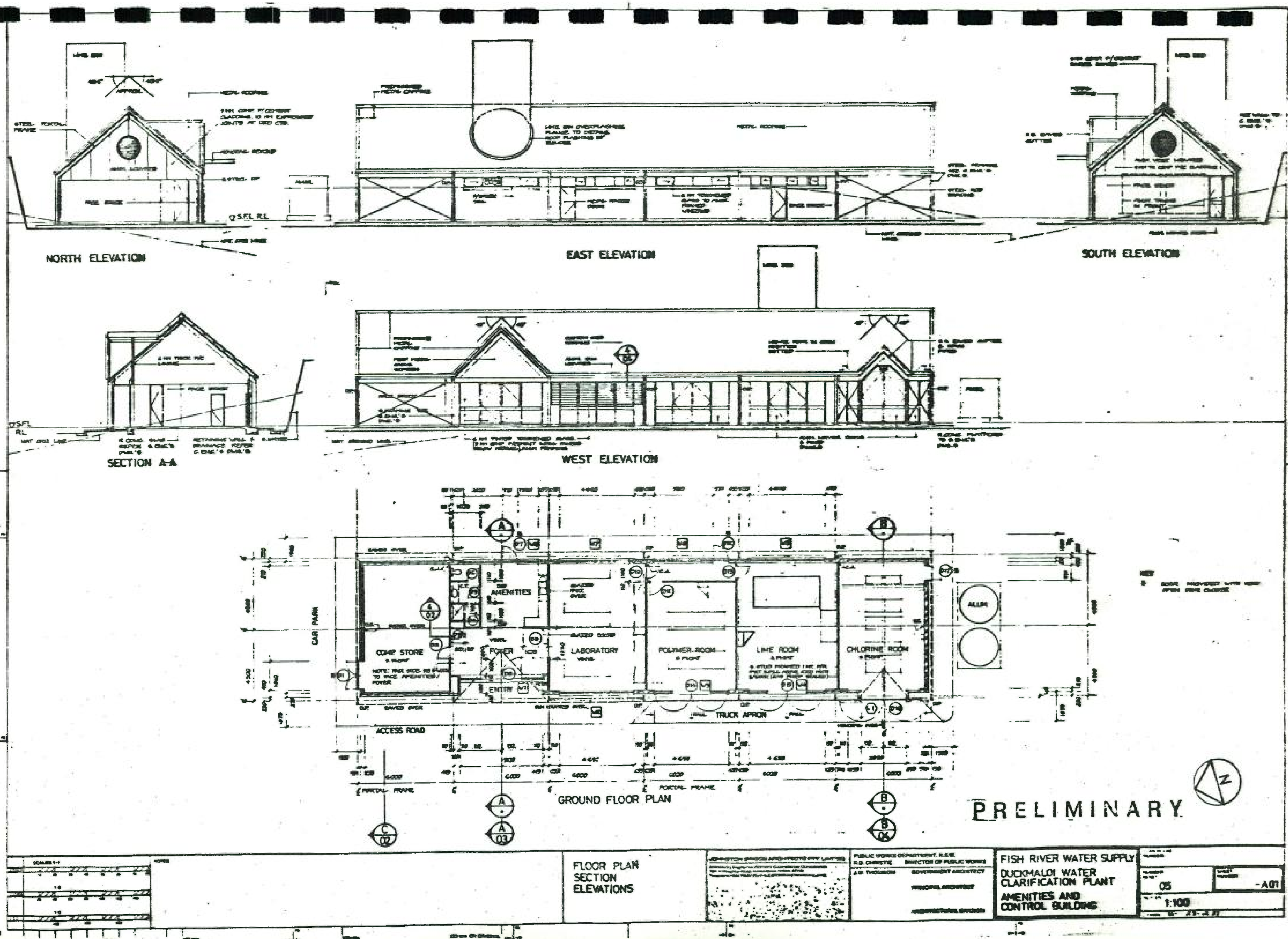

NORTH ELEVATION
EAST ELEVATION
SOUTH ELEVATION
SECTION A-A
WEST ELEVATION
STEEL PORTAL FRAME
METAL ROOFING
SFL RL
COMP STORE
AMENITIES
FOYER
ENTRY
LABORATORY
POLYMER ROOM
LIME ROOM
CHLORINE ROOM
ALUM
CAR PARK
ACCESS ROAD
TRUCK APRON
PORTAL FRAME
GROUND FLOOR PLAN
PRELIMINARY
FLOOR PLAN
SECTION
ELEVATIONS
FISH RIVER WATER SUPPLY
DUCKMALOI WATER CLARIFICATION PLANT
AMENITIES AND CONTROL BUILDING
05
A01
1:100

FIGURE F.2

APPENDIX G

ESTIMATIONS OF SAVINGS FROM

NON-STRUCTURAL MEASURES

G. ESTIMATIONS OF SAVINGS FROM NON-STRUCTURAL MEASURES

Three non-structural strategies are judged to offer direct benefits by reducing urban demand - leak detection, metering of individual consumers, and altering the tariffs to reflect a policy of paying for use.

G.1. Leak Detection

A preliminary study of the night flows in Oberon (PWD, 1987a) indicated that up to 30% of the flow was being lost in leakage. A programme of leak detection and maintenance was then initiated and savings of **50 ML/a** appear to have been made.

A leak detection programme in the Upper Blue Mountains is not judged by the **Water Board** to be economical to pursue. Studies of a leak detection programme in another of the Board's areas with similar geology indicated that only 5% of flow could be saved (Bellamy, WB, pers. comm., 1987). Likewise, tests by the **Greater Lithgow City Council** have indicated that there is little leakage in Lithgow.

Leak detection programmes in the villages of Rydal and Cullen Bullen are being considered. A nominal allowance for savings in the consumption by minor consumers is **10 ML/a.**

G.2. Metering

Anderson and others (1986) have found that when a range of country towns in N.S.W., whose climates range from semi-arid to sub-tropical, are metered, and excess water charges levied, consumption drops by 20-40%. (See also Clewett, 1986.) There are two main causes of this. Firstly, consumers become less casual about allowing wastage, such as through overwatering lawns. Secondly, people become motivated to reduce leakage, once they have to pay for excess water.

As a leak detection programme will also result in some leaks being fixed, the reduction in consumption through metering would be less than the 20-40% mentioned above, if both leak detection and metering are undertaken. A reasonable assumption therefore might be that if meters are installed in conjunction with a leak detection programme, and a tariff structure which charges for excess water is introduced, consumption might be reduced by a further 10%.

In 1986, the consumption of piped water in Greater Lithgow was 3,400 ML, of which 2,200 ML was domestic consumption. As most of the domestic consumption of Greater Lithgow is not metered, there might be a saving of around **700 ML/a** (20%) and possibly more, if meters are installed.

About 20% of the houses, shops and industrial establishments in the **Blue Mountains** are not metered, and it might be thought that the overall demand could be reduced, if these were installed. However, the consumption is already far less than for much of Sydney, around **200 kL/a** per dwelling. Since all residences have an annual allowance of **300 kL/a,** the installation of meters would have a negligible effect. Consequently, although the Board does have a policy of installing meters into all its properties, there would seem to be no reason for the Water Board to give any priority to metering the remaining areas of the Upper Blue Mountains.

All the minor consumers of the FRWS are metered.

It can be seen that if all the residential properties in Greater Lithgow are metered, it may result in reducing demand by 700 ML/a.

In addition, Council has been provided with a kit dealing with "Wise Water Use", and will be encouraged to consider a demand management programme which includes the installation of water meters.

G.3. Paying for Use

In the Hunter Valley, a change in tariffs by the Hunter District Water Board (HDWB) (Holroyd, 1986) to one which was based more on consumption than on land values was followed by a reduction in average demand of about 20% (Broad, pers. comm., 1986).

However, it may be that not all of this reduction was caused by the new pricing structure. During the period that the HDWB experienced its lessening demand, this was parallelled by a similar though smaller decrease in consumption in Greater Wollongong, even though the tariff structure had not been altered. (It should be noted that the base year for the calculations was a drought year, whereas the subsequent three years were relatively mild and wet.) If it is assumed that the causes of the drop in consumption in Wollongong also applied to the Hunter Valley, this could reduce the net savings by the HDWB to around 10-15% (Bellamy, WB, pers. comm., 1987; Anderson, PWD, pers. comm., 1987).

As it is, the decrease in consumption which could be attributed to revised pricing policy could be even less than this. Horvath (1986) has noted that when the leak detection programme in the Hunter Valley began, it became apparent that many of the meters were faulty and were reading too low. Once new meters were installed, this should have caused some of these customers to become aware that their consumptions were too high. So in part, the reduction in demand noticed by the HDWB can be attributable to installation of effective meters rather than purely the change in pricing policy.

The **Greater Lithgow City Council** and **Oberon Shire Council** charge according to the value of the property, for which the payer obtains an allowance of water whose amount varies with the total rate paid. If the allowance is exceeded, a charge is levied on the excess. **Oberon Shire Council** charges its domestic consumers for excess water at the rate of 26¢/kL, and its commercial and industrial consumers 22.5¢/kL; while the **Greater Lithgow City Council** charges its domestic consumers for excess water at the rate of 75¢/kL, its commercial customers $1.00/kL, and its industrial consumers $1.30/kL. Its single and semi-detached dwellings are not metered.

It is difficult to amend pricing in a manner which promotes the concept of paying for use, yet preserves those elements of cross-subsidisation in the water rates which have widespread communal support. If, as is presently envisaged, the Local Government Act is amended to allow a tariff to be structured along these lines, councils would have increased freedom to modify their rates so that ratepayers paid for their consumption of water. If it is assumed that consumption could be reduced by 10% by modifying tariffs in this way, this would result in savings by Oberon Shire Council of about **60 ML/a.**

In the case of **Greater Lithgow,** there should be no need to raise the tariffs charged for excess water, since they are already quite high.

The **Water Board** also charges its domestic customers a rate based on the unimproved value of the property. However, it gives each tenement a fixed allowance of 300 kL/a, and above this charges 38¢/kL. Non-domestic customers are charged a rate based on the average annual rental of the property, and for this an allowance based on the value of this rate is given. The rate for excess water is again 38¢/kL.

At present, the Board is moving towards a tariff structure which has an increasing component requiring payment for use. However, this process is likely to be gradual. Furthermore, with the average consumption by a resident in the Blue Mountains (200 kL/a) being already far less than the current allowance of 300 kL/a for the Board's residential customers, it will be a very long time before a revised tariff structure would have any appreciable influence on the consumption in the Blue Mountains.

The Fish River Scheme's minor consumers have a minimum allowance of 200 kL/a each, and are charged 32.5¢/kL for excess water. However, their average consumption is 800 kL/a, more than twice the consumption of the urban consumers supplied by the FRWS. However, most of this excess consumption is caused by only a few of the minor consumers, namely the mines and schools. It appears reasonable to assume, that if the rate for excess water was increased, say to the same as charged by GLCC, this may help reduce demand by perhaps 10% or roughly **20 ML/a.**

In summary, it would appear that some lessening of demand could result from altered tariffs which concentrate more on paying for use than now. How much these savings could be, might be as much as 20%. However, given that these reductions can often be attributed in part to other factors such as climatic variations and other, concurrent water conservation programmes, it would appear prudent to assume that savings of the order of 10% of urban consumption might be achieved. For the FRWS, this could total around **70 ML/a.**

G.4. Summary

The above assumptions have been used in the calculations of the reduction in demand, set out in Table G.1. It can be seen that a total saving of around **790 ML/a** might be attained.

TABLE G.1. REDUCTIONS IN DEMAND THROUGH NON-STRUCTURAL MEASURES

	Oberon	Lithgow	Minor Consumers	Totals
Supply from FRWS (ML/a)	600	2092	200	2900
Supply from other sources (ML/a)		1308		1308
Consumption from all sources	600	3400	200	4200
% reduction through leak detection	(already	0	5	
Years to implement	done)		2	2
Savings through leak detection (ML/a)		0	10	10
% reduction through installing meters	(already	20	(already	
Years to implement	metered)	3-5	metered)	3-5
Savings through installing meters		700		700
% reduction through tariffs	10	0	10	
Years to implement	3-5		2	3-5
Savings through pay-for-use (ML/a)	60	0	20	80
Total potential savings (ML/a)	60	700	30	790
Estimated net consumption (ML/a)	540	2700	170	3410
Total years to implement	3-5	3-5	2	3-5

APPENDIX H

ORGANISATIONS CONTACTED

H. ORGANISATONS CONTACTED

When comments were first sought from most of the organisations listed below, the preferred proposal was for a pumping station and transfer pipeline from Duckmaloi Weir to Lake Oberon, as outlined in Section 3.2.2.4 (p.26). When the WCP became the preferred option, organisations were not contacted again, unless it was apparent that the environmental effects of concern to them would increase. In the summaries of replies by organisations given below, only those comments relevant to the preferred project have been set down.

Australian Gas Light Company: No reply received.

Australian Heritage Commission: No reply received.

Australian Museum: No reply received.

Australian Mining Title Services Pty. Ltd. (for Australian Feldspar Pty. Ltd.): Comments do not relate to the currently preferred project.

Bathurst City Council: "It would appear from the context of your letter and also other information available to Council, that the proposed Scheme does not materially affect Council's operations.

"However, Bathurst City Council has consistently opposed any diversion of westward flowing water to the east. This attitude has been reinforced during the recent drought when even the amount of water diverted to Lithgow and the Blue Mountains would have been of considerable assistance to Bathurst.

"It is appreciated that the Fish River Scheme is an existing operation, but Council would be concerned at any proposal that would increase the diversion of water. It could even be argued that, in the recently completed investigation by the Department (Report No. 283), use of Fish River Dam for augmentation of Bathurst Water Supply was an option that should have been considered. This, of course would entail constructing replacement storage for Fish River Dam on an eastward flowing stream.

"Additionally, of course, Report No. 283 highlights the likely future shortfalls in availability of water for the Bathurst area."

These points are discussed in Sections 3.2.2.2 (p.24), 4.3.2.2. (p.38), and 4.3.2.3 (p.38).

Bathurst Conservation and Field Naturalist Society: No reply received.

Billiton Australia (for The Shell Company of Australia Ltd): Comments do not relate to the currently preferred project.

Blue Mountains City Council: No reply received.

Catchment Areas Protection Board: The proposal will not affect any area of protected lands. However, the Duckmaloi River is prescribed under Section 26D of the Water Act, 1912. Therefore, if any trees within the bed or 20 metres from the bank are to be destroyed or damaged, the Board's approval will be needed.

Central Acclimatisation Society: "This Society is principally concerned by the considerable increase in volume of water which it is proposed to extract from the Duckmaloi River, ie. an increase of more than twice the volume presently extracted.

"Obviously, such an increase will considerably reduce the available flow, particularly during times when maximum stream flows are required to ensure survival of the trout population downstream of the Duckmaloi Weir.

"During discussions with environmental consultant, Mr. Lustig, it was indicated that the Fisheries Division, Department of Agriculture, had indicated their belief that maximum stream flows needed to be maintained during the cooler months when trout are spawning. Presumably, their rationale is that the redds should not be unduly affected, thereby ensuring the maximum hatching of trout ova. We would argue, however, that there seems little purpose in protecting the juveniles, only to lose them, together with the adult fish, due to reduced stream flow and high water temperatures during summer.

"Additionally, the reduced flow in the Duckmaloi River will considerably affect the flow of the Fish River. (The Fish River, like the Duckmaloi, downstream of Duckmaloi Weir, is an important trout fishery.) This could, in turn affect the flow in the Macquarie River, the most significant stream in this region, which gains much of its flow from the Fish River, particularly during summer.

"This matter is complex; the Macquarie, formed at the confluence of the Fish and Campbells Rivers, is already under considerable stress, due to the abstraction of much of its flow for irrigation purposes and Bathurst's domestic needs. Whilst the flow of the Campbells River is regulated by discharge from Ben Chifley Dam, the discharges are kept to the absolute minimum, by utilising the flow from the Fish River. In any case, the situation is becoming increasingly serious - Bathurst City Council is proceeding with the introduction of a Volumetric Allocation Scheme, but little regard is being paid to the environmental consequences resulting from increased demands upon the system, which are our concern, principally the effects of reduced stream flows.

"The proposed increase in extraction from the Duckmaloi River will only serve to exacerbate ~~the~~ situation, which has only fleetingly been referred to above. However, one of the consequences is that it will severely affect the efforts of the Bathurst Branch of this Society in its efforts to re-establish native fishes in the Macquarie River system.

"Returning to the Duckmaloi, the immediate effect of reduced stream flow will be to place the trout population downstream of the weir under considerable threat, particularly during summer when it is likely the greatest demand could be expected to be placed upon the water supply.

"Unfortunately, any reduced flow and subsequent increase in water temperature would not make the stream suitable for native fishes, principally because the species which might be available for public stockings, Murray cod, golden and silver perch, would not really be suitable, as all, besides requiring higher water temperatures than are generally experienced at the altitude of the area in question, require deeper holes than are now found in many of the streams in this area, especially upstream of Bathurst. The only native species of interest to recreational anglers likely to be suitable to the existing stream environment or an altered environment, are Macquarie perch and trout cod. However, the latter species, trout cod, are endangered and despite current attempts to breed them at the Inland Fisheries Research Station, Narrandera, many problems remain to be overcome before they are likely to be available, let alone considered for stocking of streams. In the case of Macquarie perch, although not as threatened as trout cod, their range (as far as is known they were never found north of the Abercrombie River), and attempts to artificially rear them at the Inland Fisheries Research Station have been unsuccessful. When the problem of artificially breeding Macquarie perch is overcome, there will still remain unresolved, the possibility that they may not be allowed to be liberated because of restrictions of translocation of species.

"The conclusion to be reached is that because of the altered stream environment, the only species of fish which are of interest to recreational anglers, are suited to the stream conditions and are presently available, trout, could be seriously affected by the proposal."

These points are discussed in Sections 4.3.4 (p.43) and Appendices I and K.

Crown Lands Office: Access along Crown Roads should not be impeded.

Department of Agriculture: "The streams in the region are all gazetted trout waters and therefore demand special protection. Brown trout, rainbow trout, and freshwater blackfish are the major angling species found in the area.

"The proposed augmentation involves pumping water out of the weir on the Duckmaloi River into Oberon Dam. Thus, not only will there be reduced flow in that stretch of the Duckmaloi River between the weir and Duckmaloi Junction but there will be a consequent reduction in the input of the Duckmaloi River to the Fish River.

"Both streams, especially the Fish River below Duckmaloi Junction, are important trout fisheries. Trout grow moderately well, but generally do not breed, in the Duckmaloi River beween the weir and Duckmaloi Junction and in the Fish River between Duckmaloi Junction and the township of Tarana. While these sections of the streams therefore do not require the high flows normally necessary for spawning, they do need assured maintenance flows.

"Analysis of Water Resources Commission streamflow data indicates that flows in the Duckmaloi River from Duckmaloi Weir to

Duckmaloi Junction, suitable for maintaining good trout habitat and allowing migration, should approximate 11 ML/day. It appears likely that a flow of this size below the weir would be sufficient to ensure fair habitat maintenance flows as far downstream in the Fish River as Tarana.

"Maintenance of fish populations would therefore require that water should not be pumped from Duckmaloi Weir if it would cause the flow immediately downstream of the weir to fall below an instantaneous value of 11 ML/day. It is understood that pumping a large volume in a short time is the most efficient method of water transfer, that pumping will therefore be confined to high flows, and that it is expected to abstract 2000-3000 ML per year (some 15% of the average catchment yield). Accordingly, our requirement should not adversely affect the scheme."

Following further discussions with Fisheries Division (Tom Johnson, 1987), its requirement for downstream releases was modified to:-

December-June	5 ML/day
July-November	20 ML/day

unless the inflow was less. The 20 ML/day was to allow winter migration, and this was expected to ensure there was a suitable habitat for trout as far downstream as Tarana.

Since then, there have been numerous discussions with officers of Fisheries Division during the course of this study.

These points are discussed in Section 4.3.4 (p.43) and Appendices I and K.

Department of Environment and Planning: Agreed that the issues outlined in the PWD's letter are the ones of major significance. (These were: the need for this project; the transfer of water from west to east; how any reduction of flow downstream would affect the trout and native fish; and the effects on the platypus.) Details of statutory requirements for the Environmental Impact Statement were provided. (However, since the preferred option does not have a significant effect, this document has not been issued as an EIS.)

Department of Health: Satisfied that there are no public health problems of significance associated with this proposal.

Department of Industrial Development and Decentralisation: No reply received.

Department of Leisure, Sport and Tourism: No reply recived.

Department of Local Government and Lands: No reply received.

Department of Main Roads: No surface structures should be located within existing main road reserves. No hazard to traffic is to be created during construction, and any damage to road pavements should be satisfactorily restored.

Department of Mineral Resources: No objections.

Department of Water Resources: (formerly known as the Water Resources Commission): "The Commission has reviewed the details of the proposed works and has no objection to the proposal. Further the Commission considers that the proposal would not conflict unreasonably with downstream water users provided the following flows are allowed to pass the Duckmaloi River gauge, whilst the pump is in operation:-

(i) a flow of 2.0 megalitres per day during the months of September to April inclusive; and

(ii) a flow of 0.5 megalitres per day during the months of May to August inclusive.

"In addition to the flows for downstream users, the Commission would expect the Department to consider and, if necessary, estimate in its Review, the size of any additional flows which may be required for downstream environmental or instream needs. Consultation with the Division of Fisheries, Department of Agriculture and the National Parks and Wildlife Service may assist the Department in its assessment of downstream environmental or instream needs."

These points are discussed in Sections 4.3.4 (p.43) and 4.3.2 (p.38), and Appendices I and K.

Duval Mining Australia Pty. Ltd.: No reply received.

Electricity Commission of N.S.W.: No objections.

Forestry Commision of N.S.W.: Not affected.

Friends of the Macquarie: No direct correspondence received, but in a letter to Bathurst City Council, concern was expressed about diverting extra water from west to east of the Dividing Range.

This point is discussed in Section 4.3.2 (p.38).

Goldfields Exploration (for Renison Ltd.): No reply received.

Greater Lithgow City Council: No reply received.

Heritage Council of N.S.W.: No reply received.

Maritime Services Board: Comments not relevant to preferred option.

Ministry of Transport: No matters of concern to Ministry.

National Parks and Wildlife Service: No objections provided that:-

(i) if any aboriginal relics are found during construction the Senior archaeologist is to be contacted; and

(ii) PWD takes ameliorative measures to ensure the survival of the Platypus population in Duckmaloi Weir. The Service recommended the engagement of Dr. D. Goldney for the platypus studies.

These points are discussed in Sections 4.3.5 (p.47) and 4.4 (p.48), and Appendices J and L.

National Parks Association: No reply received, but in earlier comments on long-term augmentation strategies for the FRWS, the Association wrote that it is unacceptable to place further demands on the water resources of the Macquarie Valley, when eastward-flowing sources are available. It stated that the Macquarie Marshes are already degraded by Burrendong Dam, and irrigators on the Macquarie face economic hardships because of inadequate water supplies during dry years. The principle of pay-for-use should be applied to encourage careful use by urban users.

These points are discussed in Sections 3.2.1.4 (p.21) and 4.3.2 (p.38).

National Trust: Visual qualities should be taken into account and wetland areas avoided. Impact on trees should be minimised and the working area should be fenced to prevent damage to trees and to prevent compaction of the earth around the bases of trees.

These points are discussed in Section 4.3.3 (p.40).

Nature Conservation Council of N.S.W.: "The Nature Conservation Council of New South Wales presents the following comments on the proposal.

"1. The current proposal to increase the rate of extraction from 1200 ML/a to an average of 3800 ML/a will reduce the total volume of water flowing downstream from the Weir.

"As reductions in volume will decrease flow rates and peaks, both of which are important in maintaining the natural environment of any river, the Nature Conservation Council sees the need to determine how reduced volumes and therefore flow rates and peaks will affect the health of the Duckmaloi River's ecosystems. Specifically, the impact on native aquatic life, particularly native fish and platypus populations, needs to be determined.

"The Nature Conservation Council strongly urges waterway management which protects the capacities of rivers, creeks and wetlands to support their dependent indigenous flora and fauna. Council believes this principle has not always been upheld in the past. For example, Council understands that current water extraction practices may have been favourable to exotic fish such as trout, at the expense of native fish. Council therefore urges very strongly a thorough investigation of the effects of existing and proposed operations on native aquatic organisms. It is most important that whatever rules for downstream water release are adopted, these should not favour exotic fish at the expense of native fish, Thorough study of the system is necessary to enable any modelling and/or predictive work, so as to be able to devise and implement downstream release rules which favour native fish and aquatic life over exotic species.

"The likelihood of eutrophic algal growth, commonly associated with nutrient-rich, low flow streams, should be investigated as part of these studies.

"2. The Nature Conservation Council notes that water diversions east to west or west to east are likely to have significant effects on aquatic and surrounding environments on either side of the diversion. Such projects should not be undertaken without a full study identifying all possible environmental consequences, and should not be proceeded with where adverse environmental effects are possible. Adverse impacts may occur along the river in locations quite remote from the actual diversion site.

"3. The Nature Conservation Council understands that the works associated with the pumping station will require that the weir be emptied for approximately one week. As the weir supports a significant population of platypus, the NCC would be concerned that the greatest care be taken not to jeopardise the viability or stability of the population. The NCC would suggest that Dr David Goldney of Mitchell C.A.E., be employed to continually monitor the status of the platypus population prior to, during, and after the drainage operation.

"4. The NCC would like to see a more detailed study of water supply and usage in the catchment completed. Such studies would be most appropriately undertaken through the Environmental Planning and Assessment Act as a Regional Environmental Study which would be followed by a Regional Environmental Plan (REP) for the catchment."

These points are discussed in Sections 3.2. (p.19), 4.3.1 (p.32), 4.3.2 (p.38), and 4.3.4 (p.43), and Appendices I and K.

Oberon Shire Council: No comments on environmental issues. Council asked on behalf of affected landowners that there be prompt settlement of any compensation claims.

Soil Conservation Service: The issues of soil management and drainage control during construction and operation of the proposal should be addressed. Particular attention should be given to temporary and permanent access tracks. Where pipelines are laid, it should be ensured that there is no concentration of runoff along the trenches. Topsoil should be removed and stockpiled separately during construction, and respread and revegetated as soon as construction is complete.

The Duckmaloi River is a Prescribed Stream under Section 26D of the Water Act, and the destruction or injury of trees in the bed, or within 20 metres of the banks will require the authority of the Catchment Areas Protection Board.

The first paragraph is noted in Section 4.3.3.2 (p.42)

State Pollution Control Commission: No reply received.

Telecom Australia: No reply received.

Total Environment Centre: "As discussed with your officers previously we believe that crucial elements of any Environmental Impact Study, in addition to environmental surveys, should be:

(i) development and computer testing of a water management plan, with a commitment to agreement as to water allocations, before construction;

(ii) investigation of a plan to revegetate the catchment to improve the quality abd duration of flows, in the medium term, perhaps in conjunction with a regional environmental plan;

(iii) assessment of wild, scenic and river values."

These points are discussed in Sections 3.2.1.5. (p.22), 3.2.2. (p.23), and 4.3.3.1 (p.40).

Tourism Commission: Proposal will have no significant implications for tourism in the area.

Water Board: No comment.

Wentworth Falls Angling Society (affiliated to the Central Acclimatisation Society): "Members of the society are somewhat dismayed to hear of the proposal to increase the volume of water removed from the Duckmaloi River to supplement the storage of Oberon Dam.

"The following reasons are tendered:

(a) The Duckmaloi River represents the premier trout stream in the Central Tablelands because of relatively easy access from the Hampton/Oberon roadbridge, Oberon/Edith roadbridge and the road to its junction with the Fish River. Access is also available from the pine plantations to the east and to a public recreation spot downstream from the current weir.

(b) Water flow although reduced below the weir is currently sufficient to sustain the fish population downstream. Even during marginal times eg. during the recent drought, the greatly reduced water flow was just sufficient for survival of the fish. At this time, only the mainstream of the river contained sufficient water to allow the fish to spawn. If additional water were to be pumped from the river to meet consumer demands during such periods then the majority of the fish (and platypus) population would perish.

(c) The lowest section of the river has a marginal environment for Rainbow trout. However, the Brown trout population is self-generating in most circumstances. To our knowledge, stocking with Brown trout has not taken place for many years but Brown trout represent the majority of fish caught below the weir.

The Duckmaloi River will not support a native fish population under current or reduced water flow conditions.

(d) During the drought the Trout population was struck by attacks from a parasitic worm. This was attributed in part to the low water flow concentrating the fish into certain areas allowing ready access to the population. All legal sized fish contained these worms during this period.

Since the flow has increased, the number of affected fish appears to have decreased slightly in fish catches. Reduced water flow may reverse this trend and cause additional stress in a high stress, low water situation. The full effects of parasitic worms on Trout is not known at this stage.

(e) Over the years, the Duckmaloi River has built up a reputation throughout Australia as a quality Trout stream holding good populations of fish in beautiful surroundings. The river is mentioned in several Angling books written on fishing in NSW.

No other river in the Central Tablelands fulfills the requirement of good fish populations as well as easy access over the entire length of the river.

(g) It is understood that Bathurst City uses the water flow from the lower Fish River as a major portion of its water supply, The Duckmaloi River is the major tributary of the Fish River and the effects of reduced flow of water to Bathurst City would be vast.

(h) And lastly, the quantity of water required to supplement the Oberon Supply would significantly reduce the flow below the weir. Even, if the complete requirement was not removed it would be difficult to assess the most opportune time to pump out water that would minimally affect aquatic life downstream. In addition, water demand would be greatest during low rainfall periods and this would be the occasion when reduced flow would cause the most damage."

These points are discussed in Sections 4.3.2.3 (p.38), and 4.3.4 (p.43), and Appendices I and K.

Windradyne Local Aboriginal Land Council: The concurrence of this council was sought to the archaological report (Appendix L). No reply has been received.

APPENDIX I

AQUATIC ECOLOGY

I. AQUATIC ECOLOGY

(prepared by W.S. Rooney and Assoc. Pty. Ltd.)

I.1. Introduction

This Appendix describes the ecological studies conducted as part of this EIA, and discusses the impacts of the proposal on the aquatic ecosystem. There is also a discussion of the water quality of the Duckmaloi River, with particular reference to dissolved oxygen characteristics.

The Duckmaloi River supports a reasonably large population of platypus (refer to Appendix J of this EIA), and is therefore of value as a habitat for this unique species. Furthermore, this stream is a recognised trout fishing stream and thus has sport recreational value. The weir has created an ideal habitat for both of these species within the impoundment.

The purpose of our investigation was to, firstly, determine the variety and richness of aquatic life within the stretch of river considered likely to be affected by the proposal, and secondly, to attempt to assess the effect on this ecosystem of a reduction in flow of the river below the weir. The ultimate objective of the study was to estimate the minimum flow over the weir which would satisfy the instream requirements of the river between the weir and McKeons Creek.

I.1.1. Study Area

The study area was restricted to the impoundment behind the weir and the three-kilometre reach of river immediately below the weir, down to the junction of McKeons Creek with the Duckmaloi River. The study area, shown in Figure I.1, is at latitude 33°45', longitude 149°56' and at an altitude of 1060 m.

The greatest impact of reduced water flow would be felt between the weir and the first permanent downstream input of significant surface flow, which is Teatree Creek, about 1.6 kilometres downstream of the weir. However, Teatree Creek can be reduced to a trickle during drought, so the next confluence, McKeons Creek, about 1.4 km. further downstream, is regarded as an essential input for the maintenance of sufficient flow.

This three-kilometre section of river was categorised into habitat types and each different habitat was semi-quantitatively sampled for fish and qualitatively sampled for invertebrate life.

