# South Esk – Great Lake Water Management Review

# Scientific Report on the Lake River

## August 2003

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# LAKE RIVER

## 1. ASSESSMENT OF ISSUES AND STATUS

Water flow in the majority of the Lake River is controlled by releases from Woods Lake Dam, which was initially constructed in 1905 and later modified in 1962 to ensure water supply to farmers of the Lake River valley following construction of Arthurs Dam. The creation of Arthurs Lake resulted in a reduction in yield for Woods Lake of about 75%, with this resource being diverted to Great Lake via the Arthurs Flume.

Water releases from Woods Lake are managed by Hydro Tasmania, which is bound to supply water to properties within the Lake River Irrigation District, an area that extends down as far as the junction of Brumbys Creek with the Macquarie River. Consequently this has resulted in a modified seasonal pattern of flow in the river, with greater flows during the summer months (November to April). As the holder of the water licence for this section of river, Hydro Tasmania is responsible for the sustainable management of this water and the aquatic environment of both the Lake River and Woods Lake.

This technical study was developed following the Environmental Review and community consultation phase of the South Esk-Great Lake Water Management Review, which began in 1998. This review raised two main issues for the Lake River below Woods Lake: the provision of water for the environment (environmental flows) and water quality. Although not raised as an issue, irrigation demand and usage was also reviewed during this study.

### Previous Environmental Flow Calculations

#### *Assessment of Hydrologic Models for Deriving Appropriate Flows*

A hydrological model for the Woods Lake catchment has been developed by Hydro Tasmania (McConachy, 1998) to examine the security of supply from Woods Lake for irrigation demand lower down the Lake River. The development of this model built on earlier studies that were carried out by Hydro Tasmania to compare the level of security provided by the storage before and after the damming of Arthurs Lake.

The work by McConachy (1998) further refined the previous model and used it to estimate the long-term security of Woods Lake under different scenarios of predicted future irrigation demand. The study also accessed survey results of irrigation demand from the Lake River irrigators conducted by the Department of Primary Industries, Water and Environment in the mid 1990s, which indicated that the extraction of water from the Lake River was likely to increase significantly in the future. Data obtained from the Department of Primary Industries, Water and Environment at that time showed that annual irrigation usage was around 13,300 ML per annum and estimated that an additional 35,000 ML of water might be required in future (these data have since been revised – see below). The report stated that an annual irrigation demand exceeding 48,000 ML would require a flow that exceeds the ability of the valve at Woods Lake.

During the 1998 study, the seasonal irrigation demand was broken down on the basis of changes in evaporation to give a rough estimate of the change in monthly irrigation use. This assumed an amount of irrigation for each month between October and April and was also adjusted according to rainfall for each month. Results from the model showed that Woods Lake could provide irrigation demand up to 32,000 ML per annum securely when an environmental flow was not included. If included, this dropped to 28,000 ML per year. No downstream pick-up was modelled, and was therefore not factored into the analysis.

In this model the ‘environmental flow’ released from Woods Lake to the lower Lake River was modelled as a percentage of inflows to Woods Lake. The maximum environmental flow released was $0.6m^3s^{-1}$, which is equivalent to 20 % of the average natural flow in the Lake River.

Issues arising from the hydrological modelling of McConachy (1998) are:

- The constructed model did not include catchment pick-up downstream from Woods Lake.
- A ‘natural’ flow model for the Lake River downstream from Woods Lake is required to better understand flow patterns and assess the environmental flow requirements of the river. This model should seek to estimate flow for at least 2 sites in the river and should consider pick-up from the catchment area above and below Woods Lake. Recession curve and duration analysis of data from this model could also be used to develop a hydrologically based environmental flow allocation.

### *Present Irrigation Demand*

Following completion of the work by McConachy (1998), Hydro Tasmania employed a water bailiff for the Lake River to improve water management practices and make better estimates of irrigation use. In a report to the Lake River Irrigators Committee in June 2001, the bailiff estimated that 6,391 ML of water was extracted from the stretch between Woods Lake and the Macquarie River and a further 850 ML was taken from the Macquarie River between the Lake River and Brumbys Creek during 2000 - 2001. He also estimated that 4,520 ML was extracted from the Macquarie River between Brumbys Creek and the South Esk River. These figures are lower than those for the previous season (see Table 1).

| River Reach | Estimated Water Use (1999-2000) | Estimated Water Use (2000-2001) |
|---|---|---|
| Woods Lake to Macquarie Junction | 7,454 ML | 6,391 ML |
| Macquarie Junction to Brumbys Creek | 895 ML | 850 ML