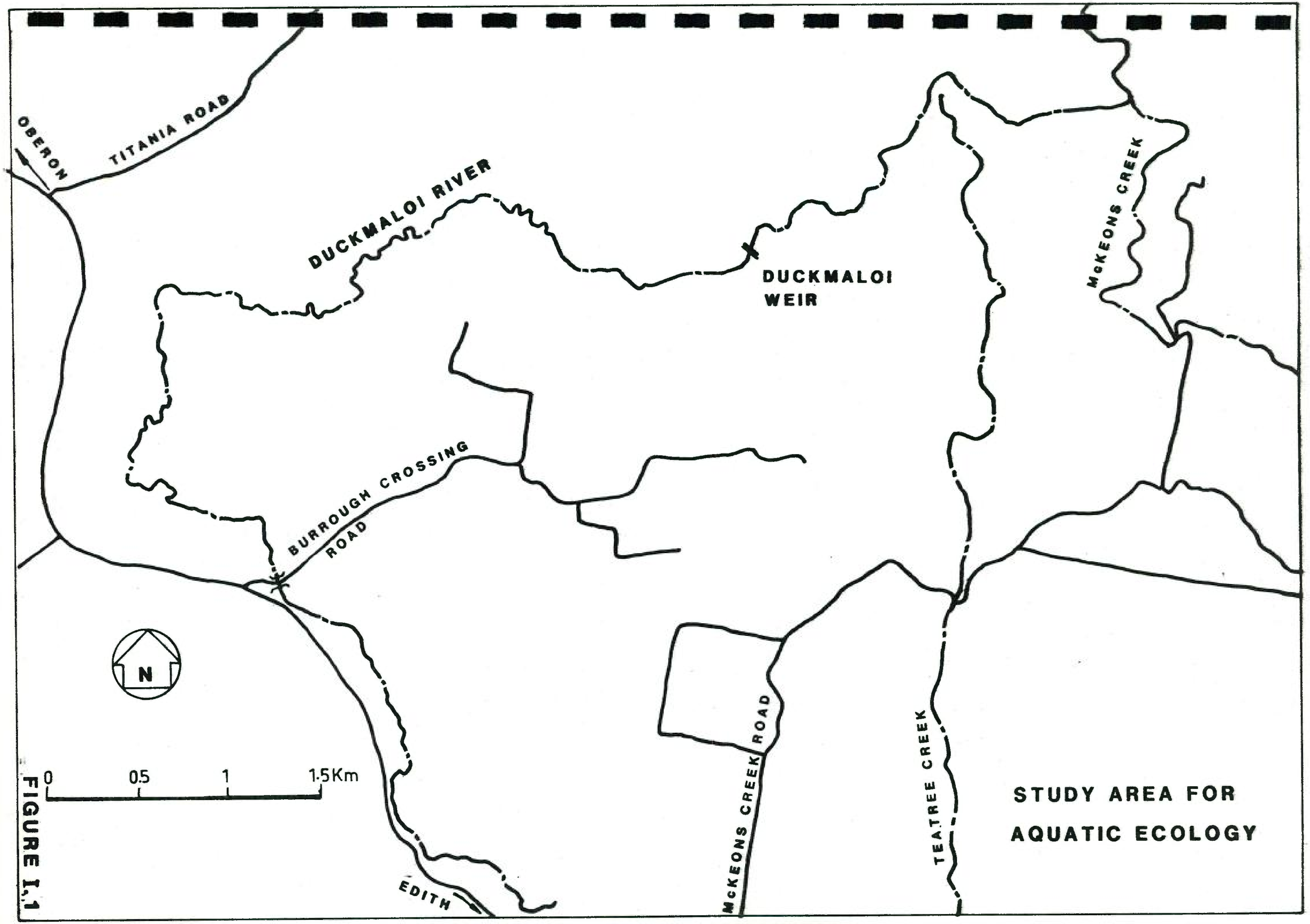


FIGURE 1.1

STUDY AREA FOR AQUATIC ECOLOGY

I.1.2. Scope of Work

The ecological assessment consisted of a review of relevant literature, discussion with representatives of the amateur fishing group and state government fisheries biologists, and two field trips to the study area, each of a week duration.

The first field trip, in January, 1987, was intended to sample the diversity of aquatic life found in the river and the weir. This was achieved by:

- intensively sampling fish within seven pools using electrofishing equipment and an icthyocide (rotenone);
- dip net samples of several pools and riffles for invertebrates;
- sediment cores in the mud/sand substrate of the impoundment behind the weir to analyse for benthic macroinvertebrates;
- visual observation;
- collection of water samples for chemical and biological analysis.

The second field trip, in February, 1987 was designed to simulate drought conditions by manipulating the flow over the weir and observing the effects downstream. Diurnal oxygen and pH profiles were monitored downstream of the weir during the experiment.

I.2. Results

I.2.1. Fish in the Duckmaloi River Below the Weir

The fish sampling program yielded only three species; rainbow trout (**Salmo gairdneri**), brown trout (**Salmo trutta**), and mountain galaxias (**Galaxias olidus**). Body length from tip of snout to caudal fork was recorded for each fish caught; weight was recorded from a subsample of each size class and for all legal size trout. All large trout and a subsample of galaxias were examined for parasites. Full details of the results are tabulated in Appendix I.A.

Seven sites, representing the range of fish habitat found within the study area, were chosen for sampling. These sampling sites are shown on Figure I.2 and are described as follows:

Pool I: shallow s-shaped pool (max. depth 0.3m) with gravel bottom, shaded and some instream log cover; riffles up and downstream; no steep or undercut banks. 15 m long x 3 m wide = 45 m^2

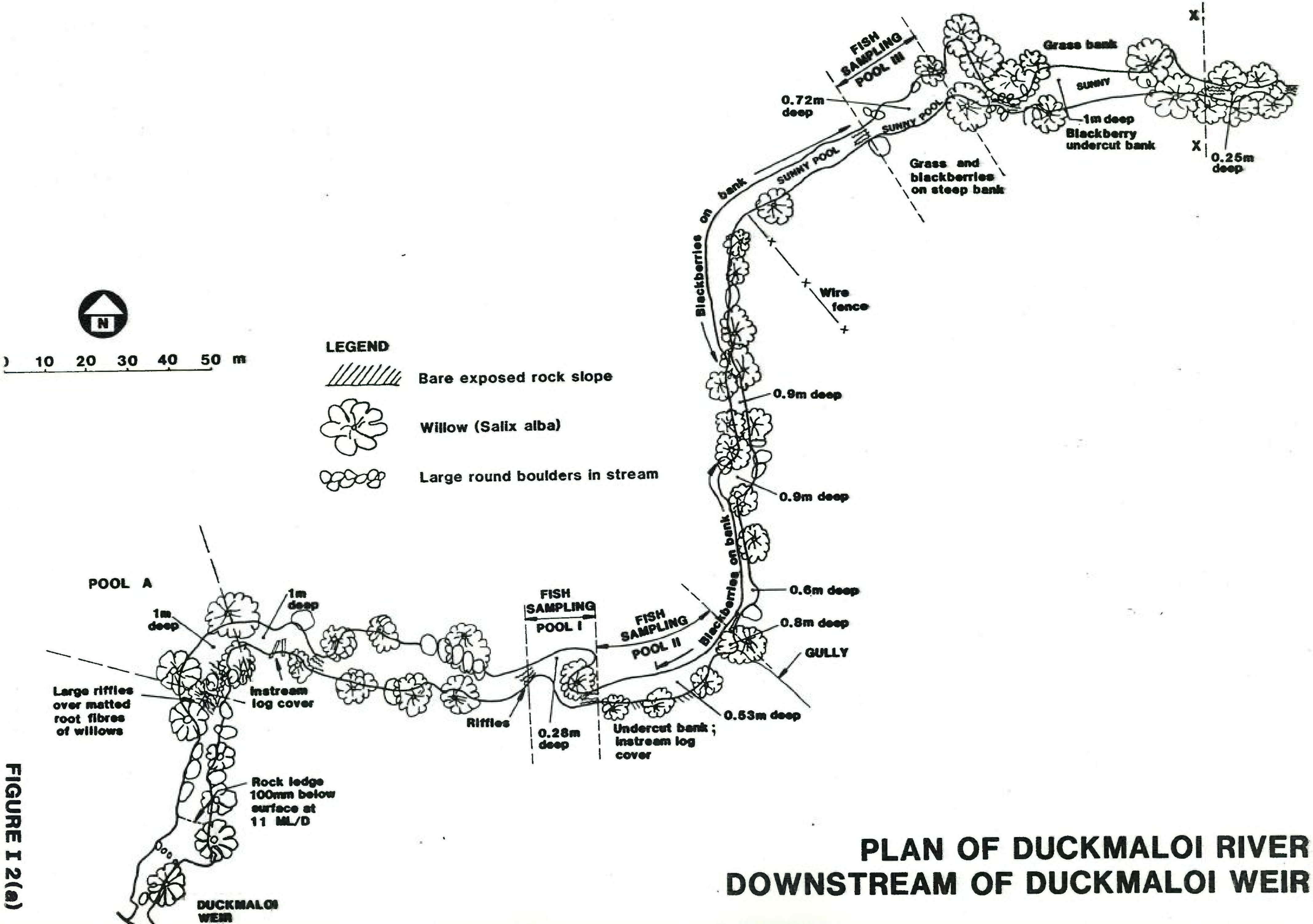


FIGURE I 2(a)

PLAN OF DUCKMALOI RIVER DOWNSTREAM OF DUCKMALOI WEIR

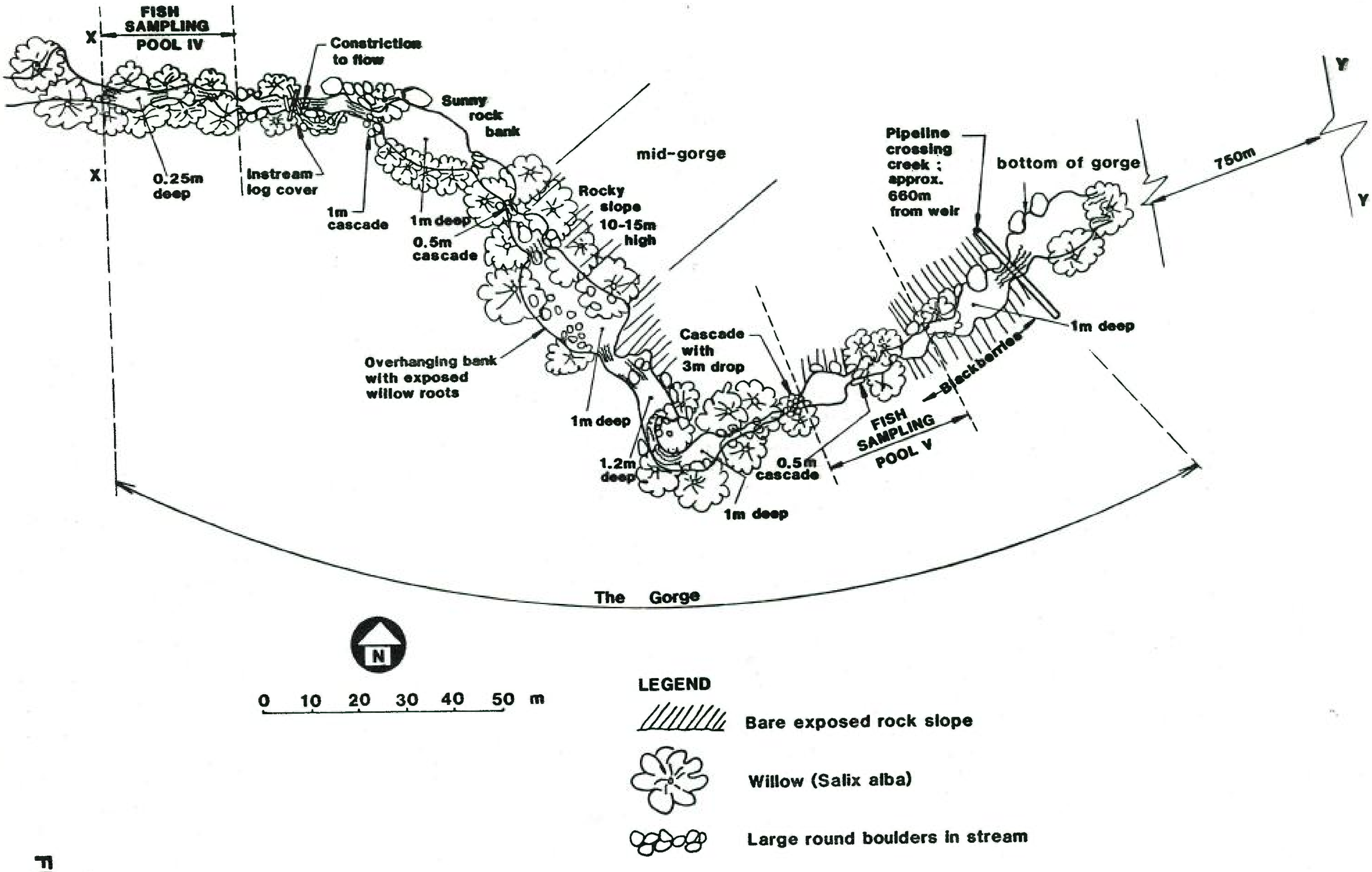


FIGURE I 2(b)

PLAN OF DUCKMALOI RIVER DOWNSTREAM OF DUCKMALOI WEIR

NOTE:

STREAM DEPTHS ARE MAXIMUM FOR EACH POOL

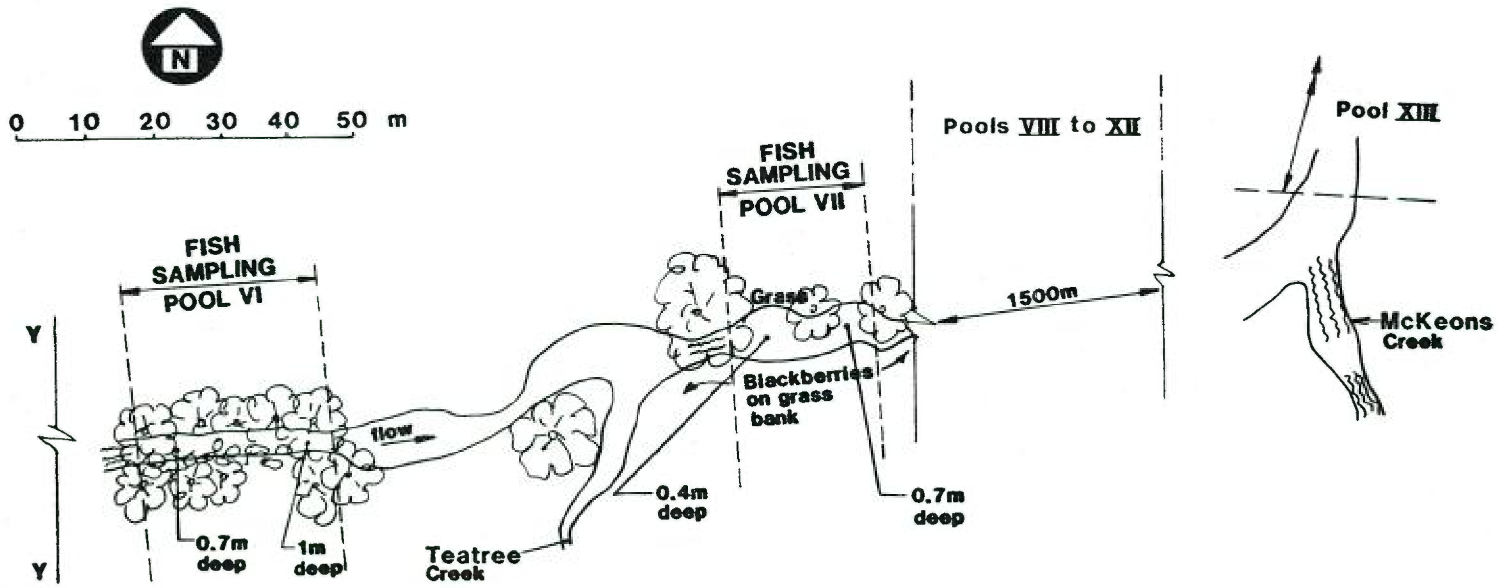


FIGURE I 2(c)

PLAN OF DUCKMALOI RIVER DOWNSTREAM OF DUCKMALOI WEIR

Pool II: moderately deep channelised area (max. depth 0.8 m) immediately below Pool I, with gravel bottom; shaded; some instream log cover; riffles up and downstream; undercut bank on south bank. 36 m long x 5 m wide = 180 m^2

Pool III: moderately deep pool (max. depth 0.7 m), with rock-boulder bottom; grassy bank with sunny exposure. North bank gently sloping to water; south bank steep and high with blackberries mixed with grasses. 22 m long x 8 m wide = 176 m^2

Pool IV: series of shallow pools (max. depth 0.3 m) and riffles; rocky boulder bottom and banks with willow root mats in riffles and some banks; shaded; fast flowing over rocks with a vertical drop of >1m over the length of the pool. 27 m long x 3 m wide(ave.) = 81 m^2

Pool V: The Gorge. Series of moderately deep pools (max. depth 0.7 m) and cascades through large granite boulders and bedrock outcrop; moderately shaded; steep rocky banks; rock bottom. 23 m long x 5 m wide(ave.) = 115m^2

Pool VI: deep channelised pool (max. depth 1.0 m); well shaded with overhanging willows; no riffles; rocky bottom with fairly uniform depth (0.7 - 1.0 m). 28.5 m long x 3.5 m wide = 100 m^2

Pool VII: shallow channelised pool (max. depth 0.4 m); solid rock bottom grading to 0.7 m-deep gravel bottom; predominantly exposed to sun; 3 overhanging willows on north bank; rock riffles (0.2 m deep) on upstream end. South bank: blackberries on grass bank. 20 m below junction of Teatree Creek. 24 m long x 4 m wide = 96 m^2

Fish sampling was by means of electrofisher, which stunned the fish long enough to measure length and weight before returning them to the river where they fully recovered. Three passes were made through each selected pool with the electrofisher; the catch results are summarised in Appendix I.A.

We tested for sampling error by removing all fish from a 10m section of the river immediately after electrofishing. This was done by blocking the river to fish movement using stop nets up- and downstream immediately after electrofishing, and applying a measured quantity of the selective icthyocide rotenone. After one hour 26 small galaxias, with a total biomass (wet weight) of 43 grams, were collected. Compared with the data collected by electrofisher, we interpret the results to suggest that electrofishing collected about half of the smaller fish numbers, but was successful in collecting all of the larger fish and about 85 percent of the total fish biomass in a given stretch of river. From that indication of sampling success it is possible to roughly estimate fish abundance and biomass in each pool,and very coarsely, in the three kilometre stretch of river under study. These estimates are provided in Table I.1.

A neutralising barrier of potassium permanganate was spread across the downstream stop net during the rotenone application to ensure that minimal damage was caused to fish downstream. Careful observation for two hours following the test yielded a total of 20 galaxias, 2 rainbow trout (both less than 150 mm long) and one brown trout (about 175 mm long) downstream of the net. Thus, only slight impact was observed downstream and the sampling methods were considered to be environmentally benign.

Table I.1. Estimate of Fish Abundance and Biomass in Various Pool Habitats

Pool No.	Total No. of galaxias caught	Estimate of total no. of fish in pool	Estimate of abundance (No./m²)	Measured biomass (g/m²)	Estimate of total biomass in pool (g/m²)
Pool I (45m²)	5	10+9=19	0.42	1.6	1.9
Pool II (180 m²)	27	54+6=60	0.33	4.0	4.7
Pool III (176 m²)	27	54+7=61	0.35	0.5	0.6
Pool IV (81 m²)	27	54+25=79	0.98	4.1	4.8
Pool V (115 m²)	4	8+11=19	0.17	5.5	6.4
Pool VI (100 m²)	39	78+4=82	0.82	6.1	7.2
Pool VI (96 m²)	52	104+2=106	1.1	1.0	1.2

In order to estimate the fish productivity of the study area we must first assume that the area of pool types sampled is roughly proportional to the habitat types within the study area. Using the average biomass and abundance data from Table I.1, and assuming an average stream width of five metres, it could be roughly estimated that there are in the order of 9000 fish (mainly galaxias) with a biomass of about 49 kg in the three kilometre section of river from the weir to McKeons Creek.

Table I.1 shows that the abundance of fish in the gorge area is low compared to the other sites, but high in total fish biomass. It is suggested that this is due to the fact that the gorge is a preferred trout habitat. Eleven trout were caught, including the largest trout caught during the survey (refer to Appendix I.A for details). The pools in the gorge are somewhat isolated from one another during periods of low flow and it is felt that the trout prey upon the galaxias, which cannot readily escape. Furthermore, there is little other invertebrate food in this area, as is found in riffles or sand substrates; the large clean rock substrate is not well suited as an invertebrate habitat. Therefore, the number of galaxias is much reduced. This native species is the dominant fish in all other habitats and has the greatest influence on fish abundance.

Pool IV (a series of shallow pools and riffles) was another site favoured by juvenile trout, although not by large trout, probably because of the small wetted area and shallow depth.

Although no quantitative sampling was carried out in the weir, many large trout were observed surfacing to feed on insects at dusk; many were also caught in the gill nets set for platypus. Thus, the weir has provided considerable new habitat for trout (and platypus, according to the results from Goldney - Section J)

I.2.2. Invertebrates from the Duckmaloi River and Weir

Qualitative sampling by dip net in pools and riffles downstream of the weir yielded the animals in Appendix I.B. In each pool or riffle the catch effort was standardised to five minutes per site. In the case of pools, the dip net was continuously moved around the edges and bottom of the pool for five minutes. In riffles, the dip net was positioned downstream of a person trampling and disturbing the willow root mat and stones which formed the riffle. Disturbance continued for five minutes.

Samples were also collected from the weir impoundment. Three passes of the dip net were made along the grassy bank adjacent to core Station 1 (see Figure I.3) for a distance of five metres. Each replicate pass was along the same section of shoreline. Results are also provided in Appendix I.B. It was visually estimated at the time of collection that about half of the total invertebrate biomass was collected after three passes. Each pass produced about the same volume of biomass, suggesting no tapering off of catch/unit effort after three passes. Based on the data from Appendix I.B, we estimate over 1000 insects/m^2 of grassy shoreline in the weir.

Finally, sediment cores were taken from two locations within the impoundment, shown on Figure I.3. Four replicate cores, each 10 cm deep and 0.03 m^2 in area, were taken at each station, giving a total sample area of 0.126 m^2 per station. Station 1 was in coarse sand with some silt in a water depth of 0.3 m; Station 2 was in fine mud in 0.4 m of water. All cores were immediately sieved on site through a 1 mm sieve and all organisms retained were counted and identified.

The results show that the grassy shoreline of the weir was, by far, the richest locality within the entire study area in terms of invertebrate biomass, and numbers of individuals and species, yielding 2876 individuals from 29 species (refer to Appendix I.B). Furthermore, the coarse sand adjacent to the grassy shoreline was the next most productive habitat. The sandy sediment cores contained a total of 1116 individuals from 18 species, although the fine mud in the backflow area was almost devoid of life, with a total of only 33 individuals from four species. Clearly, ample food supply exists along the grassy margin of the weir for many fish and platypus.

Within the habitat downstream of the weir, the riffles clearly contained more animal numbers and variety than the pools: the riffles averaged 140 individuals in 19 species per sample; the pools averaged only 8 individuals in 5 species per sample (refer to Appendix I.B). This coincides with published reports from overseas studies which claim that riffles are the most productive part of a flowing stream (e.g. Blyth, 1980; Wesche, 1976). Therefore, riffles are the most important food source for fish, platypus, birds and other members of the food web. Riffle areas must be kept wet and viable so that a continuum is maintained from pool to riffle to pool and so on along the stream length. If flow is reduced to a point where the wetted surface area of

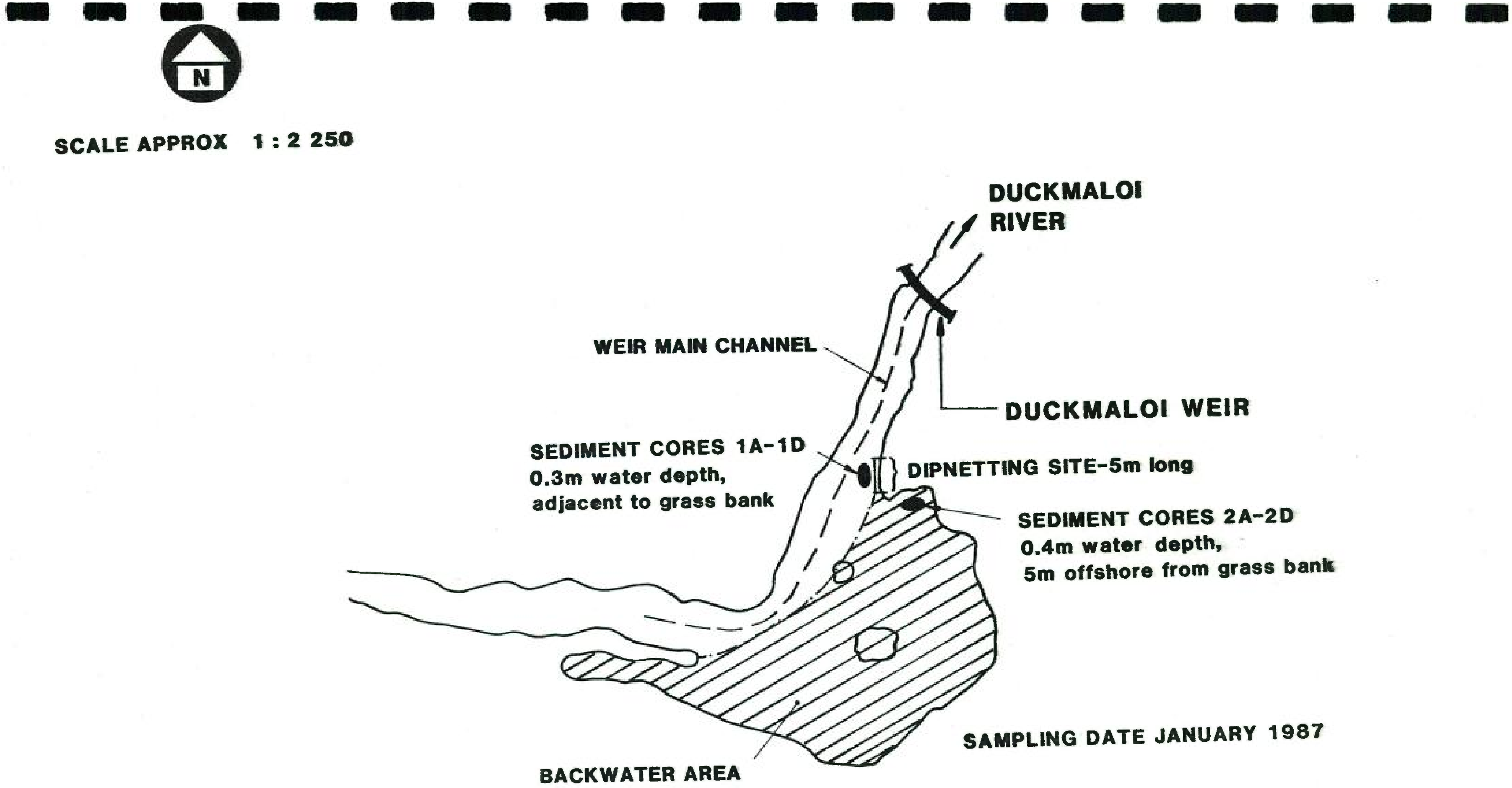


FIGURE 13

LOCATION OF AQUATIC INVERTEBRATE SAMPLING SITES IN DUCKMALOI WEIR riffles begins to decrease significantly, then severe degradation, and eventual collapse of the aquatic ecosystem, will result. This is discussed further in Section 3.

I.2.3. Water Quality in the Duckmaloi River and Weir

Water samples were collected from various locations and at different times during the course of this study and tested by the Department of Health or a commercial NATA-registered laboratory. All results are presented in Table I.2. The Public Works Department (PWD) has been monitoring water quality on a monthly basis at the weir for several years. Summary graphs of their data are shown in Figures I.4-I.10.

TABLE I.2. WATER QUALITY DATA FROM DUCKMALOI RIVER AND WEIR

(Summer 1986/87)

	4/12/86 Duckmaloi below weir	4/12/86 Duckmaloi Burroughs Crossing	4/12/86 Duckmaloi Weir surface	4/12/86 Duckmaloi above Teatree
Specific conductance	50	52.1	53.2	53.7
pH	7.4	7.2	6.8	7.4
Nitrate (mg/L as N)	0.62	0.58	0.25	0.42
Total reactive P (ug/L)	10	21	7	10
Alkalinity as CaCO3 (mg/L)	17.7			
Total hardness as CaCO3 (mg/L)	21			
Kjeldahl nitrogen (mg/L as N)	0.4	0.8		
Non-filtrable residue (mg/L)	5	2	<1	2
Chemical oxygen demand	29	59		

	5/12/86 Teatree Creek	5/12/86 McKeons Creek	9/12/86 Duckmaloi Weir (WB)	6/1/87 Duckmaloi Weir (WB)
Colour			80	100
Turbidity (NTU)			12.6	8.9
Specific conductance	40.5	30.1		
pH	7.2	7.1	7.1	7.0
Nitrate (mg/L as N)	1.23	0.54		
Total reactive P (mg/L)	0.011	0.017		
Chloride (mg/L)				4
Alkalinity as CaCO3 (mg/L)	7.6	4.9	24	27
Total hardness as CaCO3 (mg/L)	15.5	12.5	27	28
Kjeldahl nitrogen (mg/L as N)	0.5	0.4		
Iron (mg/L)			1.19	1.27
Chlorophyll a (mg/m3)			2.49	
Non-filtrable residue (mg/L)	6	2		
Chemical oxygen demand	27	8		

TABLE I.2. (cont.)

	19/1/87 Duckmaloi Weir (WB)	1/2/87 Duckmaloi Weir	1/2/87 Duckmaloi River Pool 1	1/2/87 Duckmaloi River Pool 5
Total reactive P (mg/L)		0.052	0.029	0.028
Kjeldahl nitrogen (mg/L as N)	0.71	0.50	0.45	
Chlorophyll a (mg/m3)	12.67	7.2		1.1
Pheophytin a (mg/m3)		7.6		1.7
Non-filtrable residue (mg/L)	6	3	3	
Algal count (cells/ml)				
- total count		4,130		
- Cryptomonas		1,310		
- Trachelomonas		1,030		
- Chroomonas		590		
- Navicula		490		

	13/2/87 Duckmaloi River below weir
Total reactive P (mg/L)	0.037
Kjeldahl nitrogen (mg/L as N)	1.17

Probably the most important water quality parameters in terms of fish requirements are dissolved oxygen and temperature. These are the parameters most sensitive to fluctuations in flow, and there is an inverse relationship between oxygen content and temperature. As flow drops, temperature rises due to slower movement through sunny areas, over warm rocks, and greater penetration of the sun's heat. At 10°C fresh water can dissolve over 11 mg/L of oxygen by normal mechanical aeration, whereas at 20°C, the same water is saturated at about 9 mg/L. At 25°C about 8 mg/L can normally be dissolved; this is the lower limit for trout breeding.

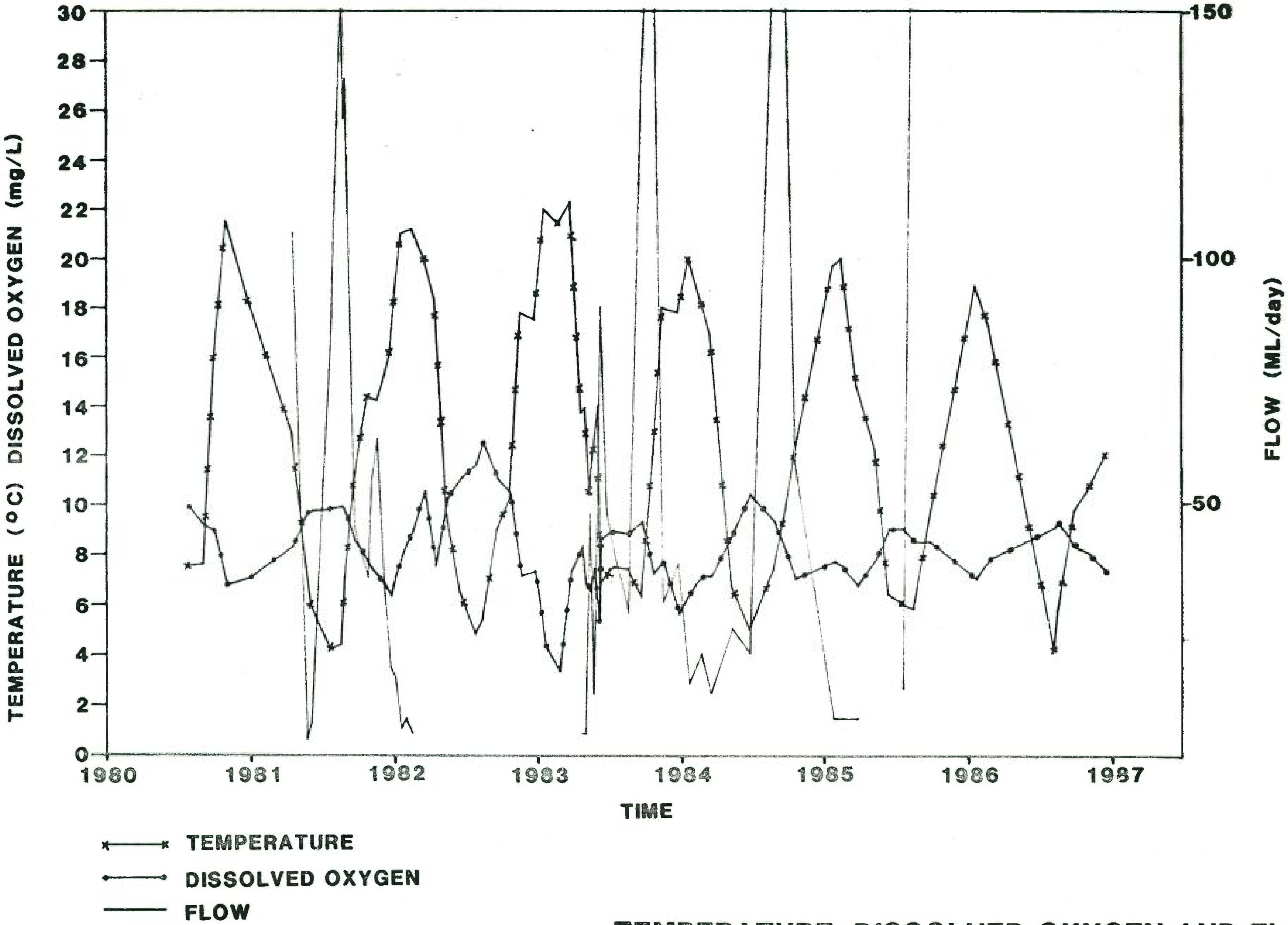


FIGURE I 4

TEMPERATURE, DISSOLVED OXYGEN AND FLOW AT DUCKMALOI WEIR

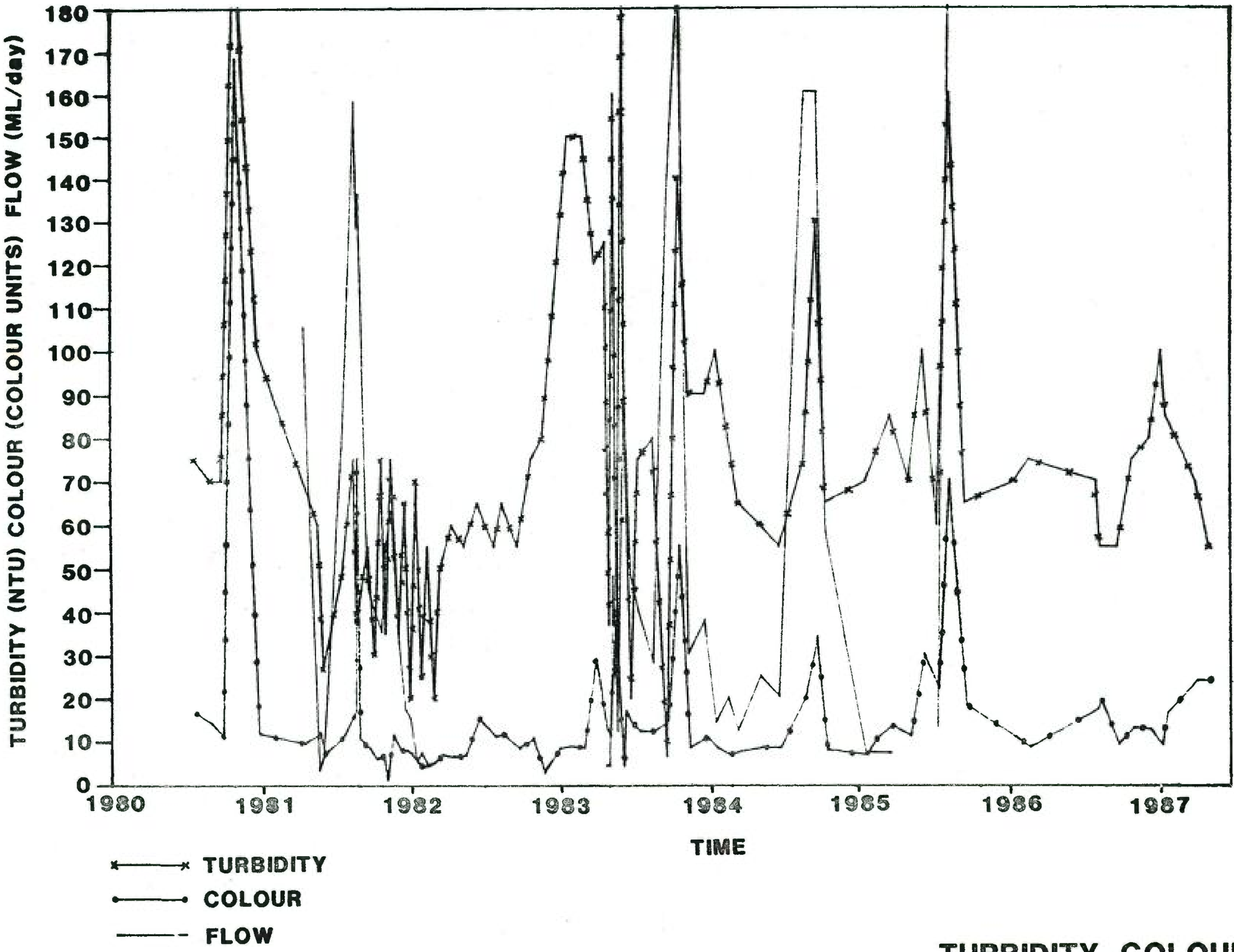


FIGURE I 5

TURBIDITY, COLOUR AND FLOW
AT DUCKMALOI WEIR

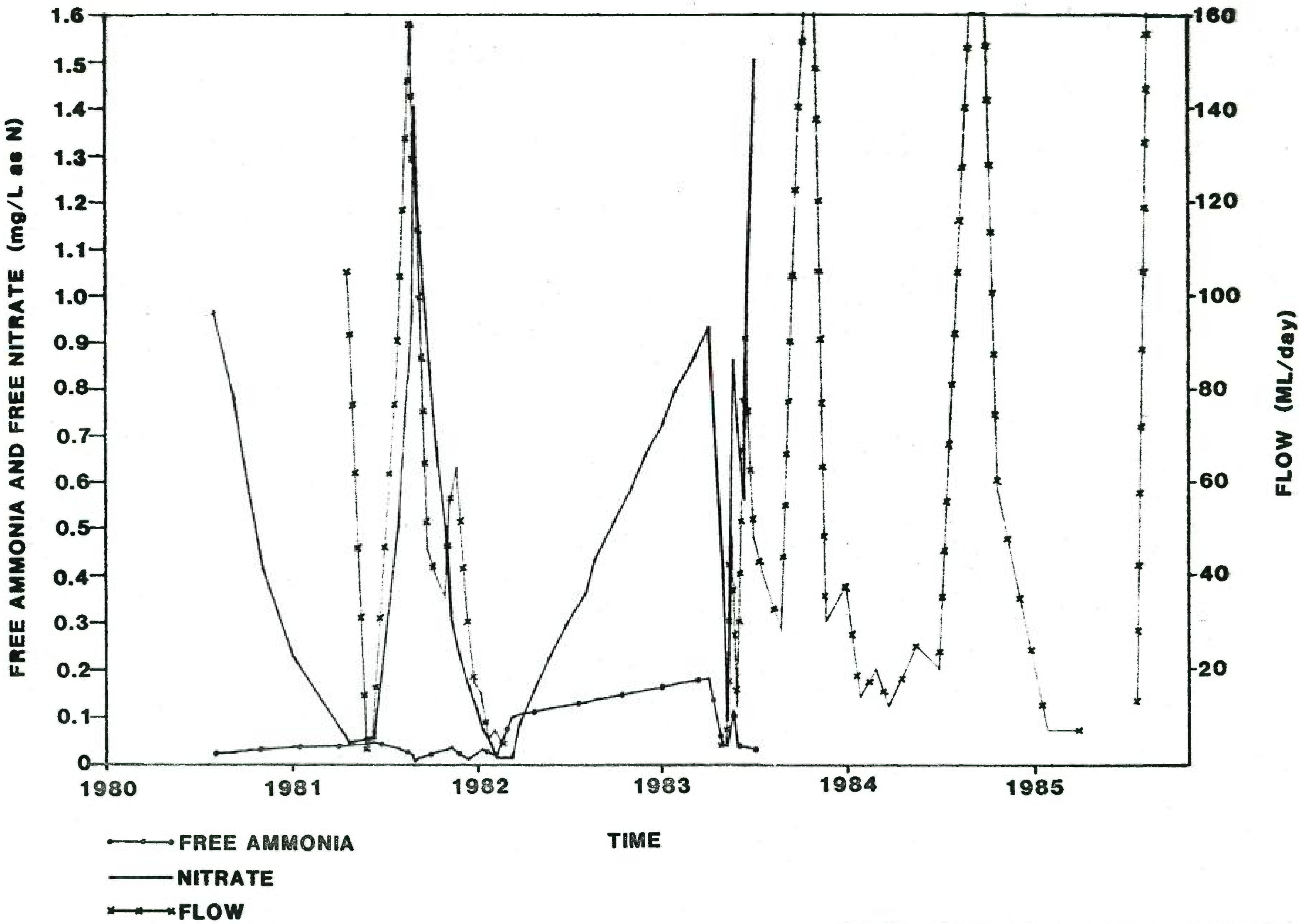


FIGURE I 6

FREE AMMONIA, NITRATE AND FLOW AT DUCKMALOI WEIR

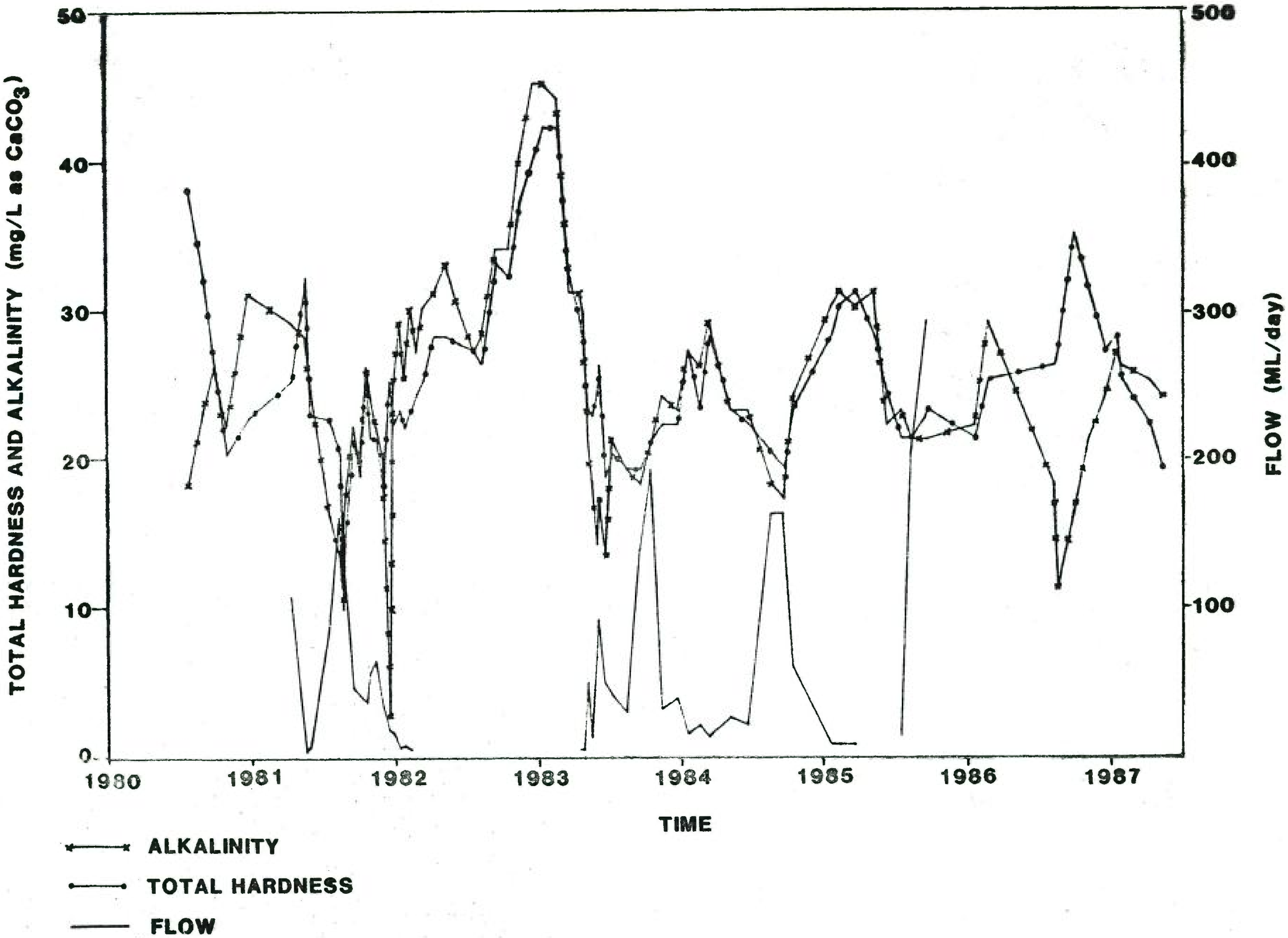


FIGURE I 7

ALKALINITY, HARDNESS AND FLOW
AT DUCKMALOI WEIR

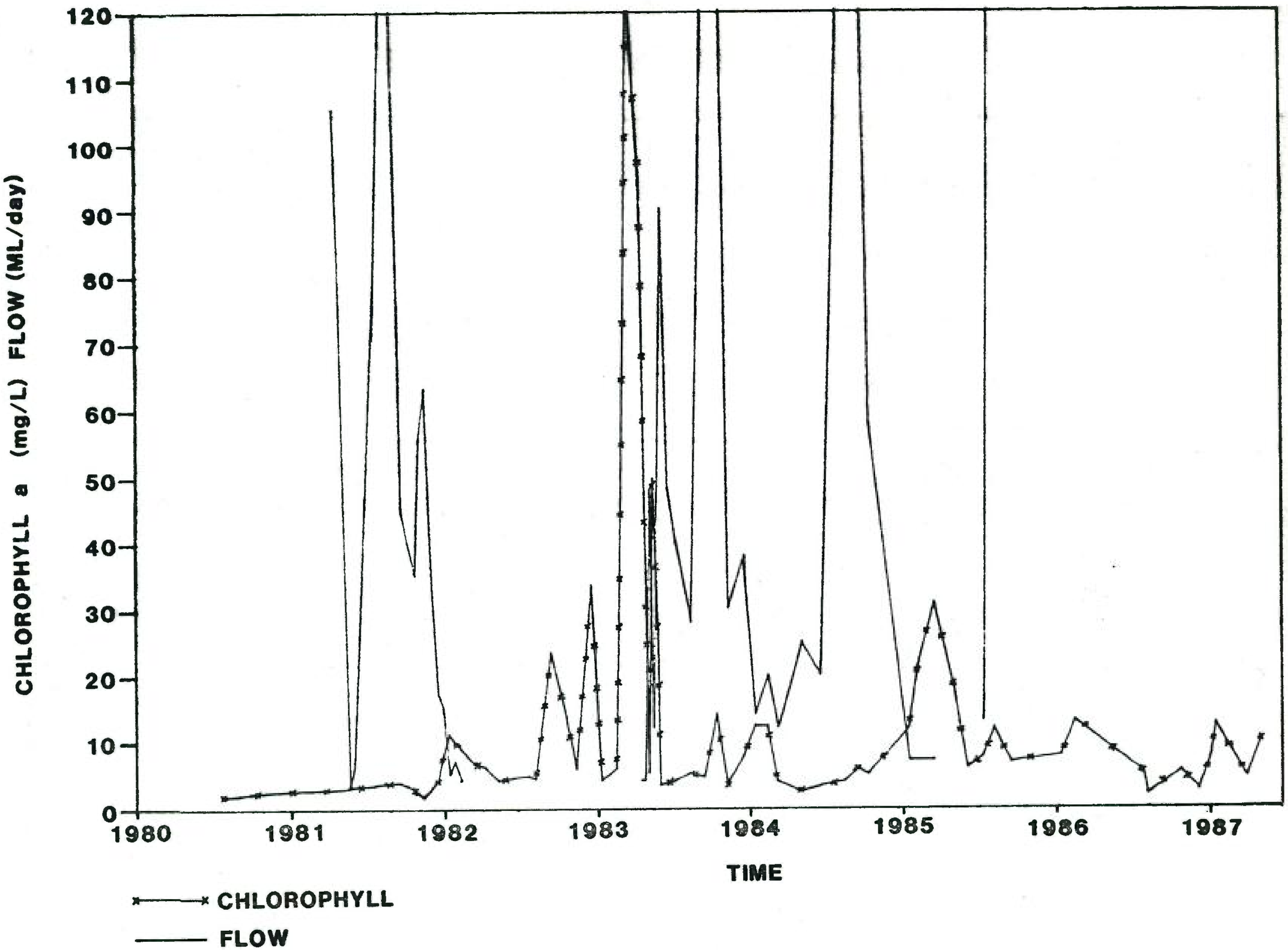


FIGURE I 8

CHLOROPHYLL AND FLOW AT DUCKMALOI WEIR

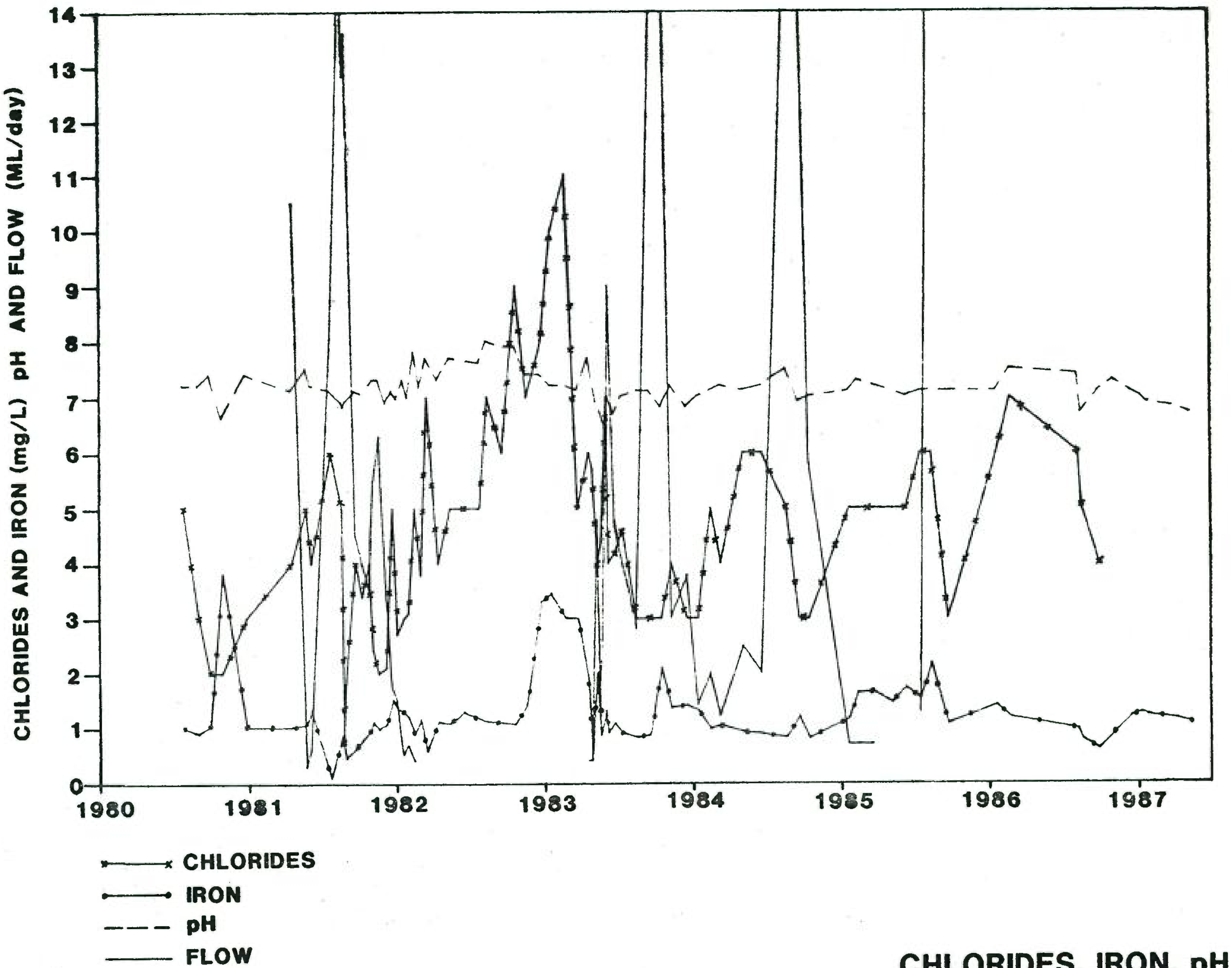


FIGURE I 9

CHLORIDES, IRON, pH AND FLOW
AT DUCKMALOI WEIR

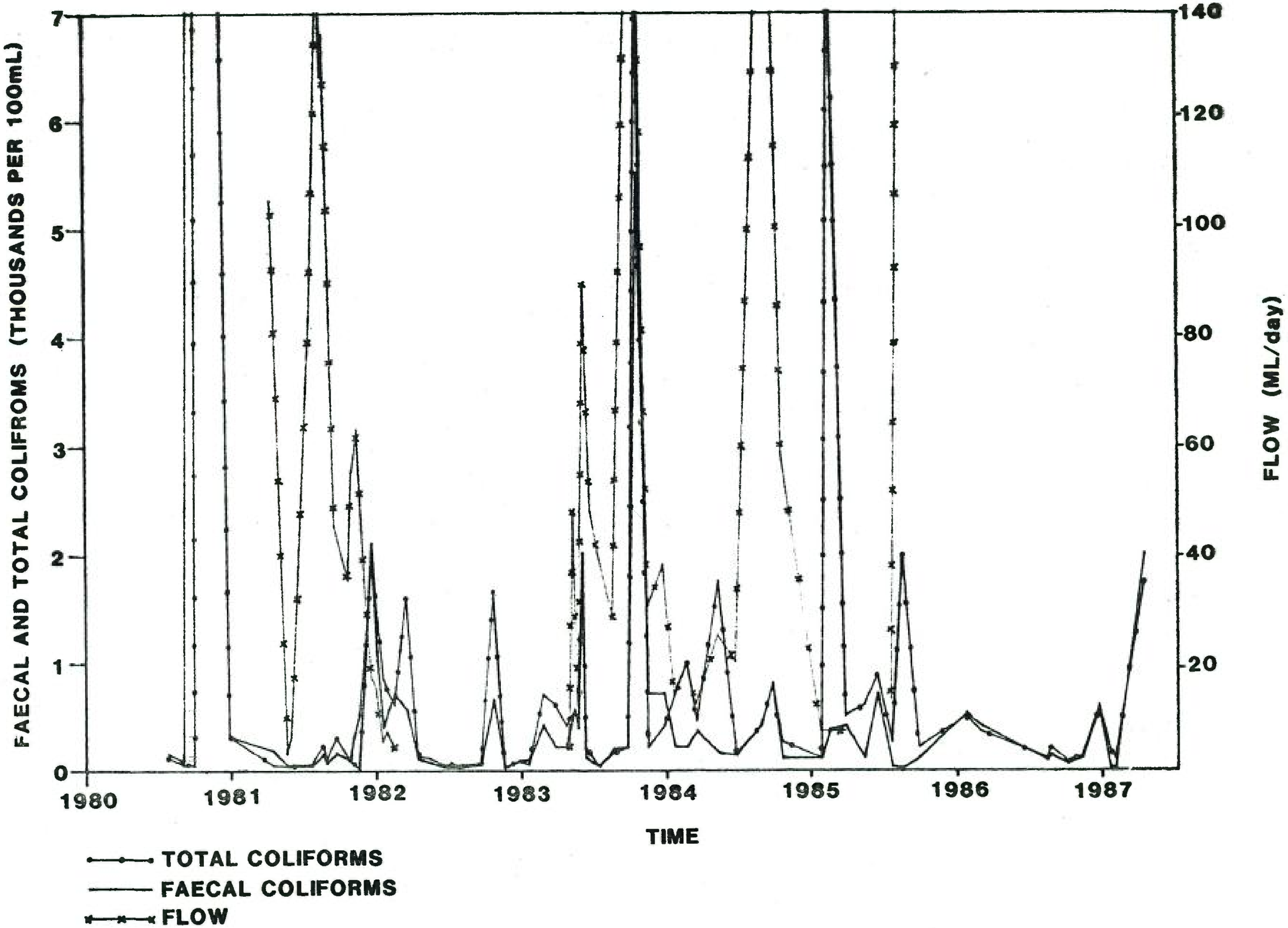


FIGURE I 10

COLIFORMS AND FLOWS AT DUCKMALOI

I.2.3.1. Temperature

Our data show that temperature varies several degrees over the normal day/night cycle; it varied between 13 and 16°C downstream of the weir in December, 1986 and between 15 and 23.5°C in mid-summer, depending on flow and weather conditions. In May, 1987 the temperature was slightly over 10°C on an overcast day.

The highest water temperatures were measured in a sunny pool immediately below the weir. This was a result of the warm stratified surface water within the impoundment spilling over the weir. River water temperatures quickly dropped a couple of degrees as the water passed into the shaded and cooler river channel. Temperatures did not rise above about 21°C beyond the first pool below the weir.

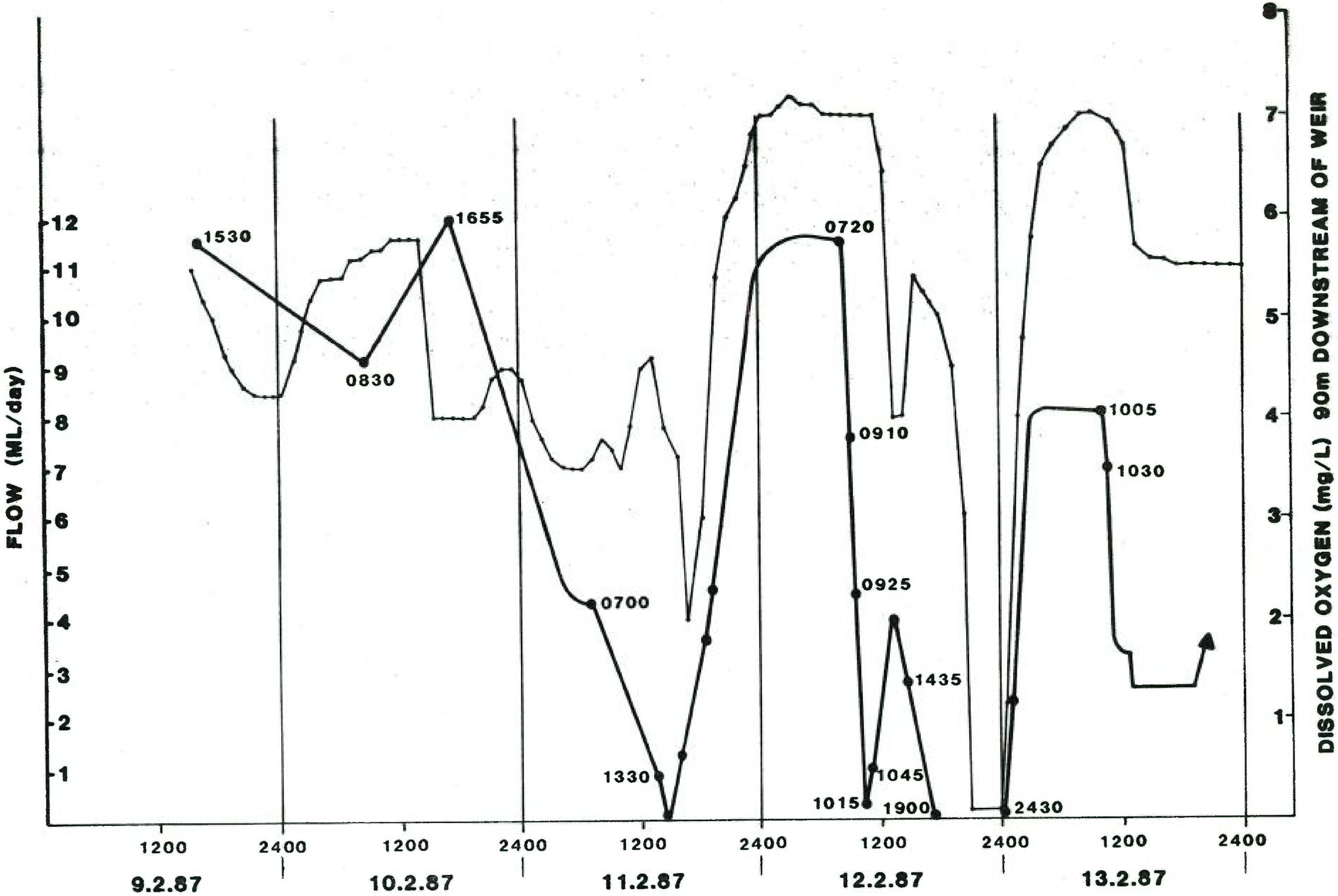
Long-term monthly data from the PWD and WB show that surface temperature varies annually between about 4 and 22°C in the weir. We have found a marked Temperature/Dissolved Oxygen (T/D.O.) stratification in the weir during summer. The highest temperatures are naturally found at the surface and, perhaps surprisingly, the highest dissolved oxygen is also at the surface. In this case it is not merely the temperature which affects the capacity of water to hold oxygen (lower temperature : higher oxygen capacity). In a standing body such as the weir, oxygen is not provided by mechanical aeration, but by photosynthetic activity of plant material, predominantly algae and phytoplankton. Photosynthetic production can cause temporary oxygen supersaturation. The weir contains high levels of the filamentous green algae Cladophora sp. and occasionally bloom proportions of flagellate planktonic algae and diatoms which produced dissolved oxygen values of 12 mg/L at a temperature of 25°C at the surface of the shallow backflow area in mid-summer; this is about 150% saturation.

I.2.3.2. Dissolved Oxygen

The weir storage shows the greatest variability in dissolved oxygen of any habitat measured, depending on season, flow and depth. In mid summer the water near the surface can be supersaturated while water at the bottom near the weir itself is at or near zero oxygen content.

Our experience over many years in rivers and billabongs around Australia has indicated that dissolved oxygen can be a sensitive indicator of the health of a water body. It responds quickly to changes in flow, primary productivity, biological and biochemical oxygen demands such as respiration and temperature fluctuations. It is the heartblood of a stream and can be used to help determine the minimum flow requirements of a stream.

We monitored D.O. at many points along the stream and in the weir at various times of day and night. The data are presented in Table I.3. We installed a chart recorder to a D.O. probe at a pool 90 m downstream of the weir and monitored the diurnal fluctuations in D.O. during the drawdown experiment. This showed a very clear pattern which corresponded to the fluctuations in flow (refer to Figure I.11). The normal diurnal cycle peaks during the afternoon when photosynthetic production is at a maximum.



FLOW

DISSOLVED OXYGEN

FLOW AND DISSOLVED OXYGEN PROFILE BELOW DUCKMALOI WEIR

FIGURE I 11

The minimum occurs just before sunrise when maximum demand, placed on the system by animal and plant respiration, has been operating for the longest time.

TABLE I.3. DISSOLVED OXYGEN IN DUCKMALOI RIVER AND WEIR
(See Figs I.2 and I.3 for locations.)

Date	Time	Location	Depth	Flow ML/day	Temp.	Dissolved Oxygen mg/L	Dissolved Oxygen %
03.12.86	12.45	Bridge at Burroughs Ck. Crossing Rd.	0.3	40.0	14.5		83.0
	14.00	weir backwater	0.3	40.0	14.5		152.0
	14.50	weir main channel	0.3	40.0	16.5		97.0
			1.6	40.0	13.5		73.0
04.12.86	16.30	Pool A	0.3	40.0	16.0		86.0
	17.00	Mid-gorge	1	40.0	15.5		82.0
	17.45	weir wall u/s	0.1	40.0	15.5		92.0
	18.00	weir wall d/s	0.3	40.0	15.5		82.0
05.12.86	5.30	weir backwater	0.3	40.0	15.0		78.0
			0.5	40.0	14.5		76.0
	6.00	weir main channel	0.3	40.0	14.0		64.0
			1.6	40.0	13.5		62.0
	6.30	weir wall d/s	0.3	40.0	13.5		76.0
	6.50	Pool A	0.3	40.0	13.5		76.0
	7.10	Mid-gorge	1	40.0	13.5		82.0
	10.50	McKeons Ck	0.2	14.0	12.0		84.0
	11.50	Teatree Ck.	0.2	5.0	14.0		81.0
	12.15	u/s of Teatree Jn.	0.3	40.0	14.0		79.0
26.01.87	16.30	weir main channel	0.3	4.5	24.8	12.00	150.0
	16.45	weir backwater	0.5	4.5	17.0	11.50	111.0
28.01.87	8.30	Pool 1	0.2	4.5	18.4	6.40	65.0
		u/s of Pool 1	0.2	4.5	18.6	6.60	70.8
	12.15	Pool 1	0.2	4.5	18.8	6.20	64.0
	15.00	Pool 3	0.7	4.5	19.7	5.70	59.5
29.01.87	8.30	Pool 6	0.2	4.5	17.5	7.20	76.0
	11.00	Pool 5	0.5	4.5	18.4	7.00	75.6
30.01.87	15.15	weir wall d/s	0.3	4.5	23.7	6.30	76.5
31.01.87	10.00	weir wall d/s	0.3	4.5	18.6	6.70	72.0
09.02.87	15.30	Pool A		9.1	21.4	5.75	64.0
10.02.87	8.30	Pool A		9.1	20.0	5.70	63.0
	9.45	Weir main channel	0.3		21.1	7.40	84.5
			1.5		18.7	4.80	59.2
	10.00	Weir backwater	0.5		18.9	5.90	71.0
	10.15	Weir backwater			21.3	6.70	79.0
	12.00	Pool 2			20.3	6.80	79.0
	13.30	McKeons Ck		5.3	22.5	7.14	81.0
		Pool 3			21.0	6.05	67.5
		Pool 3 - above riffles		7.2	20.7	5.90	66.0
	14.00	Pipeline Crossing			21.2	7.50	85.0
	16.00	Weir wall d/s	0.3	12.0	23.0	7.50	87.0
	16.55	weir wall u/s	0.3	12.0	20.8	10.50	115.0
	17.40	weir main channel	0.3		24.1	10.90	124.9
			1.5		18.1	4.70	48.0

TABLE I.3. (cont.)

Date	Time	Location	Depth	Flow ML/day	Temp.	Dissolved Oxygen mg/L	Dissolved Oxygen %
	18.00	Weir backwater	0.3		23.8	10.20	124.7
	18.15	Teatree Creek			22.5	7.14	81.0
	18.18	Weir backwater			25.2	11.90	147.8
	18.20	Teatree Junction u/s			20.6	7.05	78.0
	18.25	Teatree Junction d/s			21.2	7.00	80.0
11.02.87	7.12	weir wall u/s	0.3	4.3	19.8	7.85	87.5
	7.20	weir wall u/s	1.5	4.3	16.7	0.23	2.2
	7.28	weir wall u/s	1	4.3	18.4	5.30	60.0
	7.40	Pool A			20.3	3.50	40.0
	7.45	Upstream of Pool 6	0.3	4.3	19.2	6.64	71.7
	7.55	Pool 6			19.2	6.75	74.0
	8.00	Fish Pool 3			20.5	4.70	52.5
	8.10	Pool 4			20.5	4.70	52.5
		Pool 6			19.1	6.44	69.0
	8.25	Mid Gorge			20.4	6.80	75.0
	8.35	Pipeline Crossing			20.3	7.20	79.0
		u/s of Teatree Jn	0.3		19.0	6.03	65.1
	8.40	Pool 6			17.9	7.77	82.1
	8.50	d/s of Teatree Jn			18.6	6.93	74.5
	9.05	Pool 6			18.7	6.05	65.0
	9.20	Pool 7			18.7	6.19	66.7
	9.30	Pool 8			18.8	6.43	69.2
	10.00	Pool 9			18.8	6.21	67.1
	10.20	Pool 10			19.0	6.22	67.5
	10.35	Pool 11			19.5	6.49	71.3
	10.50	McKeons Jn. u/s			19.8	6.60	72.7
	11.05	McKeons Jn. d/s			19.8	7.01	77.3
	11.30	McKeons Ck.			20.2	7.43	82.9
	11.55	u/s of Teatree Jn			19.7	6.49	71.6
	12.05	Tea Tree Creek			19.7	7.60	84.1
	12.15	Teatree Jn. d/s end of riffles			20.1	6.85	76.2
	17.00	Pool 3			21.2	6.00	67.5
		Pool 6			23.0	8.17	95.8
	17.10	u/s of Teatree Jn			21.2	8.64	97.5
	17.15	Pool 4			21.4	6.00	68.0
	17.25	d/s of Teatree Jn.			21.8	8.67	99.2
	17.30	Mid Gorge			21.0	6.80	77.3
	17.45	Pipeline Crossing			21.1	7.30	83.0
	17.50	McKeons Jn u/s			22.2	9.32	107.7
	18.00	McKeons Jn. u/s			23.7	8.56	101.2
	18.10	McKeons Jn d/s			22.5	9.04	105.3
	18.16	Pool A			23.2	5.70	66.6
12.02.87	7.34	Pool 3		11.5	18.4	6.24	67.4

TABLE I.3. (cont.)

Date	Time	Location	Depth	Flow ML/day	Temp.	Dissolved Oxygen mg/L	Dissolved Oxygen %
	7.50	Pool 4			18.2	7.32	78.8
	8.00	Bottom of Gorge -			18.3	7.38	79.4
		Pipeline Crossing					
		Pool 6	0.3		14.9	8.20	81.9
	8.25	Mid Gorge			18.1	7.25	77.0
	8.35	Pool 4			18.2	6.57	74.3
		u/s of Teatree Jn.			17.5	6.76	71.3
	8.50	d/s of Teatree Jn.			17.1	7.11	74.1
	9.40	McKeons Jn u/s			17.3	7.01	73.6
	9.55	McKeons Creek			16.7	8.02	83.2
	10.05	McKeons Jn d/s			17.3	7.41	77.8
	10.35	At Weir - Bottom	1	0.5	16.7	1.75	18.2
		Weir wall u/s	0.3	0.5	18.4	6.71	73.1
	10.50	Weir wall u/s	0.3	1.0	19.1	6.85	74.7
	11.05	Pool A			18.4	4.50	48.0
	11.15	Pool 3			18.2	6.63	71.7
	11.28	Pool 4			18.3	6.53	70.6
	11.48	Mid Gorge			19.1	7.70	83.8
	11.50	Bottom of Gorge			18.8	7.30	80.8
	12.10	Pool 3			18.9	6.80	74.0
	16.40	Pool A		1.8	21.3	0.94	7.4
	17.10	Pool 3			20.0	6.35	70.4
	17.45	Pipeline Crossing			20.4	7.50	83.9
13.02.87	16.00	Pool 3			20.4	7.00	78.5
	17.05	Pool 4			20.7	7.30	83.0
	17.12	Mid Gorge			20.7	7.10	80.0
	17.30	Bottom of Gorge			20.5	7.50	84.0

In many situations the oxygen tension (ie. degree of deficiency) becomes critical just before sunrise, and we can see that the carrying capacity of our rivers and lakes is determined by the temperature and period of darkness.

Superimposed on this natural D.O. cycle was a marked drop in D.O. downstream of the weir when the flow dropped during the drawdown experiment. A graph showing fluctuations in D.O. with flow is presented as Figure I.10. This graph demonstrates a rapid and significant response in D.O. to flow fluctuations within the low-flow range. The normal diurnal D.O. variation in the stream during summer appears to fluctuate between 4 and 7 mg/L of dissolved oxygen. When water flow is reduced from 11.5 to 9 ML/day, D.O. was reduced from 5.75 to 4 mg/L in the pool 90 m below the weir, with a time lag of several hours. When flow is further reduced, each incremental drop in flow becomes more significant in terms of total flow. Fluctuations take effect much more quickly at very low flow levels; i.e. the whole system is much less resilient to change. From the data on Figure I.10 it appears that flows of 3-4 ML/day were sufficient to sustain a daytime dissolved oxygen value of about 5.5 mg/L, which is within the range produced by the normal background flow during summer. However, this flow rate was not maintained during hours of darkness, and so the minimum diurnal D.O. was not recorded for this flow. It seems apparent that D.O. would drop to a level significantly below 4 mg/L just before sunrise at a flow of 3 ML/day. When water flow was stopped, D.O.

dropped to near zero during hours of darkness. This data is related to tolerance levels for trout and other aquatic life in Section 3 below.

I.2.3.3. pH

The pH of the river is approximately neutral to very slightly basic, with values ranging from 6.8 to 7.6 from sites upstream, in, and downstream of the weir during our survey. The long-term monthly data from PWD (Figure I.6) show a similar result, with a slightly greater range (approximately 6.6-8.0). This range is within the acceptable range for freshwater aquatic life (pH 6.5-9), and for domestic water supplies (pH 5-9) (U.S. EPA, 1987). Because the river is very poorly buffered (see conductivity and alkalinity), it is very susceptible to pH changes by the addition or loss of any acidic or basic compounds.

I.2.3.4. Conductivity

Conductivity is a measure of the total dissolved salts in a liquid, because charged ionic species in solution conduct electricity in a manner proportional to their concentration. Conductivity may range from a low value of around 50 microsiemens/cm in snow, rainwater, or surface water flowing over rocks very resistant to attack, to about 50,000 microsiemens/cm or more, which is the approximate conductance of seawater.

The Duckmaloi River yielded values of between 50-79 microsiemens/cm, while Teatree Creek and McKeons Creek were consistently less (between 30-57 microsiemens/cm), suggesting that the creeks are extremely low in solutes, and all are very poorly buffered against changes in pH; McKeons and Teatree Creeks contain even less dissolved salts than the Duckmaloi River, and would be among the purest creeks in Australia. Very seldom are values below 50 microsiemens/cm recorded.

I.2.3.5. Alkalinity

Alkalinity is a measure of the ability of water to neutralise acid, and is therefore a measure of the buffering capacity of the water. Since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality.

Low values of alkalinity (below about 20 mg/L) indicate poorly buffered water, or little solute available to neutralise any acidic addition to the water. Values from the Duckamloi River and weir ranged between 18-30 mg/L (Figure I.8), while Teatree and McKeons Creeks were even lower (5-16 mg/L).

The recommended criterion for safe water quality (US EPA, 1987) is a **minimum** of 20 mg/L as $CaCO_3$ for freshwater aquatic life except where natural concentrations are less.

I.2.3.6. Turbidity

Turbidity measures the clarity of water in terms of the transmission of light through the sample. Clarity of water is ecologically important in aquatic systems to allow sufficient light penetration for plant growth. Water clarity is also very important aesthetically and for safe recreational use. Metropolitan drinking water should possess a turbidity of 1 nephelometric turbidity unit (NTU) (Hart, 1974; USEPA, 1987), and the PWD have a long-term objective of a maximum turbidity of 5 NTU. The natural waters of our study area were clear and had low-flow values of between 3.0 and 5.2 NTU during the summer of 1987. Long-term data gathered by the PWD and WB show a low-flow range in the weir of between 4 and about 50 NTU; the turbidity of flood water is much higher, with values ranging between 50-190 NTU (see Figure I.5). Values from about 100 NTU and above come from water which is extremely turbid and would be termed muddy.

It is evident that water in the weir will normally require treatment to reduce turbidity if it is to meet drinking water standards. It appears that the cause of the turbidity is primarily colloidal iron (see values for iron below), but is frequently exacerbated by phytoplankton which reach bloom proportions in the weir during summer.

Turbidity and **non-filtrable residue** are not excessively high during low-flow conditions. Much of the apparent turbidity and colour could be caused by a high density of red and brown algae and diatoms.

I.2.3.7. Non-Filtrable Residue or Suspended Solids

Non-filtrable residue (NFR) is the amount of organic and inorganic particulate matter in the water. NFR and turbidity are important in municipal water supplies for obvious reasons; they also affect the quality of aquatic life in streams and lakes. Many animals, including fish that lay eggs, can be affected by siltation which prevents or reduces oxygenation of the eggs. It can also reduce the abundance of food available to the fish. At very high levels, particulate matter can affect fish and invertebrates directly by clogging gills, impairing vision and modifying natural movement.

There is no evidence that concentrations of NFR less than 25 mg/L have any harmful effects on fisheries; it should be possible to maintain good or moderate fisheries in waters which normally contain 25 to 80 mg/L NFR (EIFAC, 1965). Values above 80 mg/L are unlikely to support good freshwater fisheries.

Our analyses yielded values of between 2 and 6 mg/L in the Duckmaloi River, Teatree Creek and McKeons Creek, and less than 1 mg/L in the weir, showing that dry weather flow produces quite clear water which is very favorable for all aquatic life.

These results indicate that the rate of sediment transport is low for flows at least up to 40 ML/day, and this corresponds with the opinion of the Soil Conservation Service which regards the Duckmaloi Catchment as having far fewer problems of erosion than others in the district (Murray and Hird, 1976; C. Marshall, SCS, pers. comm., 1986).

I.2.3.8. Hardness

Water hardness is caused by the polyvalent metallic ions dissolved in water. In fresh water these are primarily calcium and magnesium, although other metals such as iron, strontium and manganese contribute to the extent that they are present. Although the Duckamloi River has high concentrations of iron, it appears to occur mainly as colloidal or organically chelated forms and therefore probably does not contribute significantly to water hardness. Measurement of total hardness gives an indication of the total dissolved cations without actually measuring each of the common ones; it is therefore a test which saves considerable analytical cost. Values of hardness are usually reported as an equivalent concentration of calcium carbonate (CaCO3) because of the various ions that may be contributing in different proportions, and may be classified from 'soft' to 'hard' as follows (US EPA, 1987):-

Concentration of dissolved ions ($mg/L\ CaCO_3$)	Description
0-75	soft
75-150	moderately hard
150-300	hard
>300	very hard

The water hardness in the Duckamaloi Weir varies between 10-40 mg/L $CaCO_3$ (see Figure I.8), with higher values occurring during periods of drought or very low flow as a result of the buildup of metallic ions in solution through evaporation and poor flushing or dilution. Our water samples in December, 1986 and February, 1987 yielded total hardness values of 21-30 mg/L in the weir and downstream, while Teatree and McKeons Creeks had significantly lower values (ranged from 11-16 mg/L). All results indicate 'soft' water, and is evidenced by how readily soap will lather using this water.

Hardness in freshwater is often distinguished into carbonate and non-carbonate fractions. The carbonate fraction is chemically equivalent to the bicarbonate in the water, which is measured as alkalinity. Therefore, when hardness is numerically equal to or less than alkalinity, all the hardness is carbonate hardness and there is no non-carbonate hardness. This is generally the case in the Duckmaloi system; Figure I.8 shows that alkalinity and hardness are very similar in concentration most of the time. Our data in December, 1986 and February, 1987 support this observation.

Therefore, the water is soft and virtually all hardness is carbonate hardness. There is an observed reduction of toxicity of metals in water containing carbonate hardness (US EPA, 1987). There is evidence which suggests that this phenomenon is due to the presence of calcium as well as the bicarbonate species (or alkalinity).

I.2.3.9. Nitrogen

Nitrogen occurs in free flowing streams primarily in the form of nitrate. The two other principal forms of nitrogen, ammonia and nitrite, are unlikely to occur in significant quantities in well-aerated, unpolluted waters because both forms are rapidly oxidised to nitrate.

Nitrogen is added to the stream principally via fertilisers, animal wastes (including fish and other aquatic fauna) and the breakdown of organic matter (vegetation and decaying animal matter). The criterion for domestic water supplies is 10 mg/L nitrate nitrogen, and 1 mg/L nitrite nitrogen (NHMRC, 1977; US EPA, 1987).

Freshwater aquatic life can tolerate relatively high concentrations of nitrogen without apparent ill-effect. Published data indicate that levels of nitrate nitrogen at or below 90 mg/L would not have an adverse effect on warmwater fish; nitrite nitrogen at or below 5 mg/L should be safe for most warmwater fish; nitrite nitrogen at or below 0.06 mg/L should be safe for the salmonid group of fish, of which trout are a member (US EPA, 1987). Because concentrations of nitrate and nitrite that would exhibit toxic effects on fish could rarely occur in nature, restrictive criteria are not recommended by the US EPA.

Values of nitrate nitrogen obtained during our studies of the Duckmaloi River and Weir were consistently below 1 mg/L except during flood flows, when values were between 1-2 mg/L. Teatree Creek was typically double the nitrate concentration of the Duckmaloi, and generally above 1 mg/L but less than 2 mg/L (refer to Table I.2 and Figure I.9 for measured values of nitrate and ammonia nitrogen). This is most probably due to the nitrogenous inputs from cattle and sheep excrement.

Cattle stock were observed to use Teatree Creek for drinking and shade whereas only a few sheep were observed along the Duckmaloi downstream of the weir. This is because there are more farm dams in the paddocks adjacent to the Duckmaloi within the Armstrong property to provide alternative sources of water, and the Duckmaloi River is fenced to exclude stock from the creek bed (except where sheep have managed to find or create a break in the fence). Teatree Creek is not fenced, allowing ready access to the creek bank by farm animals, most notably cattle. It appears this practice of fencing the margins of the creek not only improves safety for animals that may fall down the steep banks, but also improves water quality. Nitrogen is one of the essential nutrients for plant growth; additions above natural background levels can cause nuisance algae and weed growths, as are occasionally experienced in the weir.

We have observed that cattle do have access to the Duckmaloi River above the weir. The highest nutrient values in the Duckmaloi River (total nitrogen and phosphorus) were measured at Burrows Road crossing. In view of the nature and volume of waste from cattle, as compared to sheep, it is suggested that the practice of allowing cattle to drink and wallow in the creek should be discontinued; water should be provided to cattle from farm dams constructed away from the creek margins. This would probably significantly improve the algal and phytoplankton problems in the weir.

I.2.3.10. Phosphate

Phosphorus as phosphate is an essential nutrient for plant growth as well as for animal life. In excess of a limiting value, phosphate stimulates plant growth because it is usually the nutrient present in the least amount relative to need. Thus, an increase in phosphate allows use of other nutrients already present, causing abnormally high plant growth.

It has generally been held, based on overseas evidence, that high phosphate levels result in accelerated eutrophication, but the absolute amount varies from one area to another; a commonly used figure of 0.02 mg/L (as P) has been cited as causing abnormally high plant growth and eutrophication (Hart, 1974). It is also accepted that aquatic plant problems develop in reservoirs and other standing waters at phosphorus values lower than those critical in flowing streams. Reservoirs and lakes collect phosphates from influent streams and store a portion of them within consolidated sediments. Much of the material that combines with the consolidated sediment is bound permanently and will not be recycled into the system.

The values of phosphorus recorded during our survey are presented in Table I.2. Our results show that the range of values was from <0.02 mg/L to 0.05 mg/L. The highest results came from the weir in mid-summer, at a time when a plankton bloom was occurring in the weir and there were nuisance quantities of the filamentous green algae **Cladophora.** There is no long-term data available from PWD or WB on phosphorus in the Duckmaloi River.

It is probable that the increased quantities of phosphorus result from cattle and sheep inputs upstream. Phosphate is relatively insoluble in the soil and is not leached into surface waters with runoff. Fertilisers also add significantly to the rural phosphate runoff if heavy rainfall occurs before the added phosphorus can become bound to soil particles (in the order of a few days).

Values of phosphorus from the Duckmaloi River and weir are typical of farm land runoff in Australia and should not be cause for alarm. However, they are above natural background levels in undisturbed bush, and are a cause of the algae and plankton blooms observed in the weir. Fortunately, the reeds and rushes along the shoreline act as a nutrient sponge by absorbing large quantities of phosphorus into their cells for growth; without these nutrient-absorbing plants, phosphate levels would probably be considerably higher in the weir. Levels below 0.1 mg/L in the flowing water of the river should not cause significant weed or algal problems.

I.2.3.11. Iron

Although iron is one of the most abundant elements on earth and is an essential trace element required by plants and animals, it is toxic to aquatic life at levels of 1 mg/L or greater. Studies with trout have shown a toxic effect of iron at 1 mg/L and a 96-hour LC_{50} value of 0.32 mg/L has been obtained for mayflies, stoneflies and caddisflies, all of which are an important component of the Duckmaloi invertebrate fauna. (Data from U.S.EPA, 1976).

Iron is probably the only parameter measured in the Duckmaloi River which is above acceptable water quality standards. A water quality criterion of 0.3 mg/L iron for domestic water supplies has been established by the US EPA (1987), primarily on aesthetic grounds. Above that level it imparts a taste to water and leaves a stain on laundry and fixtures. Based on field observations, a criterion of 1 mg/L iron for freshwater aquatic life is believed to be adequately protective.

Recent values obtained from the Duckmaloi River and weir, during our study and by the PWD, range from 0.3 to 1.42 mg/L (Table I.2 and Figure I.6). Data accumulated by the WB since 1980 (Appendix I.C) show that iron levels are consistently above 1 mg/L and have reached a maximum of 3.8 mg/L.

At the pH and oxidation levels of the Duckmaloi River, virtually all the iron is the insoluble ferric (Fe+++) species (above pH 4.8 the solubility of ferric species is less than 0.01 mg/L). Therefore, the iron must occur as dispersed colloidal forms or organically chelated with humic or tannic acids.

Iron levels will have to be reduced to approximately 0.3 mg/L consistently if the water is to be acceptable for domestic use.

I.2.3.12. Phytoplankton/Chlorophyll

A frequent contributor to turbidity and colour of the water is the microscopic plant cells suspended in the water, or phytoplankton, which may reach bloom proportions. An indicator of the biomass of phytoplankton may be obtained from measurement of the chlorophyll pigment present in all green plants. For planktonic algae, chlorophyll constitutes about 1-2% of the dry weight.

Long-term data on chlorophyll from the Duckmaloi weir (Figure I.7 and Appendix B) show levels generally less than 15 mg/m^3 of chlorophyll but occasionally reaching bloom proportions of 30 mg/m^3 or more, with one reading of over 120 mg/m^3 in early 1983.

We took water samples for algal cell identification during February and May, 1987. Examination showed the presence in February of large quantities of flagellate brown algae and diatoms with brown pigments. These algae and diatoms were present in sufficient quantities (over 4,000 cells/mL) to contribute brown colour and some turbidity to the water. Several of them also produce taste and odour problems when present in high densities. The high ratio of **Pheophytin a to Chlorophyll a** (Table I.2) suggests the algae were in a poor physical condition. Algal counts and identifications are shown in Table I.4.

Table I.4. Algal Counts from Duckmaloi Weir

Date of collection	1/2/87	8/5/87
Total algal count	4130	1330
Dominent genera (cells/mL):		
Navicula (diatom)	490	360
Cryptomonas (flagellate algae)	1310	260
Fragilaria (diatom)	0	130
Chlomydomonas (flagellate algae)	0	96
Trachelomonas (flagellate algae)	1030	26
Chroomonas (flagellate algae)	590	0
Synedra (diatom)	0	13
Cosmarium (diatom)	0	13

I.2.3.13. Bacteriological Conditions

The Water Board's monthly sample in the Duckmaloi Weir has been routinely tested for total coliform bacteria and E. coli (indicators of fecal contamination). Results indicate contamination by bacteria from the feces of warm-blooded animals, but the data are not statistically adequate to demonstrate a continual health risk. In spite of this statistical inadequacy, it is significant to note that every sample tested, except one, had some fecal contamination, and 58% of monthly samples exceeded the maximum criteria for bathing and contact recreation (126 colonies per 100 ml as a geometric mean of at least 5 samples per month).

The evidence suggests that the Duckmaloi River is not safe for drinking by humans without chlorination and that bathing could cause bacterial infection. It is presumed that the bacterial levels are not high enough to present a risk to aquatic life, particularly platypus. However, no data or knowledge of the bacterial tolerances of aquatic life is available to us.

I.3. Discussion

The results described above lead to the general conclusion that the Duckmaloi River is presently in good chemical and biological condition. However, several observed characteristics provide a more refined understanding of the aquatic ecosystem:

- . Most native fish species have been eliminated from the stretch of river under study. This is a result of habitat alteration and the introduction of the piscivorous trout. Galaxias are the only native fish remaining, and they are extremely abundant.

- . The water is low in dissolved salts and nutrients and is poorly buffered; higher nutrient levels were noticeable in tributaries and above the weir where cattle were observed to have ready access to the water's edge. The increased nutrients are attributed to organic waste deposits from cattle.

- . The river is generally high in total iron content, which is in the form of dispersed colloids or organically chelated. It is this high iron content which contributes most of the brown colour and turbidity to the water.

- . Rich invertebrate life is found in riffle areas of the river and especially along the grassy shoreline of the weir. These are important food production areas for fish and platypus.

- . Platypus were observed to be common in the weir, and were found downstream of the weir below significant riffle areas. These are also the areas of highest invertebrate production.

- . Rainbow trout were relatively abundant as juveniles in most areas of the river, but large (legal catch size) trout were more common in the deepest shaded pools, primarily in the area of the gorge.

- . At the time of our study (Summer 1986-87), water flow was just adequate for survival of all forms of aquatic life and was maintaining satisfactory dissolved oxygen and temperature levels. The minimum flow recorded over the weir during the field surveys was 5 ML/day, which is 9% of the average annual flow. The average annual flow is taken to be 20,200 ML/annum or 55.3 ML/day, according to long-term flow records supplied by the PWD (PWD, 1985).

I.3.1. Instream Flow Requirements for Fish and Platypus

Considerable effort has been made in recent years to develop objective quantifiable methods of assessing the flow requirements of instream uses (Smith, 1979; Stalnaker and Arnett, 1976; Corteli & Assoc., 1977; McColl, 1982; Mosley, 1983; Co-operative Instream Flow Group, 1982; Tierney, 1982).

To assess the flow needed for maintaining stream resources, it is first necessary to know the fish species present and their ecological requirements for biological activities relating to passage along the river, spawning, feeding, and resting. In the case of the Duckmaloi River, it is also necessary to know the distribution and requirements of the platypus. Detailed information concerning this species is provided in Section J. Some comments on platypus dependancy on benthic invertebrates are provided below (Section I.3.1.3).

The galaxias are less sensitive,in terms of their requirements for dissolved oxygen and temperature, than trout, which are more demanding in the physical and biological characteristics necessary for breeding and growth. We will focus on what is needed by trout, since they are more sensitive to fluctuations in water quality. This should not be interpreted to mean that we necessarily agree with maintaining a trout fishery, since this precludes the reintroduction of other native fish species.

The water level of the weir should not fluctuate by more than the depth of the shoreline vegetation, i.e. about 200 mm, to prevent the loss of vegetation and associated rich invertebrate fauna. Provided water level remains static, the weir provides a significant benefit for platypus and fish.

I.3.1.1. Trout Requirements

The biological needs of trout have been determined from considerable research overseas. This information has been applied to Australia by Tunbridge (1980) who determined minimum and optimum flows in the Thompson River, Victoria based on biological requirements of brown trout and other fish species. rainbow trout would have similar requirements.

According to Tunbridge, large brown trout require a minimum water depth of 18 cm, and small brown trout require a minimum of 12 cm to allow passage through shallow riffles. Stream velocities should not exceed 2.7 m/sec for large trout and 1.3 m/sec for small trout.

Within this study area there are several riffle and cascade areas where water depth is frequently too shallow during summer months for passage of adult trout and occasionally even for juvenile trout. At a flow of 5 ML/day there are 4 or 5 riffles/cascades within the study area which would be too shallow for trout passage, although between impassable riffles there are fairly extensive areas of flowing water and pools in which fish could survive indefinitely. These impasses are a major reason why trout are not known to spawn in the upper Duckmaloi River.

Observations of tagged trout in Victoria show seasonal and extensive movement of juvenile fish up into the small tributaries followed by a movement back downstream as they mature. Our study area could be classified as such an upstream destination. Mature trout also make an upstream spawning run in May or June, searching for suitable gravel in which to deposit their eggs. There are very few suitable sites with sufficient cover in our study area of the Duckmaloi River. This is another major reason why trout are not known to spawn in the upper Duckmaloi. McKeons Creek does have good gravel beds, and provided water depths are sufficient, it is quite possible that spawning occurs in this creek. Suitable spawning gravels range from 0.5-60 cm in diameter and must be clean, free of silt, and percolated by cold, well-oxygenated water. According to Tunbridge (1980), the preferred water depth over gravel for spawning is 15-100 cm with a bottom velocity between 0.2 and 1 m/sec. The temperature range for spawning is 2-12°C, and dissolved oxygen must be at least 8 mg/L. Since this study area does not contain any significant natural spawning areas, we need not consider these requirements further.

The published literature provides information on the temperature tolerance of trout: Contant (1977) stated a maximum preference temperature of 19-21°C in Canada, and an upper avoidance temperature of 22°C for trout fingerlings (no upper avoidance temperature was stated for adults). Lee and Rinnie (1980) found a critical thermal maxima for brown and rainbow trout of 28.5 to 29.8°C in the SW of the USA. This variation in results depending on latitude suggests a possible acclimitisation of trout to different maxima. It is our opinion, based on the literature and an informal discussion with the NSW Division of Fisheries that the upper avoidance temperature for trout in SE Australia is about 25°C.

Alabaster and Lloyd (1980) quote a minimum dissolved oxygen concentration of 4-4.5 mg/L (from Itazawa, 1971) to maintain maximum feeding, growth, and efficient food conversion for adult rainbow trout. This D.O. minimum was also found to apply to the maintenance and growth of juveniles, but they could be acclimatised to 3 mg/L in two stages. Mortality in juveniles has been reported by Alabaster and Lloyd (1980) at 2-3 mg/L of D.O. over six days.

Therefore, we regard 4 mg/L as the minimum acceptable level of D.O. for maintenance of the trout fishery unless a lower value occurs naturally, due to drought conditions. In the event of drought all aquatic life obviously suffer significant losses.

Many juvenile rainbow trout (but few mature individuals) were found in the Duckmaloi River below the weir (Appendix I.A). The flow necessary for rearing trout must be sufficient for ensuring an adequate food supply for the fish, namely invertebrates.

Riffles are the most productive areas of a flowing stream in terms of benthic macroinvertebrates (Blyth, 1980; Wesche, 1976). This was demonstrated in our study by the diversity and abundance of invertebrates collected in the riffles when compared to the pools (Appendix I.A). The maximum production of invertebrates is controlled both by the water velocity through the riffles and the total amount of riffle area.

It is important for there to be a reasonably high water velocity over the riffles, to deliver food to platypus and trout by the mechanism called "drift". This is the movement of organisms downstream by the current, whether voluntarily or involuntarily. The supply of drift which is suitable for trout has been found to be greater in areas of faster currents. Theoretically, if more food is available, a predator will require less time and space to obtain its food, its territory can be reduced, and population densities in a given area can be increased (Wesche, 1976). However, natural low flow conditions and the high variability which dominate S.E. Australian streams would not encourage increased trout population densities.

It is clear that, as a minimum, riffle areas must be kept wet and flowing to ensure survival of invertebrate food supply. However, the minimum survival flow is not necessarily adequate to encourage trout into upstream riffle areas. The appeal of a riffle area to trout varies with the water velocity over a riffle and the surface area available (Wesche, 1976). This argues in favour of flows which are higher than the minimum survival flow.

Studies in the USA over the past 20 years have established that reduced flows (10-30% of average annual flow) will still maintain a river in a satisfactory condition for most of its natural aquatic organisms, and particularly fish (Tennant, 1976).

I.3.1.2. Platypus Requirements

Platypus (**Ornithorhyncus anatinus**) are common on the Duckmaloi River. The greatest number have been found by Goldney in or near the weir: 46 individuals were captured in 1986 (Appendix J).

Grant (1981) has observed that platypus are seldom found in impoundments or lakes greater than 5 m deep because they feed on bottom-dwelling organisms by diving and foraging with their soft bill. Benthic invertebrate abundance decreases dramatically with depth, particularly below 3 m (Bayley and Williams, 1973). Water level fluctuations associated with the storage and use of water cause a significant reduction in benthic species due to stranding. Large numbers of insects utilise aquatic grasses/reeds for protection, food supply and as an egg-laying substrate. When the shoreline plants are stranded by receding water, the insects die or move away. If stranding occurs for more than a few hours, recolonisation by new animals must begin anew. If the periods and frequency of stranding are great enough, the vegetation will also die from insufficient water.

The weir is an ideal platypus habitat because it is shallow (less than 3 m deep), the water level does not fluctuate at the present time and it has extensive reed/grass banks on its margin which provide a suitable habitat for a large invertebrate fauna (primarily insects and crustaceans).

The food of platypus has been investigated by examining their cheek pouches (see Grant, 1981; Faragher et al, 1979). The platypus diet consists mainly of the larval stages of insects, small crustaceans and molluscs (bivalves and gastropods). The invertebrate groups which had been previously identified in cheek pouches are marked with an asterisk in the invertebrate faunal collection from the Duckmaloi River and weir (Appendix I.B). It is evident that the grassy shoreline of the weir contains the highest standing crop of suitable food organisms, followed by the riffle areas in flowing water.

The location and number of platypus captures by Goldney (Appendix J) is very clearly related to the abundance of food supply.

Therefore, the critical requirement for platypus is to maintain a fairly uniform water level in the weir (within a range of about 200 mm, or the height of the grass and reed stems), except during the times of natural flood and drought, and also to maintain the continuum of riffles and pools in the zone between the weir and the junction of McKeons Creek.

According to the proposed operating scheme, both of these requirements will be met. The water level of the impoundment behind the weir does not fluctuate except during flash flooding because outflow (via the weir or pipeline) always equals inflow. The downstream riffle areas will be maintained in a wetted condition because a minimum of 6 ML/day will be continuously released for riparian rights except when natural inflow is less.

There will undoubtedly be times when the weir requires maintenance and the water within the impoundment should be reduced or completely drained. This will cause the greatest adverse impact on the platypus, primarily because its food supply will be destroyed. A fairly large population of platypus has now become established near the weir and depends on its food resource for its well-being. Sudden removal of its food would cause extreme competition and possible death to many platypus because they would not have sufficient time to disperse to other satisfactory food-producing areas. Furthermore, there are few good riffle areas from the top of the gorge area to McKeons Creek (a distance of nearly 2.5 km), so it is unlikely that the large platypus population could be supported by suitable habitat on the Upper Duckmaloi River.

It is recommended that maintenance techniques be employed which do not require a complete drawdown of the weir (e.g. temporary sheet piles or a suitable steel or timber frame which would exclude water from a section of the concrete weir). This is the preferred solution. Alternatively, the period of drawdown should be as brief as possible (a few hours to a day or two maximum) and outside of the breeding and lactating season of the platypus (August-March). The best period may be April-May. If lengthy periods of stranding are unavoidable, the platypus should be captured and relocated until benthic food organisms have successfully recolonised the shoreline.

I.3.2. Instream Flow Criteria

Several criteria have been developed overseas (primarily in the USA) to assess the minimum survival and maintenance flows for rivers and streams. The four most common methods were reviewed and related to the Australian environment by Richardson (1986). They all rely on historical flow data for their assessment, and two of these also require biological information for their application:

1. The Montana Method - developed by Tennant (1976); this is the simplest model and describes habitat quality in terms of percentage of mean annual flow (MAF). No specific biological data is required.

2. Flow-Duration Curve Analysis - developed by Stalnaker and Arnette(1976); monthly flow duration curves are used to recommend the 80th percentile flow for minimum habitat maintenance and 40th percentile flow for suitable spawning conditions. No specific biological data is required.

3. Transect Analysis - reviewed by Stalnaker and Arnette (1976); requires knowledge of some biological characteristics of the stream. The requirements of fish and invertebrates are related to hydraulic characteristics at several key transects along the river.

4. Incremental Method - developed by Bovee and Milhous (1978); it is developed from the Transect Analysis method and used hydraulic simulations to predict available habitat area over any flow range. It is a cumulative assessment of a particular reach using multiple transect data. Biological requirements of species present are necessary.

The reader is referred to Richardson (1986) for a more complete description and assessment of the various methods. With reference to our study, the collection of extensive life history data and species distribution, as required by the last two methods, was not considered practical for a report of this nature. Furthermore, as Richardson (1986) concedes, the Montana Method compared very favorably with the more complex techniques in terms of predicting minimum survival and acceptable maintenance flow for fish. The Montana Method was more conservative than the Flow Duration Curve Method in her study of the Tweed River.

It is also important to note that all of the methods are concerned primarily with fish. In the Duckmaloi River, platypus are considered to be the most important species. However, since they are amphibious, their direct requirements are considered to be less than for fish. Benthic invertebrates, as the food supply for both fish and platypus, should be considered when applying these methods to platypus.

The overseas methods for assessing minimum survival flows are based on a flow regime where the mean annual flow more closely corresponds to the median flow over time than is the case in Australia. Here, flash floods are superimposed on a generally low flow condition which means that the median flow is probably considerably less than the mean, which is skewed upward by the influence of peak runoff events.

Therefore, the direct applicability of the Montana Method to Australian conditions is questionable since our flow regime, particularly in southeast Australia, is dramatically different from that in the northern USA. The high variability of flow experienced in our rivers is significant compared to the US, where slow release of snow melt over the summer months produces a steadily decreasing discharge.

In addition, we are not considering flow requirements for trout breeding within the study area, since it is assumed they would not breed in this reach of the river even if the flow was unregulated (see discussion above).

Notwithstanding the above discussion, the Montana Method could be applied as a preliminary reconnaissance method of predicting acceptable flow levels in the absence of detailed biological data, since it may well be somewhat conservative.

The mean annual flow (MAF) of the Duckmaloi River at the weir is taken to be 21,500 ML/a or 59 ML/day (PWD, 1985a). Applying the Montana Method, the quality of the flows would be indicated by the following criteria, as adapted from Tennant (1976).

TABLE I.5. Instream Flow Requirements for Fish, Wildlife, Recreation and Related Environmental Resources for the Duckmaloi River.

Description of Flows	Recommended Base Flow Regimes (% of MAF)	Flow at Duckmaloi Weir (ML/day)
Flushing or maximum	>200	>110.7
Optimum range	60-100	33.2-55.3
Outstanding	50-60	27.7-33.2
Excellent	40-50	22.1-27.7
Good	30-40	16.6-22.1
Fair or degrading	10-30	5.5-16.6
Poor or minimum	10	16.6
Severe degradation	<10	<5.5

The above requirements suggest that a minimum survival flow for fish and aquatic invertebrates would be 10% of MAF, or about 5.5 ML/day over the weir. Our measureming of D.O., temperature and turbidity, as well as observing the relationship of wetted perimeter, richness of aquatic life and the health of the fish confirm that this is an acceptable minimum flow for maintaining acceptable environmental quality. **It is therefore recommended that the minimum instantaneous flow over the weir be not less than 6 ML/day except when natural inflow to the impoundment is less. In that case, outflow over the weir must not be less than inflow.**

The minimum amount which will be extracted for water supply augmentation is 7 ML/day; below that quantity, it is deemed to be too inefficient to operate the water clarification plant. Therefore, if 6 ML/day is to be reserved for instream uses, the minimum flow at which extraction should occur is 13 ML/day. At this flow and above, extraction may increase with flow up to the maximum capacity of the pipeline - 33 ML/day. When 33 ML/day is being extracted, total inflow to the weir will be 39 ML/day, providing the same 6 ML/day discharge over the weir for instream use. Above 39 ML/day, any increase in the inflow will be allowed to discharge downstream.

This extraction programme thus allows for instream requirements during critical periods of low flow, particularly drought. During times when input to the Duckmaloi Weir is less than 13 ML/day, no water will be taken from the weir. According to long-term flow records, this occurs about 40% of the time.

According to the criteria set out in the Montana Method, flows of 30-100% of MAF, or between 17 and 55 ML/day in the Duckmaloi River, would be excellent for maintenance of all aquatic life. Allowing for maximum extraction (33 ML/day) our long-term records indicate that the downstream flows would remain above 17 ML/day for another 40% of the time.

Thus for 80% of the time, there would be no significant adverse impact from extracting water from the weir. This leaves about 20% of the time when moderate flows (13-39 ML/day) would be reduced to 6 ML/day by extraction. There would be a further 10% of the time when discharge rates were no longer "ideal" for aquatic life (60-100% of MAF) as suggested by Tennant. This is because inflows of 39-50 ML/day would be reduced to between 6-17 ML/day.

Of the 30% showing some reduction in quality below the ideal (>17 ML/day), at least 16% is very slight, in that the flows may be classified as "fair" (20-30% of MAF or 11-17 ML/day) according to the Montana Method. Thus only 14% of flows could be considered to experience a significant reduction (ie. to between 6-11 ML/day).

In summary, for about 14% of the time, a three-kilometre reach of river below the weir would experience a significant reduction in flow. These periods of disruption to natural flow do not occur during low-flow conditions because water is not extraced when inflow drops to 13 ML/day or less. Flushing events are also not significantly affected because at flows of 150 ML/day or more maximum extraction would still leave 200% MAF spilling over the weir, This occurs 15% of the time. It should be further noted that the water clarification plant would not always operate whenever extraction was permissible. Not only would there be routine maintenance of the equipment and breakdowns, but there would be no extraction whenever Oberon Dam was spilling. Therefore, the estimate of 14% of significant reductions in flow is considered to be conservatively high.

As a consequence of this operational programme, it is considered that the ecological impacts would only be felt during periods of moderate flow. Although significant at those times, the impacts would not be so severe as to affect the survival of aquatic life.

A flow over the weir of 6 ML/day is 10.8% of MAF, and is adequate for short periods to ensure fish and invertebrate survival, based on D.O. and temperature measurements, and visual observations of biological characteristics. The reduction in wetted perimeter of shoreline represented by this flow was not measured during our study, but it is estimated to be on the order of 40% reduction. This is the maximum amount of exposure recommended for riffles and stream banks (Tennant, 1976).

Of greater concern than the absolute amount of reduction caused by this scheme, is the rate of fluctuation of downstream wetted area as extraction is initiated. Tennant (1976) recommends that the water level should not drop faster than about 25mm/hour to prevent stranding and dessication of invertebrate fauna. When the pipeline is opened the drawdown from the weir will take about two to four hours to stabilise because of the time taken to empty or fill the water level behind the weir to the new level.

The rate of fluctuation will also decrease with distance downstream because of the time required to adjust the water level in each pool, and the adjustment to seepage from saturated soils. However, the reach of river from zero to approximately 100 m downstream of the weir is likely to experience fairly rapid water level fluctuations following commencement of water extraction. The fluctuations at the riffle zone 90 m downstream of the weir may affect invertebrate fauna which attempt to become established in the riffles. This could, in turn, affect the platypus which are known to frequent the pool immediately downstream of these riffles (see Section J). The potential for reduced food supply may lead to a reduction in the number of platypus and trout which are presently supported by this particular riffle/pool complex.

Beyond the gorge area, discharge fluctuations should be very gradual, due to the damping effect of the many large pools and bank storages among rocks in the gorge; this should prove slow enough to permit invertebrate fauna to migrate to wetter substrates.

Instantaneous flows should be the criteria rather than average weekly or monthly flows because it is the short term fluctuations which more seriously affect the survival of invertebrates.

I.3.3. Concerns of interest groups

The **Central Acclimatisation Society,** which represents several fishing clubs in the Central West Region, has expressed various concerns about the effects of water extraction on trout populations (Appendix H). The Society expresses apprehension over the effect of reduced flow during summer, particularly the potential for increased water temperatures, which could have an adverse effect on trout populations. We share that concern and, for that reason, have taken a special interest in monitoring actual water temperatures during mid-summer, and especially during the three-day drawdown experiment in February.

Our findings showed that both dissolved oxygen and temperatures were maintained at acceptable levels provided flows exceeded 3.5 ML/day. Below that flow, there was noticeable depletion of oxygen, and water temperatures rose to avoidance levels during the heat of the day (Section I.2.3). As pointed out in Section I.3.1.1, the maximum acceptable temperature for trout is about 25°C; the Duckmaloi River did not exceed 21°C in mid-summer at flows exceeding 3.5 ML/day.

The Society expressed concern at the further reduction in flow in the Fish River as a result of extraction from the Duckmaloi River, and suggested that this could also affect flows in the Macquarie River during summer. We do not know the daily or average flow rates of the Fish River below the junction with the Duckmaloi River, or of the Macquarie River at the confluence of the Campbell and Fish Rivers, so we cannot provide an accurate comment on the percentage of loss to these systems as a result of this proposed water augmentation scheme. However, it is our view that if extraction does not occur at all during low flow conditions, and

If the effect of extraction during moderate to high flows is regarded as ecologically insignificant on the Duckmaloi River below the junction with McKeons Creek, then the extraction programme should also be ecologically insignificant further downstream after further tributaries are taken into account. In other words, the impact of the loss of 33 ML/day during periods of moderate flow would be largely absorbed by the immensely larger catchments of downstream habitats.

The Society made the point that, because the environment of the stream had already been altered, most native fish are no longer suited to the Upper Duckmaloi River, and the only angling species now adapted to those conditions (ie. trout) may be at risk by further manipulation of their habitat. We agree with their point, and adds that it would be preferable to us to see native fish reintroduced at the expense of trout. However, we accept that this is presently impracticable since Macquarie perch and Trout cod are not yet available in commercial quantities. However, according to Fisheries Division, there may soon be commercial quantities of the perch.

From the number and size of trout found in the impoundment, it could be concluded that the weir has created a habitiat which is well-suited to trout. However, in our view it would be even better for native species: it has the warmer surface water and cool bottom water that various native species prefer; it has a suitable depth; there is ample food supply at the margins of the pond, and it provides a focus for downstream dispersal. Trout would have difficulty in breeding in the weir because of the mud substrate, the low water velocities and low D.O. in the bottom waters. It appears likely that these trout have been stocked by farmers for their own use. Native fish could utilise the shallow gravel beds of the Duckmaloi River upstream of the impoundment, whereas trout would probably not be able to spawn due to the shallow depth, paucity of gravel and low water velocity.

In any event, the use of the impoundment for drinking water, and the private ownership of adjacent riparian properties precludes the use of the weir for recreational fishing, so the advantages of the weir as a fishery are somewhat of a mute point, except insofar as it would help to provide a stock of native fish for downstream dispersal.

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APPENDIX I.A. RESULTS OF FISH SAMPLING PROGRAMME

APPENDIX A

RESULTS OF ELECTROFISHER SAMPLING:
DUCKMALOI RIVER
27-29 JANUARY, 1987

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE no./m^2	% OF TOTAL CATCH/POOL	BIOMASS g/m^2
Pool I 15m x 3m = 45m^2	*Galaxias olidus* (mountain galaxias)	37	1			
		64	3			
		56	2			
		30	1			
		32	1			
		mean = 43.8	mean=1.6	5/45=.11	36%	8/45=.18
	Salmo gairdneri (rainbow trout)	68	5			
		93	12			
		60	4			
		75	8			
		99	14			
		63	4			
		95	14			
		35	2			
		35	2			
		mean= 69.2	mean=7.2	9/45 = 0.2	64%	65/45 = 1.44
	TOTAL			14/45 = 0.27		73/45 = 1.62
Pool II 36m x 5m = 180m^2	*Galaxias olidus* (mountain galaxias)	62	3			
		32	1			
		38	1			
		66	3			
		44	2			
		33	1			
		39	1			
		40	1			
		32	1			
		32	1			
		76	4			
		77	4			
		90	4			
		69	3			
		36	1			
		12@25	12@ 1			
		mean = 39.5	mean =1.6	27/180 = 0.15	82%	43/180 = 0.24
	Salmo gairdneri (rainbow trout)	75	8			
		74	8			
		55	3			
		365	646			
		65	4			
		80	8			
		mean = 119	mean =113	6/180 = 0.03	18%	677/180= 3.76
	TOTAL			33/180 = 0.18		720/180 = 4.0

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE (NO./m^2)	% OF TOTAL CATCH/POOL	BIOMASS (g/m^2)
Pool III 22m x 8m = 176m^2	*Galaxias olidus* (mountain galaxias)	81	4			
		61	3			
		40	1			
		63	3			
		59	2			
		56	2			
		44	2			
		37	1			
		31	1			
		39	1			
		28	1			
		33	1			
		40	1			
		32	1			
		31	1			
		40	1			
		71	4			
		73	3			
		64	3			
		57	2			
		40	1			
		39	1			
		45	2			
		33	1			
		37	1			
		42	1			
		33	1			
		mean = 46.3	mean =1.7	27/176 = 0.15	79.4%	47/176 = 0.27
	Salmo gairdneri (rainbow trout)	78	8			
		75	8			
		69	5			
		62	4			
		74	8			
		62	4			
		64	4			
		mean = 69.1	mean = 5.9	7/176 = 0.04	20.6%	41/176 = 0.23
	TOTAL			34/176 = 0.19		88/176 = 0.50
Pool IV 27m x 3m = 81m^2	*Galaxias olidus* (mountain galaxias)	52	2			
		38	1			
		47	2			
		36	1			
		60	3			
		37	1			
		37	1			
		47	2			
		47	2			
		39	1			
		40	1			
		41	1			
		30	1			

* Refer to Figure I(2) for location of sampling sites.

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE (no./m^2)	% OF TOTAL CATCH/POOL	BIOMASS (g/m^2)
Pool IV (cont.)	*Galaxias olidus* (cont.)	35	1			
		35	1			
		33	1			
		35	1			
		35	1			
		37	1			
		76	4			
		40	1			
		40	1			
		38	1			
		35	1			
		36	1			
		42	1			
		44	2			
		mean = 41.2	mean =1.4	27/81 = 0.33	52%	37/81 = 0.46
	Salmo gairdneri (rainbow trout)	192	150			
		84	10			
		67	4			
		80	8			
		65	4			
		56	3			
		87	11			
		72	6			
		76	8			
		55	3			
		86	10			
		47	3			
		59	4			
		78	8			
		85	10			
		76	8			
		77	8			
		64	4			
		65	4			
		63	4			
		62	4			
		64	4			
		60	4			
		67	5			
		59	4			
		mean = 73.8	mean =11.6	25/81 = 0.31	48%	291/81 = 3.59
	TOTAL			52/81 = 0.64		328/81 = 4.05
THE GORGE (4 Pools) SITE V Total length 23m x ave 5m= 115m^2	*Galaxias olidus* (mountain galaxias)	32	1			
		31	1			
		65	3			
		79	4			
		mean = 51.8	mean = 2.3	4/115= 0.03	27%	9/115 = 0.08

* Refer to Figure I(2) for location of sampling sites.

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE (no./m^2)	% OF TOTAL CATCH/POOL	BIOMASS (g/m^2)
THE GORGE (cont.)	Salmo gairdneri (rainbow trout)	310	530			
		90	12			
		65	4			
		60	4			
		100	14			
		59	4			
		80	8			
		88	11			
		90	12			
		88	11			
		76	8			
		mean =100.5	mean =56.2	11/115 = 0.09	73%	618/115 = 5.37
	TOTAL			15/115 = 0.13		627/115 = 5.45
POOL VI 28.5m x 3.5m= 100m^2	Galaxias olidus (mountain galaxias)	82	4			
		60	3			
		45	2			
		75	4			
		68	3			
		55	2			
		65	3			
		39	1			
		37	1			
		35	1			
		41	1			
		44	2			
		39	1			
		34	1			
		58	2			
		39	1			
		40	1			
		35	1			
		61	3			
		62	3			
		34	1			
		43	1			
		40	1			
		40	1			
		36	1			
		36	1			
		30	1			
		37	1			
		31	1			
		34	1			
		41	1			
		52	2			
		43	1			
		44	2			
		38	1			
		40	1			
		42	1			
		36	1			
		36	1			
		mean = 44.8	mean= 1.6	39/100 = 0.39	91%	61/100 = 0.61

* Refer to Figure I(2) for location of sampling sites.

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE (no./m^2)	% OF TOTAL CATCH/POOL	BIOMASS (g/m^2)
POOL VI (cont.)	Salmo gairdneri (rainbow trout)	62	4			
		70	5			
		mean = 66	mean = 4.5	2/100 = 0.02	4.5%	9/100 = 0.09
	Salmo trutta (brown trout)	285	354			
		200	185			
		mean =243	mean =270	2/100 = 0.02	4.5%	539/100= 5.39
	TOTAL			43/100= 0.43		609/100= 6.09
POOL VII 24m x 4m = 96m^2	Galaxias olidus (mountain galaxias)	60	3			
		55	2			
		81	4			
		55	2			
		70	4			
		58	2			
		65	3			
		42	1			
		51	2			
		52	2			
		59	2			
		45	2			
		43	1			
		40	1			
		39	1			
		31	1			
		38	1			
		39	1			
		34	1			
		41	1			
		40	1			
		60	3			
		65	3			
		50	2			
		41	1			
		43	1			
		40	1			
		45	2			
		40	1			
		37	1			
		44	2			
		38	1			
		46	2			
		28	1			
		40	1			
		35	1			
		34	1			
		32	1			
		27	1			
		40	1			
		36	1			
		27	1			

* Refer to Figure I(2) for location of sampling sites.

SITE NUMBER* & SURFACE AREA	FISH SPECIES	CAUDAL FORK LENGTH (mm)	WEIGHT (g)	ABUNDANCE (no./m^2)	% OF TOTAL CATCH/POOL	BIOMASS (g/m^2)
POOL VII (cont.)	Galaxias olidus (cont.)	43	1			
		36	1			
		30	1			
		40	1			
		49	2			
		32	1			
		35	1			
		37	1			
		34	1			
		45	2			
		mean = 43.6	mean=1.5	52/96 = 0.54	96%	79/96 = 0.82
	Salmo gairdneri (rainbow trout)	85	10			
		68	5			
		mean = 76.5	mean=7.5	2/96 = 0.02	4%	15/96 = 0.16
	TOTAL			54/96 = 0.56		94/96 = 0.98

* Refer to Figure I(2) for location of sampling sites.

APPENDIX I.B. AQUATIC INVERTEBRATES COLLECTED

(from Duckmaloi Weir, Summer 1986/87)

AQUATIC INVERTEBRATES COLLECTED FROM VARIOUS HABITATS ON DUCKMALOI RIVER, SUMMER 1986/87.

LIST OF SPECIES	Pool I	Pool IV	Pool VI	Deep Pool below weir	Riff. I	Riff. IV	Riff. above Deep Pool	Gut 1	Gut 2	Gut 3	Coarse sand cores	Fine mud cores	On algae in weir	Grass shore in weir
Phylum Platyhelminthes														
Class Turbellaria														
Order Tricladida		1					4							
Phylum Nematoda														
Phylum Mollusca														
*Class Gastropoda														
Planorbidae														
Gyraulus sp.							30							2
Physastra sp.		1		4	15	10					8			
Pygmanisus sp.					9		6							2
*Class Bivalvia														
Sphaeriidae														
Sphaerium sp.				1	19	2					170			180
Phylum Annelida														
Class Oligochaeta														
Enchytraeidae												23		
Lumbricidae	1	3					1							
Lumbriculidae														
Lumbriculus variegatus		2												
Naididae							13							2
Phylum Crustacea														
Class Malacostraca														
* Order Decapoda														
Atyidae														
Paratya australiensis	4		1											129
Order Isopoda														
Phreatoicidae													14	10
Order Amphipoda														
Eusiridae		1	1			2							3	8
Order Cladocera							1							
Phylum Uniramia														
Subphylum Hexapoda														
Class Insecta														

AQUATIC INVERTEBRATES COLLECTED FROM VARIOUS HABITATS ON DUCKMALOI RIVER, SUMMER 1986/87.

LIST OF SPECIES	Pool I	Pool IV	Pool VI	Deep Pool below weir	Riff. I	Riff. IV	Riff. above Deep Pool	Gut 1	Gut 2	Gut 3	Coarse sand cores	Fine mud cores	On algae in weir	Grass shore in weir
* Order Ephemeroptera - mayflies														
Leptophlebiidae														
Atalonella sp.							3							8
Atalophlebia sp.	1				5	10	1	5						2
Jappa sp.					5		1							
Siphlonuridae														
Tasmanophlebia sp.												2		
* Order Odonata - dragonflies														
Aeschnidae					1									
Lestidae														7
Chlorolestidae	5		1	2							1			29
Order Plecoptera - stoneflies														
Notonemouridae					1									
Family?									1					
Orthoptera - grasshoppers														
Superfamily Acridoidea										3				
Hemiptera - bugs														
Corixidae														
Agraptocorixa sp.					1				3	1				1
Micronecta sp.1														124
Micronecta sp.2														9
Sigara sp.					1				3			6		684
Naucoridae														
Naucoris sp.											5			1154
Notonectidae														
Anisops sp.											1			341
Mesoveliidae					1	1	4							
cf. Veliidae							1							
Megaloptera - alderflies														
Corydalidae														
Archicauliodus sp.; larva			1											

AQUATIC INVERTEBRATES COLLECTED FROM VARIOUS HABITATS ON DUCKMALOI RIVER, SUMMER 1986/87.

LIST OF SPECIES	Pool I	Pool IV	Pool VI	Deep Pool below weir	Riff. I	Riff. IV	Riff. above Deep Pool	Gut 1	Gut 2	Gut 3	Coarse sand cores	Fine mud cores	On algae in weir	Grass shore in weir
Sialidae Austrosialis sp.; larva											1			
Family?; adult											1			
* Coleoptera - beetles Carabidae; adult									1					1
Helminthidae; adult									1					
Spercheidae; adult					1					8				2
Family ?; adult					1									
Family ? ; adult											2			
* Diptera - flies Chironomidae Chironominae; larva					6	16	11		2		750	2		65
Orthocladiina; larva					3	7	18		1		133			1
Subfamily ?; larva											4			
Subfamily ?; pupa sp.											26			3
Subfamily ?; pupa sp.											6			
Subfamily ?; pupa sp.											3			2
Culicidae - mosquitos Tribe Anophelini; pupa					1									4
Tribe ?; pupa					2	1	2							
Simulidae - blackflies larva						1	54							
pupa						1	56							
Family ?; adult fly	1													
* Trichoptera - caddisflies Ecnomidae; larva						1								
Hydroptilidae														7
Hydropsychidae; larva						22	16			1				

AQUATIC INVERTEBRATES COLLECTED FROM VARIOUS HABITATS ON DUCKMALOI RIVER, SUMMER 1986/87.

LIST OF SPECIES	Pool I	Pool IV	Pool VI	Deep Pool below weir	Riff. I	Riff. IV	Riff. above Deep Pool	Gut 1	Gut 2	Gut 3	Coarse sand cores	Fine mud cores	On algae in weir	Grass shore in weir
Leptoceridae sp. 1; larva	1		1											
Leptoceridae sp. 2; larva									35		2			57
Leptoceridae sp. 3														4
?Odontoceridae; larva							2							
Philopotamidae; larva					10	7	15							
Philorheithridae; larva					1	1				2	1			
?Tasimiidae; larva						1								
Family ?; eruciform larva							2							
Family ?; pupa					2	3	9							
Family ?; adult					1									
Hymenoptera - bees Family ?; adult											1			
Neuroptera; Family ?; larvae														8
Phylum Chelicerata														
Class Arachnida														
Order Acarina														
Hydracarina									8					
mite sp. 2											1			
Fish, very digested								1						
Ostracod:														
Darwinulidae														
Darwinula sp.?														30
No. of species	6	5	5	3	20	16	21	2	9	5	18	4	2	29
No. of individuals	13	8	5	7	86	86	250	6	55	15	1116	33	17	2876

TABLE I.B.1

AQUATIC INVERTEBRATES COLLECTED FROM VARIOUS HABITATS ON DUCKMALOI RIVER, SUMMER 1986/87.

NOTES:
Refer to Figures I.2 and I.3 for location of sampling sites.
Deep pool below weir - Fyke net used for platypus.
Riffles I - Above Pool I.
Riffles IV - Above Pool IV.
Gut 1 - Gut contents of brown trout caught downstream of weir 4/12/86.
Gut 2 - Gut contents from rainbow trout caught in weir 3/12/86.
Gut 3 - Gut contents from 2 rainbow trout: 1 from Pool II, 1 from Pool IV, 28/1/87.
Coarse sand cores - Station 1, Cores A-D in weir.
Fine mud cores - Station 2, Cores A-D in weir.
On algae in weir - Living on algae in weir, Dec. 1986.
Grass shore in weir - Grassy shoreline behind weir: three passes over 5 metres.

* Orders of benthic invertebrates known to provide food for platypus (from Faragher and others, 1979; Grant, 1981).

APPENDIX J

PLATYPUS

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APPENDIX J.

THE IMPACT OF THE PROPOSED FISH RIVER AUGMENTATION SCHEME ON THE PLATYPUS POPULATION IN AND AROUND THE DUCKMALOI WEIR

DAVID GOLDNEY, B.Sc., Dip.Ed., Ph.D.

1. INTRODUCTION

The Fish River Water Supply System operated by the Public Works Department of N.S.W., delivers water from the Oberon Dam and Duckmaloi Weir Catchments to the Electricity Commission's Power Station at Wallerawang and to Oberon, Greater Lithgow and the Upper Blue Mountains Area. Water in the system flows through both natural Channels and a series of pipelines. The Duckmaloi river above the Weir, is fed from a catchment area of 110km² perched on the western side of the Great Dividing Range. The small shallow Weir of 20 ML capacity is the take-off point for an existing pipeline running from the Weir to the Duckmaloi Break-Pressure Tank before continuing its flow northward to Wallerawang. A recent reassessment of the annual yield of the Fish River Water Supply scheme indicated that the existing minimum water requirements cannot be met with the desired security of supply.

The proposal currently being considered is to extract up to 33 ML/day through the existing pipeline by gravity feed, treating the turbid water at Duckmaloi Break Pressure Tank.

The effect of the proposed works on the weir storage will be limited to a draw-off which will maintain a minimum flow over the weir of 6 ML/day. The actual frequency, extent and duration of the draw-off will depend on inflow to the weir at the time.

The Duckmaloi Weir in particular, and the river up-downstream have been observed to support a significant platypus population, (Goldney, unpublished data). The platypus is common enough in the Central Western Region, and secure as a species. This particular river system appears to have unusual significance for the study of the ecology of the platypus because of its accessibility and the density of platypus. It is the task of this report to:-

(1) ascertain the density and numbers of the platypus population in the vicinity of the Duckmaloi Weir,

(2) assess their vulnerability to any disturbance posed by the increased water take-off,

(3) recommend ameliorative measures that can be taken to ensure the local survival of this particular colony.

2. REVIEW OF WHAT IS KNOWN ABOUT EFFECTS OF WATER STORAGE ON PLATYPUS

Little is known about the effects of impoundment and the construction and operation of associated engineering infastructure on platypus survival in the wild. Grant (1981) in a paper entitled 'Platypus and Dams - Questions and Hypotheses', suggested that there are three groups of platypuses which may be at risk in the process of dam construction.

He identified these as being the site population, the downstream and the upstream populations.

In a subsequent study of a 2m-depth pipehead weir constructed on the Barnard River by the Electricity Commission of N.S.W., Grant (1984) suggested that procedures could be developed which "should permit the assessment of the actual impact of this type of development" (the construction of a small pipehead weir) on these three groups of platypuses. His deliberations are summarised below.

(1) The site population
In spite of their tolerance to some levels of human activity, construction work and associated processes such as drilling, road construction and blasting significantly disturb or kill platypus and destroy sites and feeding areas. Grant suggests that it would be advisable to commence any construction work on a river in the non-breeding season. Grant (1984) hypothesized, "The strong site attachment of certain individuals should make their recapture after the development is finished and functioning highly probable unless they have been affected in some way".

(2) Upstream population
Grant in his 1981 paper noted that virtually without exception captured or observed platypus in (large) impoundments have been in water less that 5m in depth and are found mainly at mouths of creeks. In Grant's view, the main reasons for the absence of platypus in deep impoundments are the deep water and the scouring of banks due to fluctuating water levels, which prevents effective burrowing and interferes with bottom-dwelling animals. In contrast to this situation, Grant (1984) hypothesized for the shallow Barnard River Weir "that platypuses may use the impounded waters behind the weir due to its being quite shallow and not being subject to wide fluctuations in level. Follow up netting would test the validity of this prediction".

(3) Downstream populations
Grant (1981) notes that for large impoundments, the fluctuation in temperature and oxygen concentation of released water can effect both the diversity and productivity of bottom-dwelling organisms on which platypus feed. Grant (1981) points out that the most critical factor downstream of an impoundment is the decrease in flow rate. He points out that this

i reduces available forage areas

ii exposes riffle surfaces

iii separates river fom burrowing areas provided by consolidated banks.

Grant argues that by providing for adequate release of water of suitable quality, the effect of an impoundment on the downstream platypus population could be minimised.
He hypothesises in his 1984 paper that "the occurrence of site-attached animals in this area would permit assessment of any downstream effects such as siltation or reduced water flow. As it would appear that drought has an effect on the numbers of females breeding in a population (Grant, 1984), lactational data from females below the weir would provide an indication of whether reduced flows caused by extraction of water from a river would produce the same effect.
In the Barnard River, Grant (1984) captured adult platypuses downstream from the proposed development which had coped with river discharges as low as 5 ML/day. These platypuses could have been suffering from food scarcity due to possible loss of forage areas. This led Grant to recommend a water release in excess of 12 ML/day (In the Barnard scheme only) to be maintained at all times except where input was less than this flow. He further captured five animals at the weir site and relocated them to test his site-attachment hypothesis. Two returned to the construction area overnight, a journey of 5km upstream. He also showed that human activity did reduce platypus capture in the areas of greatest disturbance during dam construction. Grant points out that this may be the result of behavioural changes in the animal rather than emigration from the disturbed area.

3. SITE DESCRIPTION

(1) General

Duckmaloi Weir is located appoximately 38 km SW of Lithgow and 10 km SE of Oberon. It is set in undulating improved pasture land. The underlying granite crops out in boulder formation of various kinds.
The weir is fenced on all sides to exclude sheep and cattle from using it as a watering point but the fence is breaking down and some river bank collapse is occurring. The fringing remnant vegetation is mainly Snow Gum (*Eucalyptus pauciflora*), Yellow Box (*E. melliodora*) and Black Sallee (*E. stellulata*).

The understorey is a mixture of introduced pasture plants, exotic weeds, native grasses and herbs. Blackberry, *Rubus* sp, is beginning to dominate the understorey edge vegetation in the vicinity of the weir. Basket Willow, *Salix alba* is also prevalent along the water's edge upstream and downstream.
The surrounding land is freehold and is more or less isolated from the general public by virtue of access being via locked gates and rough tracks. Land use is for predominately grazing purposes. The top water level is at 1057 AHD. The weir wall is of concrete arch design. The area experiences warm to hot summers and cold winters. Some winter snow is

usual. Rainfall in the catchment varies from 1060 mm/a on the heights of the Great Divide to about 960 mm/a west of the weir. Oberon receives 840 mm/a. Potential monthly evaporation varies from 30mm in June-July to approximately 180 mm in January-December. Water temperature in the weir varies from summer highs of 22°C to winter lows of 4°C. Ambient temperatures can fall as low as -18°C. (Source, Soil Conservation Service, Bathurst Soil Conservation Manual)

(2) The Weir
The surface area of the weir when full is about 2.4 ha (see Figure J.1). The weir backs up water along the main channel for a distance of 410 m. Two hundred metres from the weir it forms a small alluvial shallow backwater. The depth of the weir varies from 3.4 m to 0.3 m. Sediment depth varies from 0 to 0.8 m. In the backwater area (See Photograph J.1) islands of vegetation dominated by *Juncus* sp are found. A range of water loving plants occur along the edges including *Baumea* sp, *Carex* sp, *Eleocharis* sp, various graminoids, *Phragmites* sp, *Juncus* sp and Typha sp. More details are given in Appendix I of the main report.

Downstream from the weir, the river drops from 1060 to 930 m through a steep valley and is fringed by remnant woodland and willow. It varies in width from 5m to 10m depending on water flow. Pools alternate with narrow riffle areas, (see Photograph J.2) Further down, approaching the Hampton Road (6 km below the weir), a number of larger pools are found. Upstream, the river flows through cleared flat grazing land. From the junction with Duckmaloi Creek, 15 km upstream, to the weir, the river drops from 1160 to 1060 m.

4. WATER FLOW

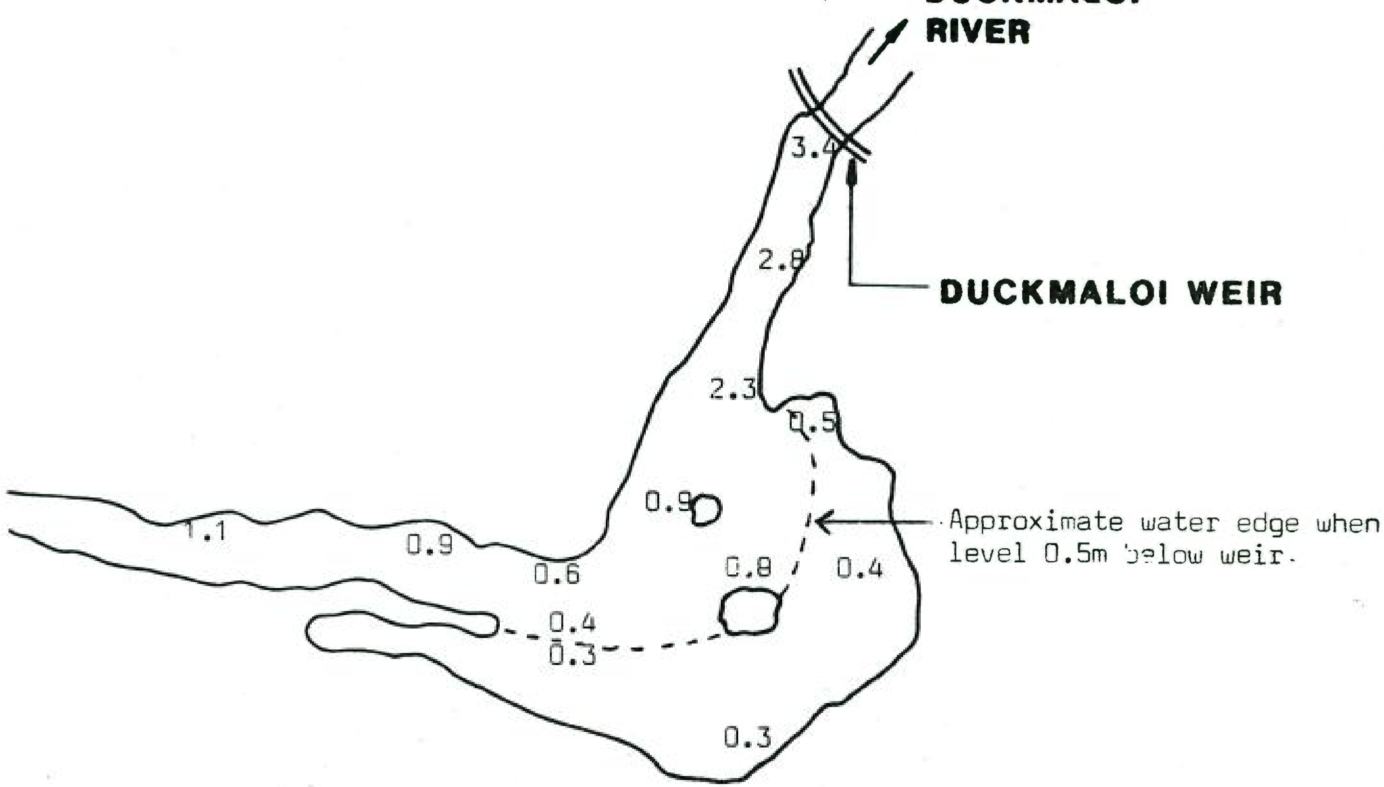
The mean annual flow passing through the Duckmaloi has been estimated at 20,200 ML/a (PWD, 1985a). The stream flow is characterized by erratic fluctuations varying from yields as high as 93 GL/a to lows of 1 GL/a. Rooney (Appendix I) has recommended that the desirable minimum flow to maintain suitable stream characteristics downstream from the Duckmaloi Weir should be 5 ML/day but adds that flows down to 3.5 ML/day could be tolerated for short periods (see Appendix I). Rooney was specifically looking at the needs of fish and small invertebrate animals.

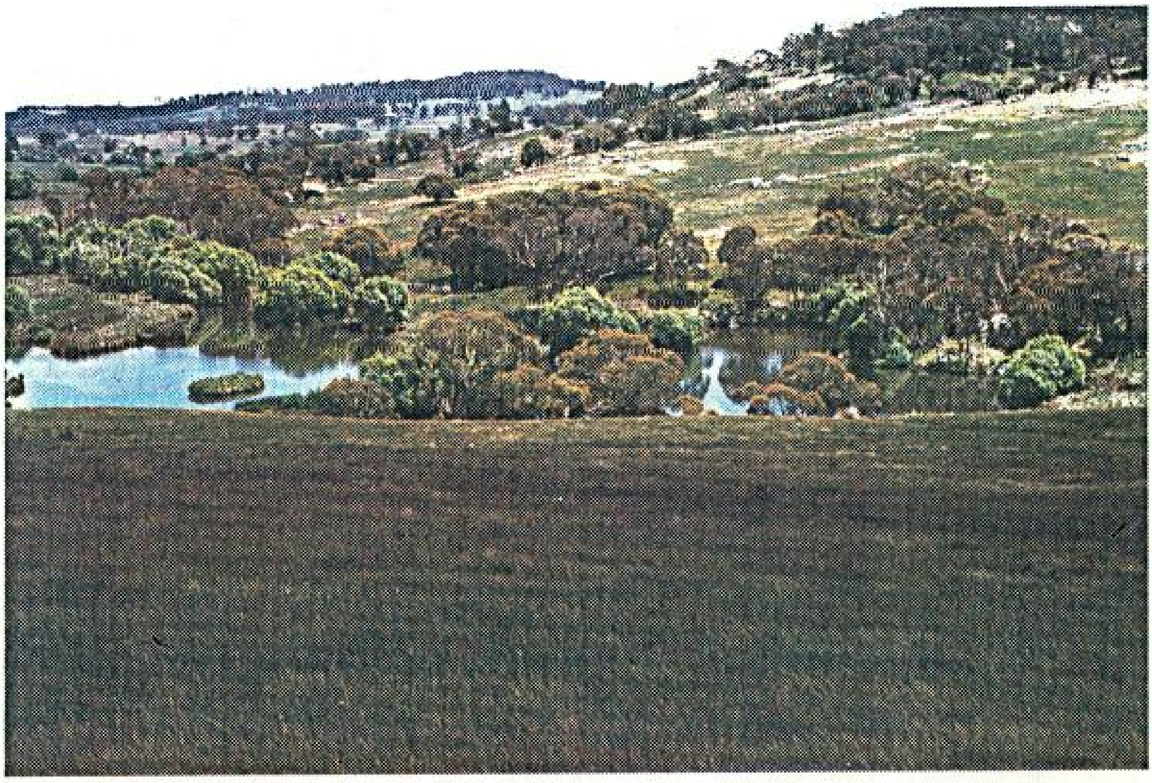
The critical question however, still needs to be addressed as to whether the present required riparian releases (0.5 to 2.0 ML/day) or Rooney's recommendation referred to above are sufficient to satisfy the environmental requirements of platypuses downstream from the weir.

The critical area of the river to be considered in this report is the 3km immediately downstream of the pipehead weir to the junction of McKeons Creek. McKeons and Teatree Creek catchments together come to approximately half the area of the Duckmaloi Weir catchment. It is reasonable to assume that additions of water to the Duckmaloi from these

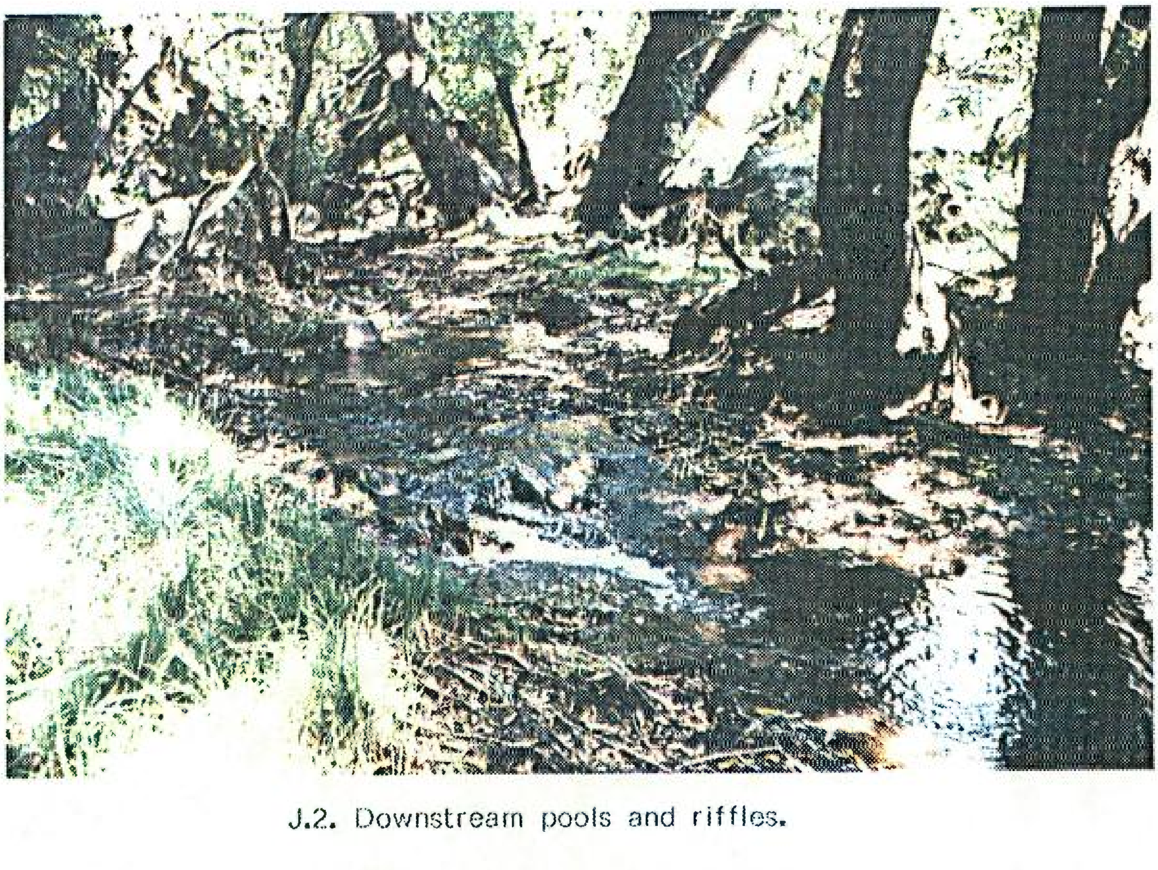
FIGURE J-1: PLAN OF DUCKMALOI WEIR WHEN WATER LEVEL AT 1058.63m

Volume 20 ML
Weir Wall 1058.63 m.a.s.l.
Area of surface water when full 2.3 ha
Length from weir to Duckmaloi inlet approx. 420 m
Maximum width 135m
Loss of surface area when water level 0.5 m below weir approx. 0.70 ha (30%)
Sediment layer varies from 0 to 0.8m in depth





J.1. Shallow backwater area.



J.2. Downstream pools and riffles.

two creeks will, under non drought conditions, ensure flows considerably above the requirements downstream from the junction with McKeons Creek.

5. WATER QUALITY

Some aspects of water quality have been monitored by the Public Works Department and the Water Board over the last 6 years. Parameters measured include temperature, oxygen, conductivity, suspended solids, colour, turbidity, chloride, iron, pH, $CaCO_3$ alkalinity, $CaCO_3$ hardness, algal concentration, colliform bacteria and *E. coli* levels. Some information for nitrate and phosphate levels is also available. Further details on water quality are discussed fully in Rooney's report (Appendix I). Rooney's results lead to the general conclusion that the Duckmaloi River is in good chemical and biological condition.

6. THE BIOLOGY OF THE PLATYPUS

It is reasonable to assume that the biology of the Duckmaloi platypus will differ little from that observed elsewhere. The following details are a brief summary of the various aspects of the biology and ecology of the Platypus recorded in Burrell (1927), Collins (1973), Dawson (1983), Fleay (1980), Grant and Fanning (1984), Griffiths (1978), Temple-Smith (1973) and Strahan (1985).

The platypus is a furred mammal that lays eggs. Both reproductive and waste products exit from the one external opening and hence it belongs to the order Monotremata. Except for mating, the animals appear to be solitary in life style, but little is known about their social system. Males can be distinguished from females by the presence of a spur on each of the hindlegs which in the breeding season produces more venom than at other times of the year. Ageing of animals can only be monitored by noting changes in length, weight, spur morphology and tagging of some type. Adult platypuses in the wild can live up to 10 years or more. In the non-breeding season, males and females are generally thought to live in short camping burrows, whose openings are usually above the water line.

Some animals exhibit strong site attachment, whilst others have been shown by radio telemetry to be quite mobile, moving distances in excess of 2km over a 24-hour period. Little is known about their home range.

The platypus tends to appear at dusk and dawn, but is active throughout the night. It feeds in water sometimes on the surface, but mainly by diving to the bottom for periods usually not in excess of 90 seconds but up to 3 minutes. There it uses its particularly sensitive 'bill' in a sweep-like action to sense and forage for a range of mainly bottom-dwelling animals, insect-larvae, worms, shrimps and occasional adult insects and fish eggs. The platypus can feed in slow-flowing and rapid areas of rivers. In cold alpine weather, the platypus may be forced to forage during part of the day in order to satisfy its energy budget. The normal temperature of a platypus is 32°C which it is able to maintain in spite of the extremes it may encounter in its environment.

Prior to mating, the female platypus is believed to build or re-occupy a complex nesting burrow from 8m to 30m in length, with side branches and a nesting chamber lined with vegetation. The burrows normally follow the slope of the bank, no more than 0.5m under ground. Mating can occur between late June to September. Gestation is believed to last about one month and incubation of the (14x17)mm egg(s), ten days. Lactation lasts up to three and a half months. Young could emerge from the nesting burrow between January and March, depending on the time of mating. The fate of the dispersing young is not known, but it is assumed in common with many wild populations that mortality in this age group is high. Some are recruited to the local population. Both immigration and emigration may occur.

Floods are one of the major hazards facing platypus but little is known of their effect. Grant (1982) in his Shoalhaven study inferred that whilst flooding probably causes some level of mortality in a platypus population, others ride out floods in an unknown manner and may not even be displaced from their home ranges. Drought is the other extreme which platypus may have to contend with, during which water pools may form, or dry up completely. Under these conditions both the reproductive capacity and absolute numbers are believed to decrease. (Grant 1984),

The population that a particular river can support is its carrying capacity and will be determined by the food organisms available on the river bottom. The relative health of a platypus and the adequacy of its diet is possible to determine using an index of tail fat.

7. THE DUCKMALOI PLATYPUS - SUMMARY OF RESULTS

Greater detail is provided in Appendix J.1 of this report.

The population of platypus in the vicinity of the Duckmaloi Weir has been investigated during 1986/87. Sixty seven animals have been captured 131 times. A picture has emerged of a mobile, relatively dense population using the weir area, with few long-term residents and with a considerable turnover occurring in the population. It is relatively common for new animals to be trapped on any given trapping expedition. The majority of juveniles appear to disperse after emergence. Their rate of mortality may be very high. The monthly 'Known to be Alive' estimates (KTBA) on the weir range from 6 to 20. Adult males appear particularly mobile, are present in significantly less numbers than females and are less likely than females to be retrapped. A population of breeding females uses the weir. Some animals are site-attached, some appear to be passing through and others probably include the weir as part of their home-range or as a refuge from time to time. Both telemetry and trapping results indicate that platypus move up and down the river. For at least some animals these distances are of the order of 2 to 3 km.

The ratio of animals present per unit distance in the Weir, Upstream, downstream from the weir to the rocky gorge, the rocky gorge and below the gorge, was determined to be respectively 30:6:6:1:6. The actual population downstream from the weir to McKeons Creek is estimated to be from 10 to 30 animals.

The relation between downstream, upstream and weir animals is not fully understood. It is assumed that animals captured on the weir are in dynamic equilibrium with upstream and downstream animals (after allowing for some unknown rate of mortality to occur) via the processes of immigration and emigration. The role of farm dams, if any, in this process is unknown.

The maximum density of platypus visually observed on the weir in winter and summer and confirmed by trapping approaches 8 platypus/ha. The high secondary productivity of the weir area with its consequent relatively high carrying capacity appears to be dependent on the ideal conditions which the weir presents.

8. IMPACTS OF THE PROPOSED DUCKMALOI DEVELOPMENT ON THE PLATYPUS POPULATION

(I) Fluctuations in the Weir water level

The proposed offtake is planned to be managed so that at least 5.0 ML/day of water is available to spill over the weir, provided there is sufficient flow from upstream. Other than in drought periods, the water level in the weir will not fall below the top level of the weir wall. Nevertheless, some small fluctuations will occur with offtake from the weir. This may be detrimental to some invertebrate animals over the relatively small falls in water level which could occur. Overall any such effects would be minimal and not in any way interfere with the platypus population.

Figure J.1 indicates the approximate position of the water edge when a fall of 0.5m occurs in the weir. Effectively, the weir surface area would be reduced by 30% because this section of the weir is so shallow.

There has been little work in Australia on the effect of water level fluctuation on benthic organisms. However, Hunt and Jones (1972) studying this effect on an artificial lake in Wales, demonstrated a potentially damaging effect on both bottom-dwelling animals and edge macro-vegetation. If, for example there was a drop in water level of 0.5m at Duckmaloi Weir in high summer, the effect on the food chain and hence on the platypus population could be significant. Whilst the loss of water surface area is only 30%, the secondary production of bottom-dwelling animals in the shallow areas is relatively much higher than in other parts of the weir (Rooney, 1987). This is because of the islands and protuberances from the edge of macro-vegetation important as food, shelter and a place where many bottom dwelling fauna lay their eggs. It may be that in times of drought, providing inflow is not less than riparian release, the Duckmaloi Weir acts as a staging area similar to the function performed by isolated water bodies for water birds in a drought year.

(2) Reduction in flow downstream

The scheme results in reduced flow downstream, since as much as 33 ML/day may be drawn off via the existing pipeline. The critical flow level(s) below which

a. platypus stop breeding
b. platypus relocate and/or perish

are not known. Presumably they will be different for river systems of varying physical dimensions. Grant (1984) captured adult platypus which had coped with river discharges as low as 5 ML/day in the Shoalhaven System. There was evidence that these animals were suffering from food scarcity due to possible loss of forage area. Obviously the 6 ML/day minimum flow recommended for the Duckmaloi will produce significantly different flow characteristics in the narrow Duckmaloi compared with the Shoalhaven System described by Grant.

It is thought that flow in the Duckmaloi has dropped to levels of 0.5 ML/day on at least 9 occasions in 100 years. J. Armstrong, a local resident has observed the Duckmaloi to stop flowing during the last major drought in the mid-1980's. Flows of approximately 6.0 ML/day are relatively common. In spite of low flows in recent droughts, the platypus population has survived. Whether mortality rates are high under conditions of low water flow is not known, nor is the potential for recovery. The critical features in this section of the river for platypus survival are the maintenance of the riffle-pool continuum and the aeration levels needed to sustain invertebrate and benthic life. Rooney's investigations show that both these critical features will be maintained when water flow falls as low as 3.5 ML/day for short periods or to 5 ML/day in the long term (Appendix I).

(3) Fluctuations in water level below the weir.

Under some circumstances, water levels below the weir could drop quickly when water off-take occurs (eg 13 ML/day to 6 ML/day). The critical feature here is the effect on invertebrate organisms along both the river's edge and associated with riffle areas. Generally, the narrower the river passage, the greater will be the effective water drop. Aeration, as Rooney has shown, will be adequately maintained. The effect on platypus would be expected to be minimal. Whilst some loss in secondary production will occur, particularly near the weir, under the circumstances described, many organisms will be able to relocate to the deeper zones of the stream. Further downstream, fluctuations will be buffered by the many large pools, thus allowing a greater number of organisms to re-establish in wetter substrates during the rapid drawdown phase.

(4) Siltation behind weir

Build up of silt will affect both the long-term viability of the pipehead weir and the viability of the platypus population. Siltation particularly in such a shallow weir, will eventually be accompanied by plant succession, the deposition of more silt and the eventual natural drainage of particular areas. Some management intervention to control siltation will be needed from time-to-time. Whilst silt control can only be expected to be undertaken by PWD for maintaining a suitable river storage, some benefits will also flow to the maintenance of the platypus population, providing this is done in conjunction with advice from a freshwater ecologist.

(5) Emptying of the weir for maintenance of existing valves and infrastructure if required.

What the effect on the platypus population will be is unknown. It is hypothesised that no permanent displacements would result from emptying the weir for a very short period of time. If the weir is emptied rapidly, then silt may be forced downstream to the detriment of that environment. While this may partially simulate flood conditions, at least in the initial phase of the increased flow of water, silt deposition patterns could be expected to be significantly different under these contrived conditions, compared with natural flooding. Rooney's recommendations in this regard appear very reasonable; viz the maximum drawdown period be as brief as possible - a few hours to a day or two maximum and outside the breeding and lactation season (Aug-Mar) - the best period being April-May.

The data from this study point to the following inferences which are of relevance to the impact of the proposed reduced flow

(a) the downstream area forms part of a corridor which platypus use moving both up and downstream

(b) the comparative numbers of platypus in the rocky gorge section are significantly less than in the weir and in other sections of the river below and above the weir pond

(c) the benthic organisms in the rocky gorge are mainly associated with the riffle areas, particularly the willow-root mats whereas the pools in this section are relatively unproductive (Appendix I).

(d) The proposed over-flows of 6 ML/day have been shown by Rooney (Appendix I) to maintain good aeration characteristics down to Teatree and McKeons Creeks. This flow will maintain critical riffle areas downstream of the weir and maintain interconnecting pools. This level of water flow should also allow for the movement of platypus upstream and downstream from the Weir to McKeons Creek. It will also allow for the maintenance of essential food sources for platypus in the riffle-pool continuum.

(e) It is probable that few if any females breed in the rocky gorge, since available sites for breeding burrows appear almost non-existent.

(f) In the river section below the rocky gorge to the junction with McKeons Creek there are relatively few riffle areas. The existing pools are interconnected by a river bed of more-or-less uniform width. Reduced flows may mean a reduction in forage areas available for platypus but this would not be directly proportional to loss of flow. A reduction in flow for example from 10 ML/day to 6 ML/day would maintain pools in aerated conditions, reduce depth of water, but not greatly reduce width of river. Hence only a small loss of benthic organisms associated with vegetation edges would occur as the river depth dropped. In my opinion this flow of water will maintain platypus population levels near those observed during 1986/87.

9. MONITORING PROGRAMME

No firm data exists on the critical flow levels below which platypus may cease using a waterway for movement, feeding and breeding purposes. Hence it would appear useful to monitor the effects of the reduced flow resulting from this augmentation scheme to determine if it impinges significantly upon the platypus population, at least in the first few years after the commencement of the scheme. Additional information on the relative importance of the weir backwater area and the shoreline vegetation to the platypus colony would also be desirable, particularly in designing a silt removal programme.

The information obtained from this monitoring would also be relevant to other weirs operated or designed by the PWD.

10. CONCLUSION

The proposed extraction of up to 33 ML/day via the existing pipeline is recommended to proceed, provided that flows of 6 ML/day are allowed to spill over the weir (except under natural low flow conditions). This will have no effect on weir or upstream animals. For downstream animals, Rooney (Appendix I) has shown that such flows will maintain an essential riffle-pool continuum, as well as sufficient aeration to maintain invertebrate and benthic life, both critical features in platypus survival.

Fluctuations due to the initial rapid draw-down when offtake commences could affect invertebrate organisms in riffles and edges, particularly in high summer. The effect of fluctuation will dampen down rapidly as distance from the weir increases and the buffering effects of pools are encountered. Since the estimated platypus population in the section between the Weir and McKeons Creek is relatively low, any effect on platypus, due to fluctuation or reduced flow, via food chains is predicted to be marginal but nevertheless should be monitored.

The measures recommended to be taken are expected to ensure the local survival of this particular colony.

11. RECOMMENDATIONS

See also recommendations in Appendix I

(1) Emptying of weir for Maintenance Requirements

RI The weir should not be emptied during the platypus breeding season. (August to March)

R2 The weir should not be emptied for a period exceeding 24 hours and should preferably be emptied during colder weather.

R3 A wildlife ecologist should be consulted before emptying the weir.

(2) Operational Phase

R4 The extraction of water should be managed so that water flows continuously over the weir. This strategy will result in water continuing to cover the weir backwater area, in which the greatest productive capacity of the weir is to be found, and will prevent surface stagnation, particularly under summer conditions when algal blooms tend to occur.

R5 A release management programme which reflects as much as possible the expected natural flows down the river should be instituted. The minimum release, other than under drought conditions should not fall below 6 ML/day.

R6 The release management programme should be developed by Public Works, Department of Agriculture (Fisheries), Department of Water Resources and relevant consultants guided by the following criteria :-

a. maintaining a suitable aeration profile

b. maintaining variability in flow

c. maintaining pools and riffles in a manner which promotes secondary production

d. controlled release of weir water when maintenance is required

R7 Silt depth be regularly monitored

R8 Management intervention be planned to control siltation in the weir and remove build-up from time to time in consultation with a wildlife ecologist.

R9 A monitoring programme be maintained for at least 2 years from the commencement of the augmentation scheme to

a. monitor the effects of water extraction on the platypus populations downstream of the weir.

b. monitor the effect of fluctuations in water level on the food sources for the platypus.

12 ACKNOWLEDGEMENTS

I wish to acknowledge the help given by Mr Peter Russell, Public Works Department, in explaining the engineering problems and hydrological phenomena associated with the proposed construction; Dr Tom Grant, Honorary Fellow, School of Zoology, University of NSW for professional advice, for commenting on this manuscript and for demonstrating a range of techniques used in the field; W S Rooney and Associates for a detailed assesment of the aquatic ecology of the study area, and for additional insights into instream flow requirements. Ian McArtney, Alex Goldney, Gavin Waters, Phillip Bray, Karl Schaerf, Terry Rowel and Mitchell College students for enthusiastic field work; Joan Goldney for typing this manuscript; The National Parks and Wildlife Service and the Agriculture Department of NSW for providing the necessary licences to work with platypus; local graziers Mr John Armstrong and Mr Sandy Colqhoun for background information and for allowing access to the weir through their respective properties; and technical staff from the Mitchell CAE for preparation and maintenance of field equipment. I wish also to thank Dr Terry Lustig (Environmental Management) and Phil Armessan and John Anderson (Public Works) for additional hydrological data and providing further insights into the environmental problems associated with this development. Finally I would like to thank PWD and Mitchellsearch for providing financial support for this research.

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APPENDIX J.1

The Duckmaloi Platypus

Research Details

THE DUCKMALOI PLATYPUS

The Duckmaloi platypus population first came to the notice of Goldney in 1977 when assessing the effect of potential impoundment sites on the environment for the Bathurst-Orange Development Corporation. By visual means he assessed the population of platypus using the weir at about 25. In the years (1979-1987), he has spasmodically come to the site and banded 30 platypus, using unleaded gill nets. About 17% of these were recaptures indicating that there was some site attachment in the population. Unfortunately aluminium bands (rather than stainless steel) were used in early captures and these have been shown to be removeable by platypus. Since there have been no recaptures of tagged animals from the period 1979-1984 in 1986 and 1987, years of intensive trapping, it is assumed that bands have been lost, or that banded animals have died or emigrated.

In the period January 1986 to December 1987, a further 67 platypuses have been captured in 26 field trips (see Table J.1 below). Numbers caught ranged from 0 to 20. The latter group were caught on May 1st 1986 at net sites 1 and 2 in less than 2 hours. Seven of these were sub-adults from matings in 1985. It could not be determined whether they were residents or passing through in a dispersal wave. A similar wave of sub-adults was captured in March 1987 again over a short period of time.

(1) Total Capture Data

Total capture data in 1986/7 is displayed in Table J.1 below.

TABLE J.1

TOTAL CAPTURE DATA JANUARY 1986 TO DECEMBER 1987

	First Captures			First Captures + Recaptures		
	TOTAL	ADULT	+JUVENILE	TOTAL	ADULT	+JUVENILE
Male	27(40.3)*	14(33.3)	13(52.0)	29(22.1)	16(16.8)	13(36.1)
Female	40(59.7)	28(66.7)	12(48.0)	102(77.9)	79(83.2)	23(63.9)
TOTALS	67(100)	42(62.7)	25(37.3)	131(100)	95(72.5)	36(27.5)
SEX RATIO M : F	1 : 1.5	1 : 2.0	1 : 1.1	1 : 3.5	1 : 4.9	1 : 1.8

* Percentages given in brackets
\+ Juvenile is any young from 85/86/87 breeding

Table J.1 indicates that more individual females are captured compared to individual males. This is also reflected in adult first captures but not in juvenile captures. First capture adults number 1.7 times that of first capture juvenile numbers. When recaptures are added to first captures, Table J.1 indicates that significantly more females than males are recaptured in both adult and juvenile members. 46% of animals (30) have been recaptured once or more. The ratio of M:F (juvenile) in 1987 is more-or-less the reverse of the ratio in 1986 (ie M:F, 1:2.7 in 1986; 2.3:1.0 in 1987).

(2) Frequency of Recaptures/Captures

Frequency of captures is recorded in Figure J.2, 54.7% of animals have been captured once only. The other animals have been captured from 2-7 times. Only 3/25 males (12%) have been recaptured more than once and none of these more than 3 times.

(3) Calendar of Catches

The calendar of catches illustrates the capture of individual animals over time (See Table J.2). The table records the month of initial capture and any subsequent recaptures; differentiates between males, females, juveniles and adults; whether an animal has been captured upstream, downstream or in the weir; and whether breeding (L = lactating).

Of particular interest is the capture of one or more 'new' animals in all but three trapping months, and the recapture of only 6 animals after a period exceeding 12 months, up until December 1987. The calendar of catches clearly illustrates the pattern of the 'appearance' of new and the apparent 'disappearance' of previously captured animals.

Only 4 platypuses have been captured downstream of the weir, due probably to the unsuitability of gill nets, and the difficulty in the placement of Fyke nets. One of these, a male, had previously been captured in the weir. Of 4 animals captured upstream of the weir pond (ranging from 0.4 to 1.0km), only two had previously been captured in the weir.

(4) Known to be alive in the Weir and the immediate vicinity

The number of animals 'known to be alive' (KTBA) in the weir and its immediate vicinity are recorded in Figure J.3. The KTBA figures represent the minimum population numbers in the area at a particular time. Numbers KTBA vary from 6-21, the two peaks being made up of significant numbers of juveniles (17). The base KTBA, prior to the appearance of new young from January to May, is of the order 6-8 animals.

Of 25 juveniles captured, only 4 females were KTBA in December 1987 but no juvenile males. No animals have been captured continuously over the 2 years of this study.

Figure J-2. FREQUENCY OF CAPTURE

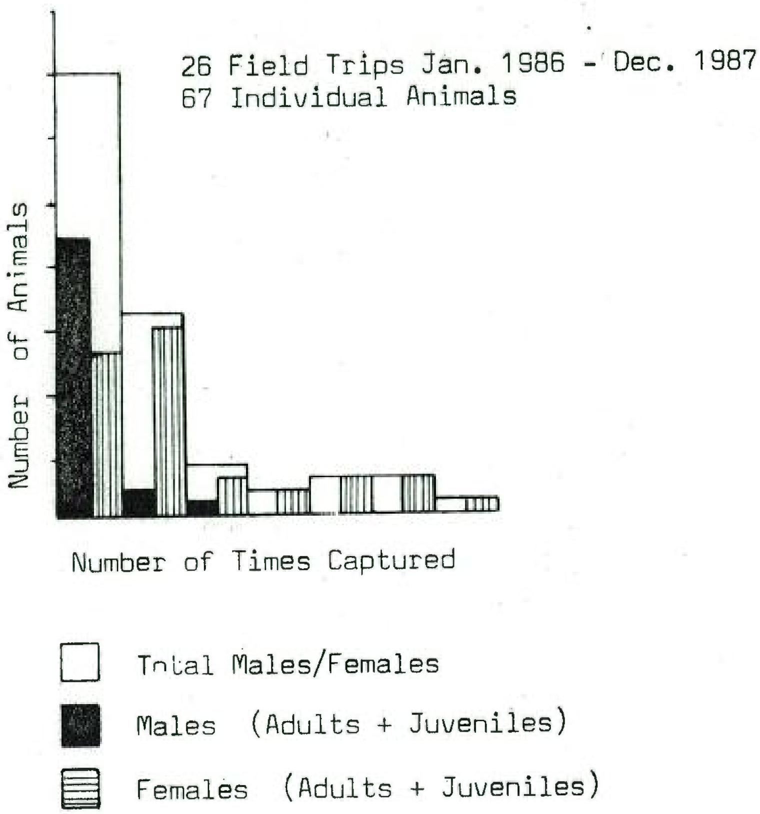
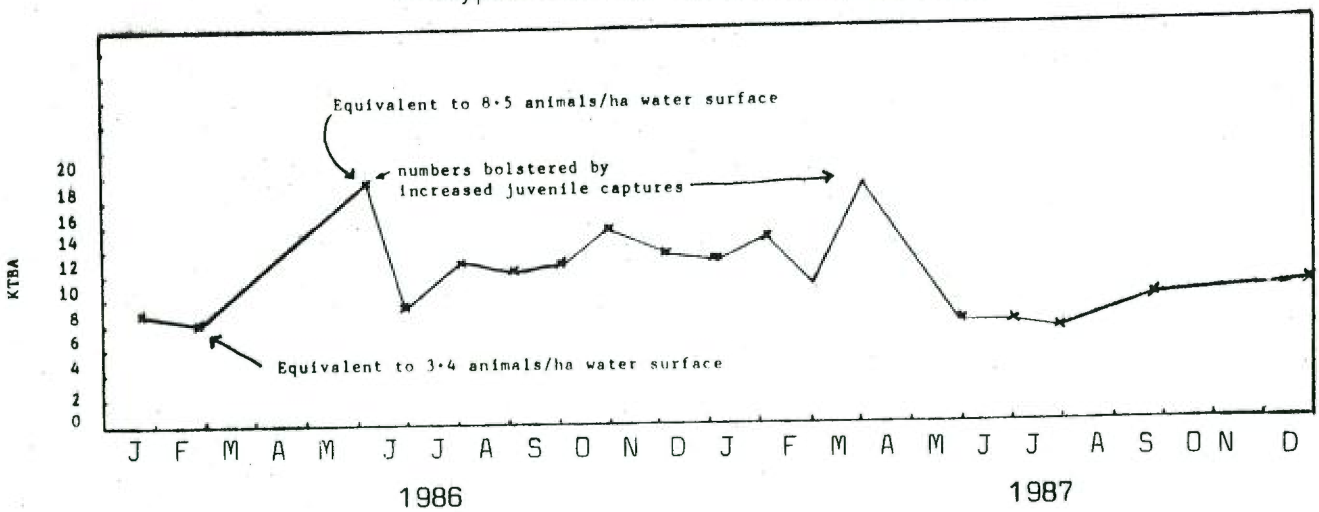


Figure J-3 PLATYPUS "KNOWN TO BE ALIVE" : DUCKMALOI WEIR AREA

Platypus KTBA on the weir varies 7-20.



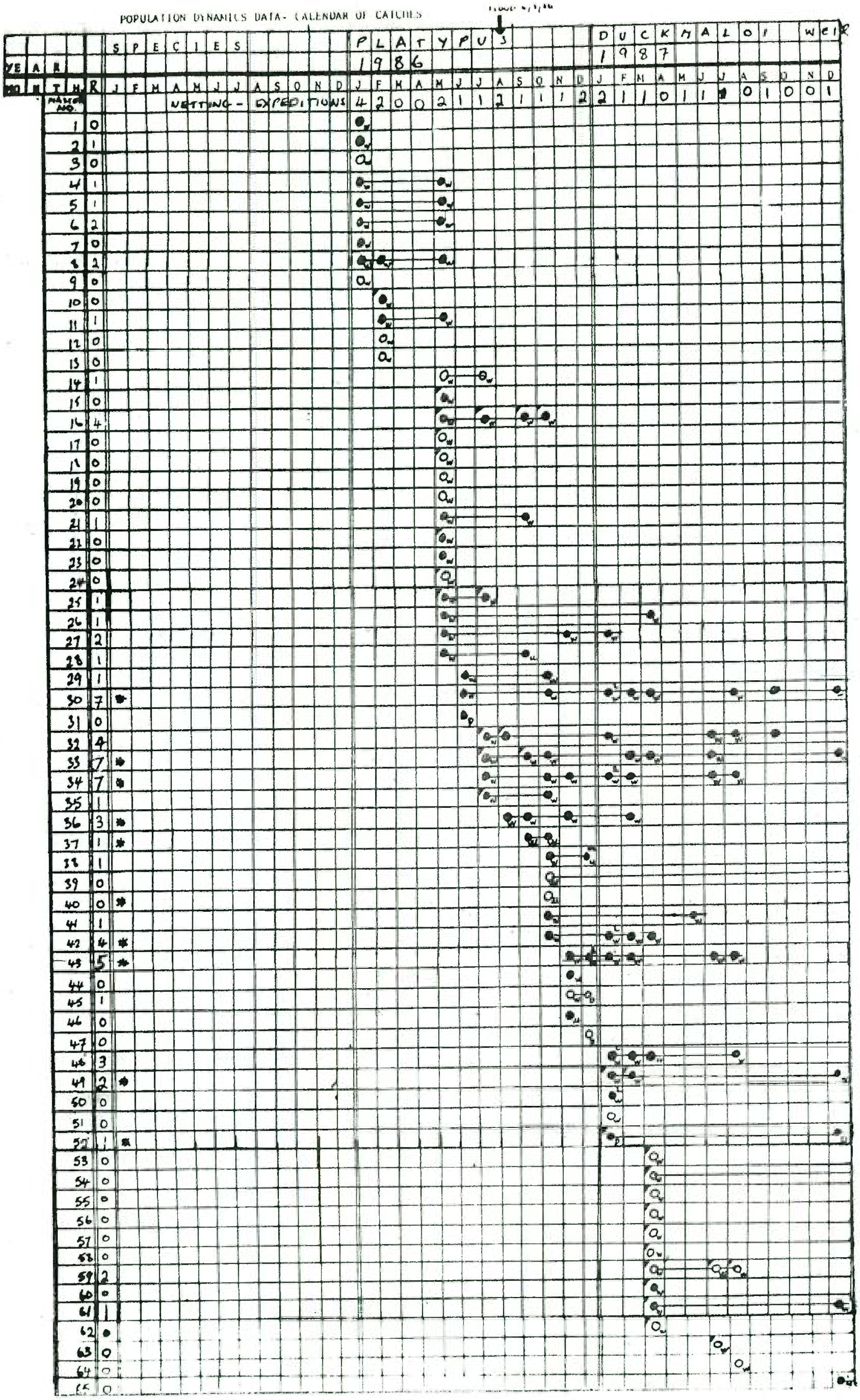
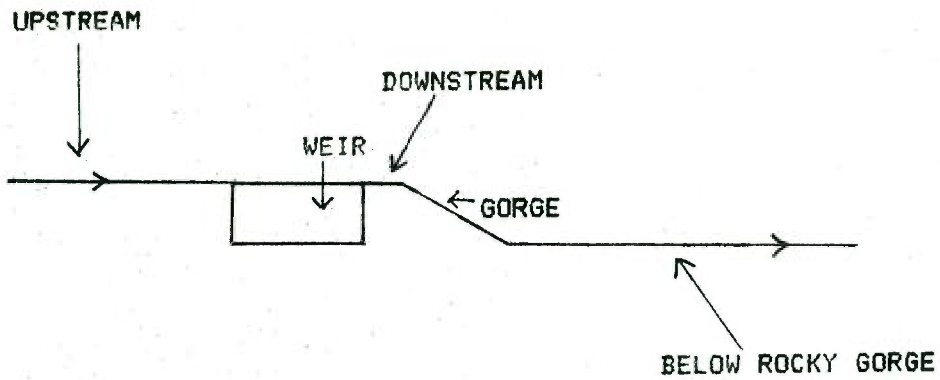


TABLE J-2 CALENDAR OF CATCHES

* Transmitter attached o Male • Female ◩ Juvenile.
W Captured on weir, D captured downstream from weir wall,
U captured upstream from weir, L lactating female
R number of subsequent recaptures

(5) Relative Numbers of Platypus

The relative population of platypus in the weir has been compared in a very coarse manner with those upstream of the weir pond and downstream of the weir. This was achieved by walking upstream and downstream from the weir at dusk or in the early morning and recording the numbers of animals observed per unit distance. Significant differences in the ability of an observer to view the river are caused through terrain and vegetation changes and an inability to walk at a constant speed. Nevertheless, the results probably reflect genuine differences in population numbers.



The ratios of animals observed in descending order were

Weir: upstream: downstream: below rocky gorge: rocky gorge

30:6:6:6:1

The high figure for the weir compared to the non-rocky upstream and downstream sections may be misleading, since obviously the surface area available for viewing in the weir area is much greater per unit distance walked. On the other hand, these data appear to correlate well with

(a) the relative abundances of benthic organisms (Rooney Appendix I)
(b) the unsuitability of the rocky gorge for burrowing by platypus.

(6) Estimated Platypus population downstream to McKeons Creek

If the following assumptions are made

(a) Weir carrying capacity varies from 4-9 platypus/ha water surface

(b) Ratio of animals observed in weir, comapred with those in various parts of the river to McKeons Creek, reflects the carrying capacity

(c) Water surface from the weir to below rocky gorge when flow 5-10 ML/day is approximately 5ha

(d) Water surface in remaining area to McKeons Creek (pools and riffles) when flow 5-10 ML/day is approximately 12ha

then the platypus population from the weir to McKeons Creek is estimated to be between (10-30) animals

(7) Movement

Monitoring of the movement of platypus has been assessed using telemetry. Small radio transmitters, with whip antennae, were attached to sheep-ear tags and placed on the tails of ten platypuses.

The animals which have been radio tagged are set out in Table J.3.

Animals 33 and 43 moved about 1km upstream on release and were found domiciled in that area for 36 hours before the transmitters ceased operation for whatever reason. Neither animal has been subsequently netted.

TABLE J.3 Radio-tagged Platypus

Field No.	Sex	Age	Place of Capture	Place of Release	Month of Release	Unit Operating
33	M	A	450m above Weir	450m above weir	Oct 1986	+No
43	F	A	Weir	Weir	Oct 1986	+No
80	F	J	Weir	Weir	Jan 1987	-No
29	F	A	Weir	Weir	Jan 1987	-No
47	F	A	Weir	Weir	Jan 1987	-No
8	F	A	Weir	Weir	Jan 1987	-No
19	F	A	Weir	Weir	Jan 1987	-No
82	F	J	200m downstream	200m downstream	Jan 1987	+Yes
14	F	A	Weir	2.00km upstream of Weir	Feb 1987	-No
37	F	A	Weir	1.5km downstream of Weir	Feb 1987	-No

+ Not recovered
- Unit removed. Limited transmisssion because of broken antennae and/or unacceptable damage to tails on recapture in nets

(A)dult
(J)uvenile

Animals 8Ø and 29, the former a juvenile, were observed over a period of 3 weeks, although not continuously. On all occasions they were found to be within the main weir area. Whilst the burrow area was located within 5Øm of the weir wall, both animals were often observed feeding in the shallow backwater section, but within 4ØØm of the burrow area. Neither were detected upstream or downstream.

Animals 47, 8, 19, all adult females, were radio tagged and released in the weir near the point of capture. Movement patterns followed over 3 weeks are similar to animals 8Ø and 29, with all movement confined to the weir area.

Animal 82, a newly emerged juvenile female, was released at the point of capture about 2ØØm downstream of the weir and observed over a period of 8 weeks, this juvenile remained within 15Øm of the point of release although moving up and downstream. The transmitter was still emitting signals in May '87, but no movement could be detected. The animal was recapturedd in a Fyke net in December '87, minus transmitter, but near the point of initial capture.

Animals 14 and 37, both adult females, non-lactating but just finished breeding, were captured on the weir on 19 February, 1987 and transmitters attached. Number 14 was released approximately 2km upstream and number 37 approximately 1.5km downstream. Female number 14 had returned to the weir within 4 hours of release and remained there until the transmitter was removed (5 weeks). She is still (Dec '87) a weir resident. Number 37 had, after two days moved upstream about Ø.75km over a considerably more difficult route. Six days later the signal could not be detected. This animal was recaptured in the weir, 5 weeks after her initial release, with the transmitter antenna broken and the unit not operating. How quickly she had negotiated her way around the weir wall to arrive back in the main weir section is therefore unknown.

(8) Breeding

Lactation data is available only from December 1986/January 1987 and December 1987. Two females captured in December 1986 were both lactating. One of these had ceased lactating when recaptured in January 1987. In that same month 5/8 adult females were lactating. One female was found lactating in December 1987. Assuming the 6 lactating females captured from the '86 breeding produced at least one young each, then, this could account for some of the 13 juveniles captured in 1987. However there is no evidence to claim that any of the young captured in the weir area are offspring of 'weir' females. That is yet to be determined by cross-checking blood samples for genetic relationships. The possibility still exists of juveniles captured on the weir being part of a juvenile dispersal wave, of which no doubt some are offspring of weir residents. To date the evidence is ambivalent. One female juvenile (judged to be newly emerged) was captured 1km upstream in a Fyke net during February 1988. Subsequently she was captured on the weir and a transmitter attached. She spent the night feeding, mainly in the shallow areas, and camped during the day in the weir area. A fortnight later she was observed, moving rapidly from some point greater than 2km upstream, to the weir area where she again fed throughout the night in the shallow areas. It appears probable that this is an 'upstream' bred animal which has subsequently used the weir as a feeding area.

The first juvenile capture was in February 1986. Two more were captured in January 1987. A flush of juveniles was captured in May 1986 (7) and March 1987 (10). Other first-captures of juveniles occurred in July (5) and August (1) 1986, and in June (1) 1987. At this stage twenty of the twenty-five juveniles captured have apparently 'disappeared' from the weir area. While these figures may subsequently change there is little reason to believe that it will on the evidence to date.

INTERPRETATION AND DISCUSSION

Sixty-seven individual platypuses have been captured 131 times. Of these, 35 have been captured only once (52%) and another 21 have been judged to have 'disappeared' from the system. Whilst recaptures have occurred throughout the study, some have been recaptured only within one calendar month, before apparently 'disappearing' from the system.

The results can be explained by one or more of the following hypotheses listed and commented on below.

(1) Some animals are passing through to areas upstream or downstream of the Weir

Only one animal, an adult male, has been captured in the weir and subsequently found downstream, indicating it had passed over or around the weir wall. Its initial capture occurred sometime after the August 1986 floods and hence its re-capture downstream cannot be attributed to its being 'washed over' the wall. On 'a priori' grounds it would appear reasonable to hypothesize that animals are free to move both upstream and downstream. The weir wall and the relatively rapid fall of the river immediately below the weir is no doubt a difficult barrier to platypus attempting to move upstream from below. One radio-tagged animal however has been observed to cross this barrier. Evidence gained from the use of both Fyke nets and telemetry indicates that platypus do move both upstream and downstream. At this point in time, movements of only 1-2 km have been observed. It seems reasonable to assume that of about 50+ animals which have been captured once or twice and which have 'disappeared', at least some, other than the few already described, are now domiciled somewhere downstream or upstream of the weir area.

(2) Some animals are able to remove leg bands and hence appear to be 'new' animals

This is unlikely since bands are made of strong stainless steel. Eight tail-tagged animals, with leg bands, have now been recaptured. Two have received a freeze-dry mark on the underside of the tail. There is no indication that bands are being removed.

(3) Some animals avoid nets after the initial capture

There is some evidence to support this statement. Animals have been observed to emesh themselves in a net only to subsequently escape. Larger animals (presumed male) have been seen to briefly touch nets and then to rapidly 'back off'. Some animals with tail-tags or bands have been recaptured only because the tag has snagged in a net as they have attempted to pass over. The lower recapture of males compared to females as reflected in the sex ratios (see Table J.1) can be interpreted in terms of their decreased 'trappability' after the initial capture.

(4) Some animals are resident but avoid nets and are never captured

There is no evidence to support this statement. It may be true for a relatively small number of platypuses. Visual counts of platypuses on the weir during any netting session appear to correlate well with the number of animals captured.

(5) Sub adults disperse in a wave

This is a possible explanation for the relatively high numbers of juvenile platypus captured on the weir in May 1986 and March 1987 but which, in the main seem to have 'disappeared' in subsequent months. If young have dispersed, it is not known whether they have moved upstream or downstream and over what distances; if they are forced into farm dams or if they suffer a high rate of mortality. Telemetry data suggests that some newly-emerged juveniles may remain in one area after emerging (See Table J.3, no's 8Ø, 82), as does trapping data (see Table J.2, animal Master no's 33, 49, 52, 61).

(6) Population turnover in the weir is continually occurring

The 'calendar of catches' data can be legitimately interpreted in this way, since new animals have been captured in all but three of 26 trapping sessions. A breeding population of females certainly exists. Its exact size has not been determined. Three lactating females present in the 86/87 breeding season were captured in the weir in July 1987 but only one of these in December 1987. Telemetry and netting studies have indicated support for strong site attachment for some animals but this appears to vary with time. One juvenile from the 85/86 breeding season and three from the 86/87 are now 'residents'. Most other juveniles appear to have 'disappeared'. The data for males strongly suggests both high mobility and continuous turnover with 'resident' status being no longer than a few months.

(7) <u>Mortality is high amongst juveniles</u>

There is some justication for this hypothesis. Only one juvenile (female) is known to be resident in the weir from the 85/86 breeding season and three females from the 86/87 season (Dec '87). If it is assumed that most juveniles are actively displaced by adults and that the available river habitat is more-or-less fully utilised by the existing adult platypus population, then this interpretation is particularly appealing. The susceptability of juveniles to predation and disease is unknown.

Hence a tentative picture is emerging of a mobile, relatively dense population using the weir area, with apparently relatively few long-term residents, and with constant turnover occurring in the population. Juveniles appear to disperse after emergence and mortality may be very high in this group. Juveniles may be site attached on emergence from burrows. The dynamics at work - mortality, natality, immigration and emigration, combine in an as-yet undefined manner to enable monthly KTBA estimates in the range 7-20 to be determined on the weir. Adult males appear particularly mobile, are present in significantly less numbers than females and are less likely than females to be re-trapped. Unfortunately, no males have been fitted with radio tags other than the unsuccessful No 33.

The relation between downstream, upstream and weir animals is not understood. It is assumed that 'new', 'disappeared' and 'resident' animals captured on the weir are in dynamic equilibrium with upstream and downstream animals (after allowing for some unknown rate of mortality to occur) via the processes of immigration and emigration. The role of farm dams, if any in this process is completely unknown. At least 2 platypuses have been reported in J. Armstrong's largest dam, some 1.5km from the weir site.

The present population, if affected by the severe drought of the 1970s and 1980s, appears to have recovered from conditions which reduced the Duckmaloi to a trickle with intermittent pools. The maximum density of platypus observed visually in winter and summer, and confirmed by trapping is approximately 8.0 platypus/ha of water surface. The high secondary productivity of the area with the consequent high carrying capacity of the weir area appears to be dependent on the ideal conditions which the weir presents. The fringing vegetation and 'islands' of water plants particularly in the shallow overspill area appear critical to the production of benthic organisms (Rooney, Appendix I).

The density of platypus observed and the hourly net capture rates in this study are comparable with studies elsewhere. A comparison with some capture rates from other studies is detailed in Table J.4.

Of particular interest is the occurrence and intensity of the August 6th, 1986 flood and the effects this may have had on the platypus population. Approximately 3m of water poured over the 20m wide weir on the night of the 6th. Two platypuses were captured one week after the flood peak including one re-capture, in a netting period cut short by abnormal fouling of the nets by debris brought down by strong currents. In subsequent trapping sessions (See Table J.2, Calendar of catches), both the patterns of capture and the numbers of animals captured was consistent with the overall data. Few 85/86 juveniles (3) have been captured since the flood. Eleven animals captured before the flood have been re-trapped after the flood.

TABLE J.4

Platypus Captured/Net hours+

River	Study	Animals Captured/Net hour
Duckmaloi	Goldney (1986/87)	0 - 2.7
Wingecarribee	Grant et al (1984)	0.21
Shoalhaven	Grant et al (1983)	1.0
Pages River	Grant quoted in Grant et al (1984)	0.03

\+ A net hour is one 50m gill net in position for one hour.

Some questions remain unanswered

* Why is there little evidence of long-term site attached animals?
* Upstream, weir and downstream animals are assumed to be in some dynamic equilibrium. It is unexpected that at least some animals which have 'disappeared' (upstream or downstream) from the weir area remain undetected. Why should this be so?
* Is there an untrappable segment of the population?
* Could netting or associated activities induce some animals to move out of an area in which they were trapped?
* What social structure (if any) is reflected in the sex ratios and in the apparent mobility which exists in the population?
* How do river flow patterns affect the apparent mobility of platypus?

The developing data set, together with the results of other researchers, whilst inadequate to answer many fundamental biological questions, may be used cautiously to frame reasonable management proposals for the long-term well-being of the platypus in this river system, as well as to assess the probable impacts of this augmentation scheme on their general well-being.

APPENDIX K

DROUGHT SIMULATION

K. DROUGHT SIMULATION

In order to determine the minimum flow which would be sufficient to maintain the aquatic ecosystems downstream of the weir, a simulation of drought conditions was attempted.

In early February, 1987, when the temperatures were expected to reach their yearly maximum, the flow passing over the weir was reduced by allowing water to flow from the weir through the pipe to the Duckmaloi BPT (Photo K.1).

The quality of the water in the weir and downstream to McKeons Creek was first recorded with no flow through the pipe. Water was then taken from the weir through the pipe, to reduce the flow over the weir.

Unfortunately, it took several days to arrive at a correct operating procedure. The two major problems were in reading the correct flow in the pipe, and in the lag time of about four hours from when the flow through the pipe was changed to when the flow over the weir became steady. On the last day, a procedure for arriving at a more rapid stabilisation was developed. Using this method, the required flow over the weir was attained within about one hour.

Although the flows (Fig. I.11) were not controlled as well as one would have wished, some pertinent results were obtained, and these were sufficient to arrive at suitable operating conditions for drawoff from the weir.

1. The flow over the weir dropped to zero at one stage (Photo K.2). The concentration of dissolved oxygen (D.O.) in a pool 70 m downstream was continuously monitored, the D.O. was seen to drop to virtually zero within one hour. This indicated that there was a very high rate of respiration in the pool. From this it would appear that the food available to the trout and platypus in this pool was very abundant.

2. From the water quality measurements and observations of the wetted areas of the river on the afternoon of 13/2/87 (flow around 3 ML/day), it was seen that while the D.O. was satisfactorily high, too many formerly productive areas had been left exposed and many small animals (food sources of the trout and platypus) were beginning to die off. It was concluded from this, that a slightly higher flow of around 3½ ML/day could be tolerated for short periods.

3. The ecologist also found that flows of above 5 ML/day resulted in values of D.O. above 4 mg/L, the minimum acceptable for trout. Accordingly, he decided that the flows should not drop below 6 ML/day, to build a small factor of safety into this lower limit.

4. The time required for the weir to stabilise its flow after a change in the rate of extraction through the pipeline varied from two to four hours. Further downstream, this lag time increased from pool to pool. It was judged that downstream of the first two or three pools, this should be sufficient to keep the effect on the benthic fauna to an acceptable level.

Table K.1 contains a summary of the notes and records taken during the drought simulation test.

TABLE K.1. SUMMARY OF NOTES TAKEN DURING DROUGHT TEST

(See Figs. I.2 and I.3 for locations.)

Date	Time	Location	Flow ML/day	Vel. m/sec	Depth	Temp.	Diss Oxyg mg/L	Diss Oxyg %	pH	Comments
09.02.87	15.30	Pool A	9.10			21.4	5.75	64.0	7.14	Cloudy, cool. About 12 mm rain previous night. Apparently heavier rain in top end of catchment.
10.02.87	8.30	Pool A	9.10			20.0	5.70	63.0	7.12	Cloudy, cool. Light mist overnight
	9.45	Weir main			0.3	21.1	7.40	84.5		at platypus net
					1.5	18.7	4.80	59.2		depth assumed
	10.00	Weir backwater			0.5	18.9	5.90	71.0		
	10.15	Weir backwater				21.3	6.70	79.0		
	12.00	Pool 2				20.3	6.80	79.0		
	13.30	McKeons Ck	5.30			22.5	7.14	81.0		Flow measured by current meter
		Pool 3				21.0	6.05	67.5		downstream of riffles
		Pool 3 - above riffles	7.20	0.49		20.7	5.90	66.0		
	14.00	Pipeline Crossing				21.2	7.50	85.0		
	16.00	Weir wall d/s	12.00		0.3	23.0	7.50	87.0		
	16.55	weir wall u/s	12.00		0.3	20.8	10.50	115.0		
	17.40	Weir main channel			1.5	18.1	4.70	48.0		depth assumed
					0.3	24.1	10.90	124.9		
	18.00	Weir backwater			0.3	23.8	10.20	124.7		depth assumed
	18.15	Teatree Creek				22.5	7.14	81.0		
	18.18	Weir backwater				25.2	11.90	147.8		
	18.20	Teatree Junction u/s				20.6	7.05	78.0		fallen willow
	18.25	Teatree Junction d/s				21.2	7.00	80.0		
11.02.87	7.00	Weir	4.30							
	7.12	weir wall u/s	4.30		0.3	19.8	7.85	87.5		depth assumed
	7.20	weir wall u/s	4.30		1.5	16.7	0.23	2.2		depth assumed. bottom at weir
	7.28	weir wall u/s	4.30		1	18.4	5.30	60.0		depth assumed. 0.3m from bottom of weir
	7.40	Pool A				20.3	3.50	40.0	7.00	
	7.45	Upstream of Pool	4.30		0.3	19.2	6.64	71.7		above riffles at

TABLE K.1. (cont.)

Date	Time	Location	Flow ML/day	Vel. m/sec	Depth	Temp.	Diss Oxyg mg/L	Diss Oxyg %	pH	Comments
		6								end of Pool 6
	7.55	Pool 6				19.2	6.75	74.0		downstream of riffles
	8.00	Fish Pool 3				20.5	4.70	52.5		
	8.10	Pool 4				20.5	4.70	52.5		
		Pool 6				19.1	6.44	69.0		at peg
	8.25	Mid Gorge				20.4	6.80	75.0		
	8.35	Pipeline Crossing				20.3	7.20	79.0		
		u/s of Teatree Jn			0.3	19.0	6.03	65.1		near fallen willow
	8.40	Pool 6				17.9	7.77	82.1		
	8.50	d/s of Teatree Jn				18.6	6.93	74.5		
	9.05	Pool 6				18.7	6.05	65.0		downstream end
	9.20	Pool 7				18.7	6.19	66.7		downstream end of riffle
	9.30	Pool 8				18.8	6.43	69.2		upstream end
	10.00	Pool 9				18.8	6.21	67.1		Riffle at upstream end
	10.20	Pool 10				19.0	6.22	67.5		u/s end
	10.35	Pool 11				19.5	6.49	71.3		u/s end. long section of riffles
	10.50	McKeons Jn. u/s				19.8	6.60	72.7		
	11.00	Teatree Creek	2.80							
	11.05	McKeons Jn. d/s				19.8	7.01	77.3		downstream of junction. u/s end of Pool 13
	11.30	McKeons Ck.				20.2	7.43	82.9		u/s of jn with Duckmaloi
	11.55	u/s of Teatree Jn				19.7	6.49	71.6		
	12.05	Tea Tree Creek				19.7	7.60	84.1		
	12.15	Natural V-notch	4.10							
		Teatree Jn. d/s end of riffles				20.1	6.85	76.2		
	13.30	Weir	0.90							
	14.15	weir	0.00							Flow over weir now a trickle. Part of crest dry.
	16.00	weir	1.30							

TABLE K.1. (cont.)

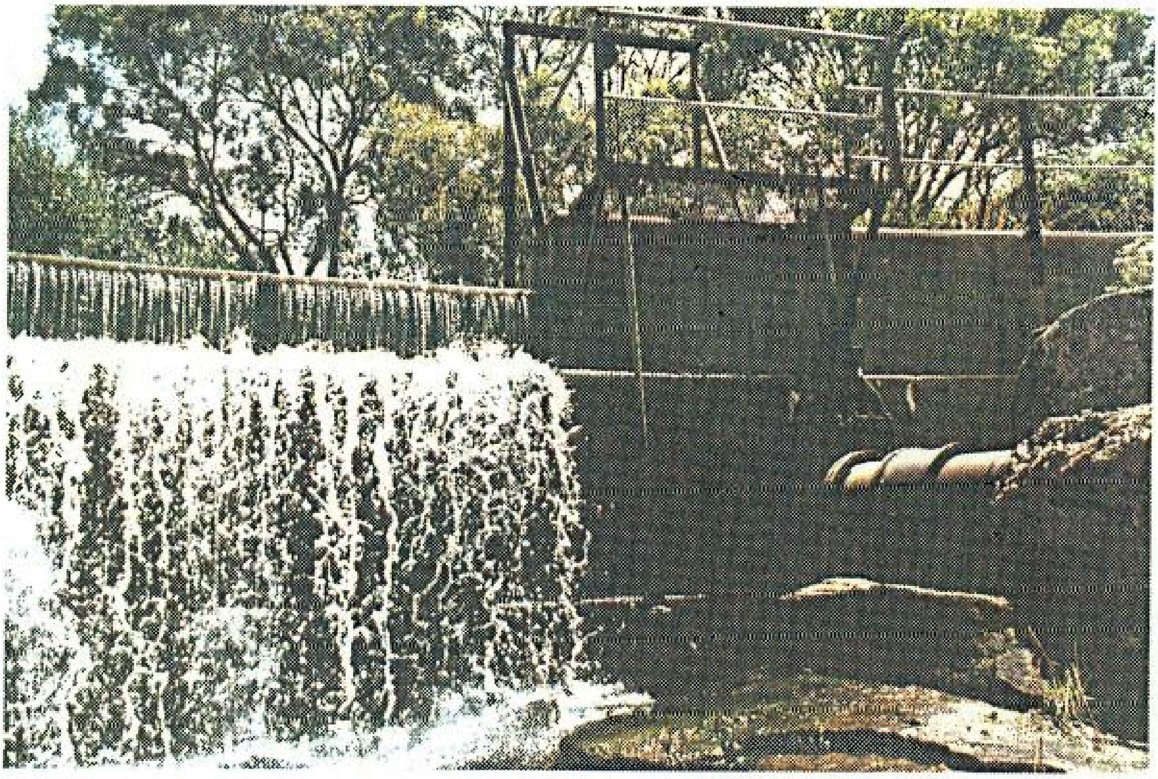
Date	Time	Location	Flow ML/day	Vel. m/sec	Depth	Temp.	Diss Oxyg mg/L	Diss Oxyg %	pH	Comments
	16.50	Pool A					3.00		6.50	
	17.00	Pool 3				21.2	6.00	67.5		
		Pool 6				23.0	8.17	95.8		
	17.10	u/s of Teatree Jn				21.2	8.64	97.5		fallen willow
	17.15	Pool 4				21.4	6.00	68.0		
	17.25	d/s of Teatree Jn.				21.8	8.67	99.2		
	17.30	Mid Gorge				21.0	6.80	77.3		
	17.45	Pipeline Crossing				21.1	7.30	83.0		
	17.50	McKeons Jn u/s				22.2	9.32	107.7		
	18.00	McKeons Jn. u/s				23.7	8.56	101.2		
	18.10	McKeons Jn d/s				22.5	9.04	105.3		
	18.16	Pool A				23.2	5.70	66.6		
	18.28	Weir	3.60							
12.02.87	7.34	Pool 3	11.50			18.4	6.24	67.4		
	7.50	Pool 4				18.2	7.32	78.8		
	8.00	Bottom of Gorge - Pipeline Crossing				18.3	7.38	79.4		
		Pool 6			0.3	14.9	8.20	81.9		At peg
	8.25	Mid Gorge				18.1	7.25	77.0		
	8.35	Pool 4				18.2	6.57	74.3		
		u/s of Teatree Jn.				17.5	6.76	71.3		fallen willow
	8.50	d/s of Teatree Jn.				17.1	7.11	74.1		
	9.10	Weir	7.60							
	9.25	Weir	4.50							
	9.35	Weir	2.66							
	9.40	McKeons Jn u/s				17.3	7.01	73.6		
	9.45	Weir	1.93							
	9.55	McKeons Creek				16.7	8.02	83.2		
	10.00	Weir	1.27							
	10.05	McKeons Jn d/s				17.3	7.41	77.8		
	10.15	Weir	0.27							
	10.35	At Weir - Bottom	0.50		1	16.7	1.75	18.2		depth, flow assumed
		Weir wall u/s	0.50		0.3	18.4	6.71	73.1		flow assumed.
	10.45	Weir	1.00							
	10.50	Weir wall u/s	1.00		0.3	19.1	6.85	74.7		depth assumed

TABLE K.1. (cont.)

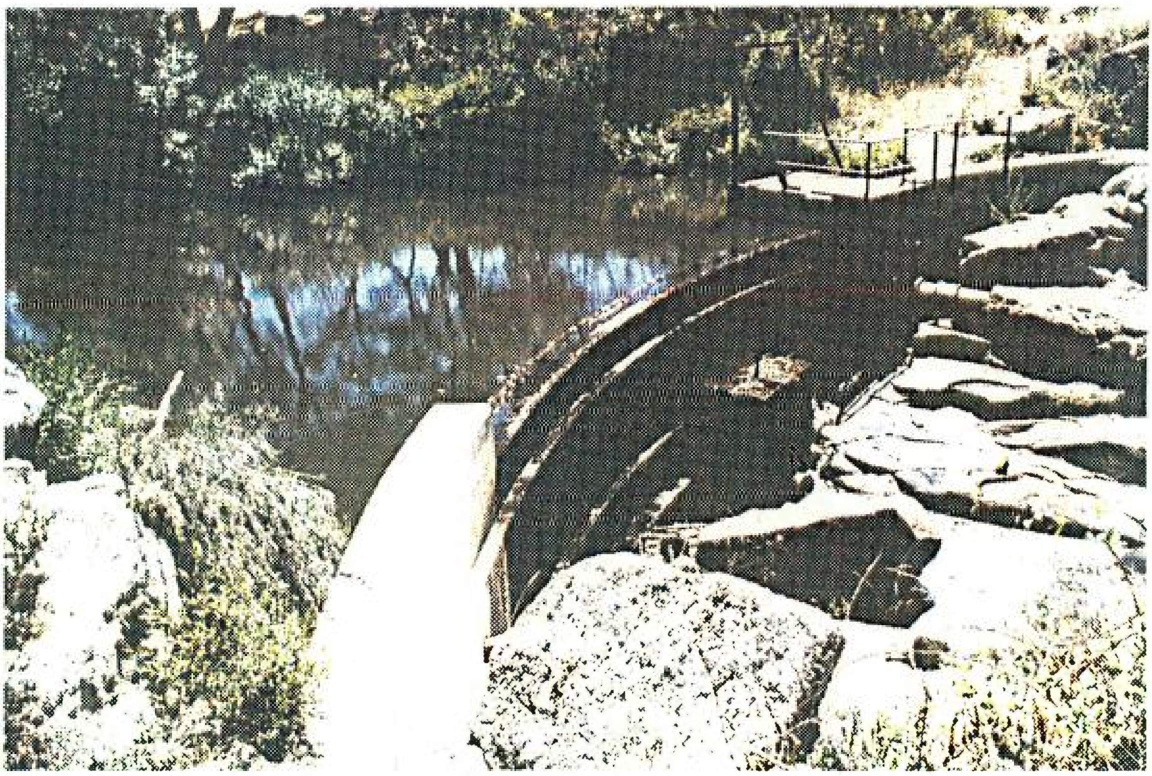
Date	Time	Location	Flow ML/day	Vel. m/sec	Depth	Temp.	Diss Oxyg mg/L	Diss Oxyg %	pH	Comments
	11.05	Pool A				18.4	4.50	48.0		
	11.15	Pool 3				18.2	6.63	71.7		Level down 11 cm
	11.28	Pool 4				18.3	6.53	70.6		Level down 10.7 cm
	11.48	Mid Gorge				19.1	7.70	83.8		
	11.50	Bottom of Gorge				18.8	7.30	80.8		Water level down 8.5 cm.
	12.10	McKeons Ck. at V-notch Weir	2.00							
		Pool 3				18.9	6.80	74.0		Water level down 14.5 cm.
	12.45	Weir	3.90							
	13.00	Weir	4.00							
	13.15	Weir	4.20							
	13.30	Weir	4.10							
	14.45	Weir	2.80							
	15.45	Weir	1.50							
	16.40	Pool A	1.80			21.3	0.94	7.4		
	17.10	Pool 3				20.0	6.35	70.4		160 mm drop since 1000 hrs.
	17.45	Natural V-Notch on Duckmaloi Pipeline Crossing		0.20		20.4	7.50	83.9		
13.02.87	0.00	weir	0.00		3cm below crest					Operator told to close pipeline completely as no water over crest since 1900 hours previous evening
	0.30	Weir								Water starts to flow.
	2.30									Flowing fully.
	10.05	weir	8.07							
	10.15	weir	7.47							
	10.30	weir	6.94							
	10.37	weir	5.78							
	10.44	weir	4.80							
	10.50	weir	4.43							
	10.57	weir	3.10							
	11.04	weir	3.20							
	11.10	weir	3.60							

TABLE K.1. (cont.)

Date	Time	Location	Flow ML/day	Vel. m/sec	Depth	Temp.	Diss Oxyg mg/L	Diss Oxyg %	pH	Comments
	11.30	weir	3.50							
	11.45	weir	3.30							
	12.15	weir	3.50							
	12.52	weir	2.60							
	13.00	Pool A	3.50							
	13.17	Weir	2.40							
	13.30	Natural V-Notch	3.20							
	14.00	Weir	2.50							
	16.00	Pool 3				20.4	7.00	78.5		
	16.15	Natural V-Notch	2.60							
	17.05	Pool 4				20.7	7.30	83.0		
	17.12	Mid Gorge				20.7	7.10	80.0		
	17.30	Bottom of Gorge				20.5	7.50	84.0		



K.1. Pipeline to Break-pressure Tank from weir.



K.2. No flow over Duckmaloi Weir.

APPENDIX L

ARCHAEOLOGY

ARCHAEOLOGICAL SURVEY OF WATER TREATMENT PLANT SITE AT DUCKMALOI NEAR OBERON, NSW

by

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February 1987

A report to NSW Department of Public Works
through Environmental Management

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1 INTRODUCTION

On 24th February 1987 an archaeological survey was carried out of areas being considered by the Public Works Department for a water clarification plant and sludge lagoons near the Duckmaloi Break Pressure Tank 9km east of Oberon NSW.

No Aboriginal artefacts or other evidence of their occupation of the area were identified during the survey which was commissioned by Environmental Management.

2 ENVIRONMENTAL SETTING

The Duckmaloi facilities are located near the junction of the Hazelbrook Road with the road between Hartley and Oberon, on a ridge between the Fish River, some 800m to the west and its tributary the Duckmaloi a similar distance to the east. The area is part of the Oberon Plateau on the western side of the Blue Mountains, and immediately east of the existing facilities is a hill some 1150m ASL. The surveyed areas [Fig 2], south west, west and north of this hill, are all within 500m of it and above 1000m ASL. No significant drainage channels occur within the areas investigated, the nearest, a north westerly flowing tributary of the Fish, is 600m from the hill.

The area has been cleared and some of it ploughed. Trees present are predominantly eucalypts and hawthorn, willows occurring along the Fish tributary, and blackberries on the slope. Ground cover, principally by native grasses, is <85%, additional visibility being available along vehicle and sheep tracks.

The study area covers Carboniferous formations of granite and granodiorite. Boulders of granite are exposed near the hilltop and on its slopes, though none of sufficient size to afford significant shelter to humans. Very few rocks were visible in the yellowish brown sandy loam soil, which was exposed to c20cm along the edge of the vehicle track.

3 ARCHAEOLOGICAL CONTEXT

The Blue Mountains, including the Lithgow-Oberon district, have been a focus of archaeological interest for some time, research having been carried out in the Capertee Valley by McCarthy [1964], Tindale [1961] and Johnson [1979], and in the Blue Mountains by Stockton [1970, Stockton and Holland 1974]. Nearly all this work has concentrated on the excavation of sandstone shelters.

On the Oberon Plateau, one of the more elevated areas of the central uplands, woodlands/forests and severe winters may have combined to discourage heavy Aboriginal occupation of the area. Pearson [1981:88] suggests that while the effects of the last glaciation, taking into account the varied interpretation of these, are unlikely to have been severe enough to prevent movement through the area, higher parts may have been too cold to be occupied.

The eastern highlands were in fact one of the less intensively occupied areas of the state in pre-European times, and in the Blue Mountains effective human occupation does not pre-date 12,000 years ago [Bowdler 1983:56]. Archaeological research indicates a consistent pattern of an earlier not very intensive occupation dating to 14-12,000 BP, widely, though not universally away from the eastern side of the Mountains [Johnson 1979:24-38], followed by a period of non-occupation, followed in turn by a more intensive occupation associated with the Australian Small Tool Tradition. In south eastern Australia, including the highlands, the most common diagnostic tool types represented in this tradition are small backed blades.

Pearson's doctoral research [1981] examined the land use patterns of Aborigines and early Europeans in the Upper Macquarie valley from Dubbo to Bathurst, providing useful information on site distribution in the region. Pearson [nd] also prepared a pilot survey on Aboriginal sites in the Bathurst-Orange development area, outlining the types of sites likely to be encountered and some of the factors governing their distribution.

The NPWS Site Register contains information on a number of sites in the Oberon district. Several of these, immediately to the south of the town, have now been inundated by the Fish River Dam.

These sites included a number of hearths, many stone artefacts such as cores, flakes, points and hammerstones, and a burial mound. Another site, an earth sculpture, located near the golf course, no longer exists. Between six and sixteen kilometres to the north east, north and north west of Oberon are a number of sites including three stone arrangement sites and three burials associated with carved trees. With the exception of part of one of the stone arrangements, all of these sites have been destroyed. Other sites include three quarries, materials present being cited as basalt, andesite, metavolcanics and amphibole hornfelses, and a stone working site associated with one of the quarries, at which flakes and chips of black and grey chert, axehead blanks and fragments of andesite are present.

Only two surveys had previously been undertaken in the Oberon region, and none in the vicinity of the present study area. The first was that by Gollan and Bowdler [1983] of the Crown-timber lands in the Bathurst area, which included five areas near Oberon:

1. Skinners Section and Tempest Purchase, c500ha, 10km SW of Oberon;
2. Beemerang and Cashel Purchases, c900ha, c24km S of Oberon;
3. Essington proposed State Forest, c2,500ha, 12km W of Oberon.

Fieldwork was undertaken by Gollan, and twelve days allotted to the Essington survey, three to Skinners/Tempest and three to Beemerang/Cashel. Only in the Essington area were any sites found, all on bedrock comprised of Silurian siltstone, feldspathic, lithic and quartz rich greywacke, rhyolite, slate, conglomerate and limestone [Burraga and Campbells Groups - Bathurst 1:250,00 Geological Series]. Ten sites were identified, all open campsites/stone working sites, two on Brisbane Valley Creek, six on Native Dog Creek and one on Chain of Ponds Creek. A major component of the artefacts at all sites were of quartz, of which there were many outcrops; other materials include a red stone not identified but locally outcropping and a grey fine-grained metamorphic rock outcrops of which were also present. Artefacts included cores, flakes and debitage, none showing signs of modification in the form of retouch or usewear. Seven of the ten sites were situated on ridges, the remainder being wholly or partially on gentle slopes. The average distance of the sites from a creek was 45m, and the average height above the creek was 19m. Extensive clearing and removal of topsoil from the ridges and slopes led Gollan to conclude that much of the artefactual material would have been relocated in the deep silt accumulated on the creeks.

In October 1986 Brayshaw and Dallas [Brayshaw 1986] surveyed the site of a proposed fibreboard plant to be established at Oberon. A total of 16 artefacts were found at four locations within a 160x110m area on the north facing slope of a hill on which the plant is to be located, about 100m from a small watercourse. These artefacts were principally of quartz, with felspar, volcanic, fine grained siliceous [FGS] and fine grained basic [FGB] materials also present. Artefact types include flakes and flaked pieces, a blade core and several other cores. Three of the cores, one a cobble and two single platformed, two of quartz and one of FGB, were very large with volumes of 2047.5cc, 2162.25cc and 5145cc respectively. Their size and minimal reduction indicated that they were probably of local origin. Two of the artefacts had sustained a degree of modification through retouch or use wear.

All of the artefacts were found at the base of eucalypts in areas around the trunks exposed to depths of up to 15cm. It was concluded that these exposures were all of one extensive site, and it became clear on inspection of the site after surface stripping by bulldozer [Brayshaw 1987] that the subsurface material was very sparse. Amongst the additional artefacts located on this occasion was a backed blade, which somewhat enhanced the archaeological significance of the site, providing a broad chronological framework within which to place occupation of the site. In this region the Small Tool Tradition and the intensification of occupation with it dates to about 3-4,000 years ago [Johnson 1979:24-38], while backed blades have rarely been found at sites younger than about 1000 years [White and O'Connell 1982:125].

The existing regional and local archaeological information viewed in the light of the study area environment indicates that certain types of sites could be expected to occur.

* Stone arrangements, though most likely to be on the tops of hills;

* Other ceremonial places, including earth sculptures, though these are particularly vulnerable to activities such as ploughing;

* Scarred and carved trees [the latter possibly associated with burials] although past clearing suggests these may have been unlikely to have endured to the present day;

* Open campsites and/or stone working floors above creeks and 50m-100m away, on ridge tops or gentle slopes, though the lack of a significant watercourse within this distance of the study area reduces the likelihood of such sites being found.

4 THE SURVEY

4.1 Procedure and Results

Prior to the field survey being undertaken the NPWS Register of Sites was consulted, as were relevant documents and consultants' reports. This facilitated prediction of site type, content and location likely to be encountered.

The fieldwork performed by the consultant, on foot. The Oberon 1:25,000 map sheet was used in the field.

In view of the size of the proposed developments it was possible to have a good look at the entire area.

No Aboriginal relics or other evidence of their occupation of the area was found.

4.2 Aboriginal Consultation

The study area does not fall within the boundary of any Local Aboriginal Land Council, the nearest one being the Windradyne LALC at Bathurst. Several attempts, all unsuccessful, were made to contact Mr John Bugg of that body prior to the field survey.

A copy of this report be sent to the Windradyne LALC for their records.

5 RECOMMENDATIONS

These recommendations are made in the light of the National Parks & Wildlife Act , 1974 [as amended], whereby it is illegal to damage, deface or destroy an Aboriginal relic without written permission of the Director. Should any such relics be located during the course of development the National Parks & Wildlife Service should be notified immediately.

It is recommended that

* The development should be permitted as planned without further archaeological investigation being required.

* Three copies of this report should be forwarded to
  The Regional Archaeologist,
  National Parks & Wildlife Service,
  PO Box 95,
  PARRAMATTA, 2150.

* One copy of this report should be forwarded to
  Mr John Bugg,
  Coordinator,
  Windradyne Local Aboriginal Land Council,
  125 William St,
  BATHURST, 2795.

6 REFERENCES

Bowdler S.	1981	Hunters in the Highlands: Aboriginal adaptations in the eastern Australian uplands. **Archaeology in Oceania 16,2:99-111.**
	1982	**Aboriginal sites on the Crown-timber lands of New South Wales.** Report to the NSW Forestry Commission.
Brayshaw H.	1986	Archaeological survey of Fibreboard Plant at Oberon NSW. Report to AMCOR through Dames & Moore.
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Johnson I.	1979	The getting of data: a case study from the recent industries of Australia. Unpublished PhD thesis, Australian National University.
McCarthy F.D.	1964	The archaeology of the Capertee Valley, New South Wales. **Records of the Australian Museum** 26:197-246.
Pearson M.	1981	Seen through different eyes: changing land use and settlement patterns in the Upper Macquarie River region of New South Wales from prehistoric times to 1860. Unpublished PhD thesis, Australian National University, Canberra.

Pearson M. [nd] A pilot survey of Aboriginal sites in the Bathurst-Orange Development Area. Report to NSW National Parks & Wildlife Service.

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White J.P. & O'Connell J.F. 1982 A prehistory of **Australia, New Guinea and Sahul.** Academic Press, Sydney.

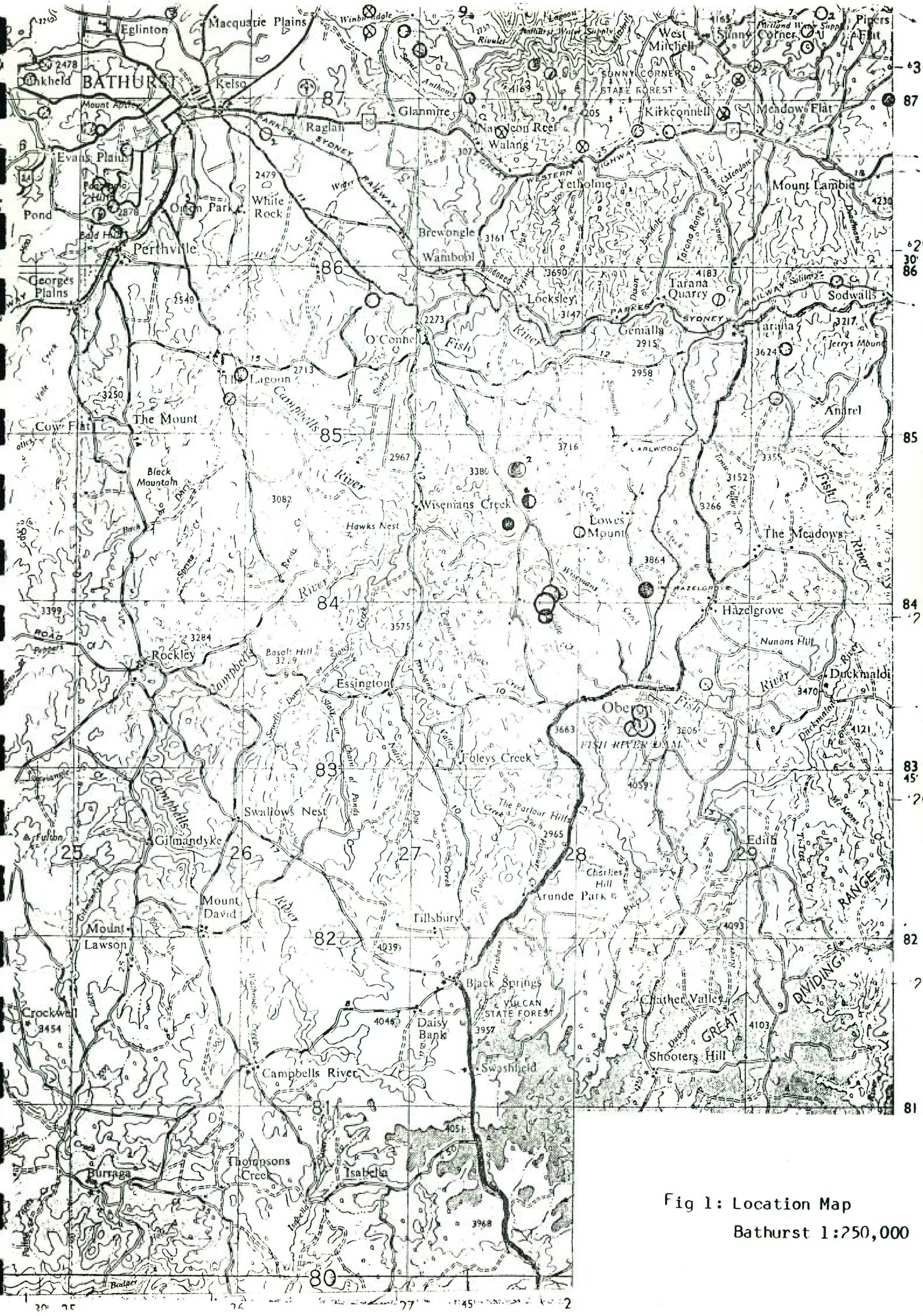


Fig 1: Location Map

Bathurst 1:250,000

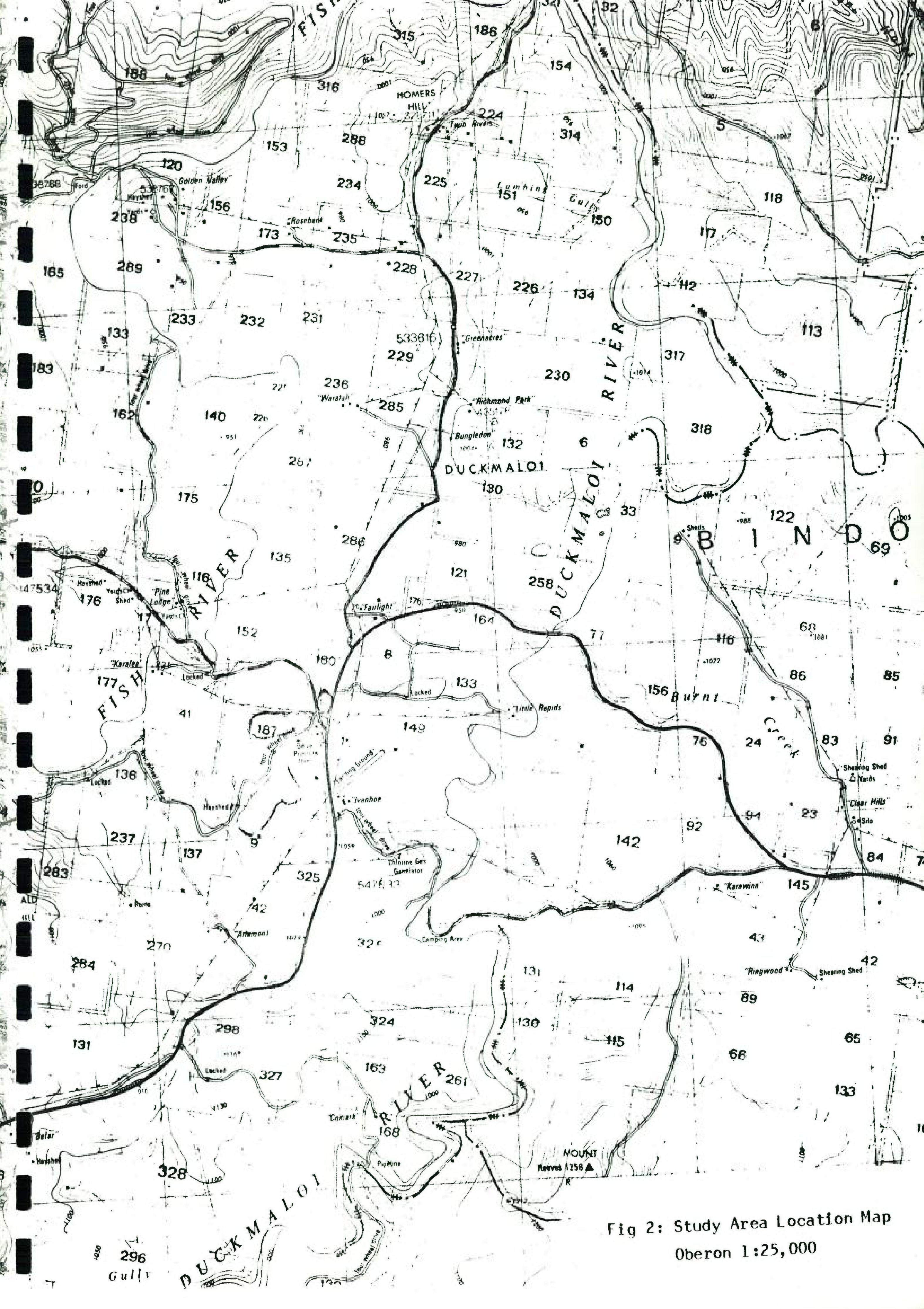
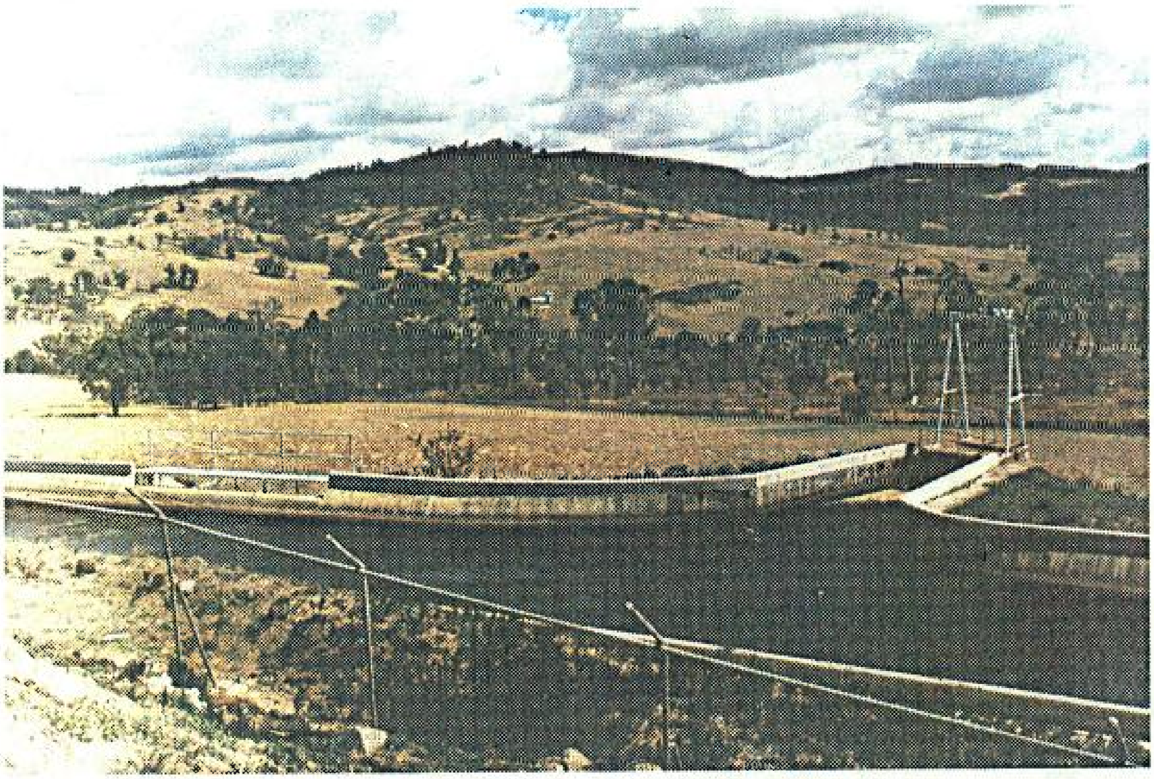
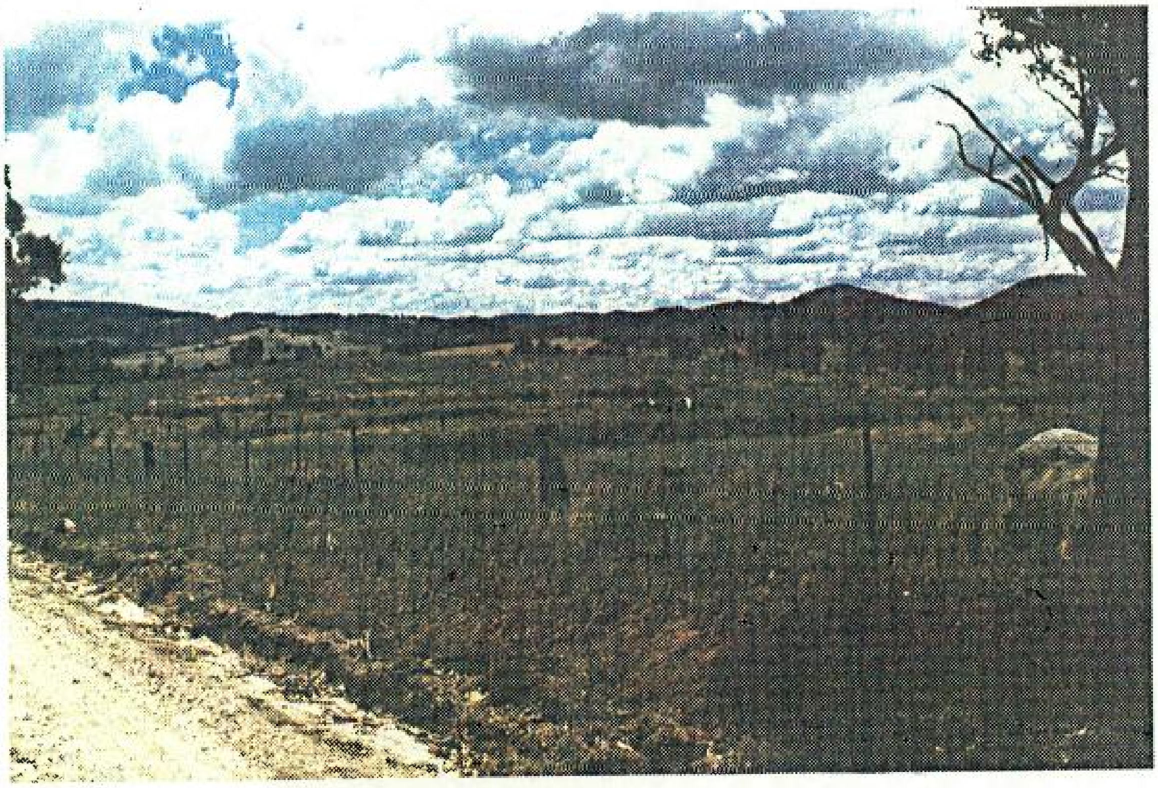


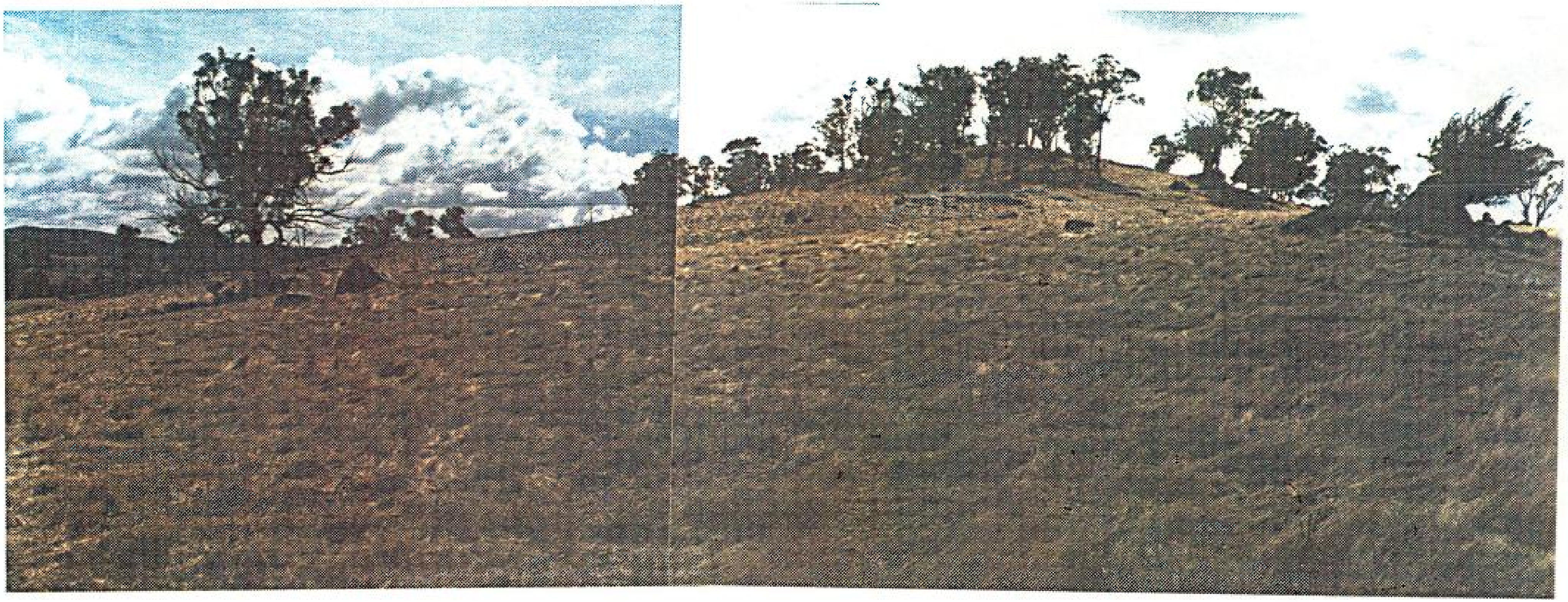
Fig 2: Study Area Location Map
Oberon 1:25,000



L.1. View north west over Break-pressure Tank.



L.2. View north east from road junction.



L.3. View north of hillslope with outcropping granite.

Borrower's name	Date	Ext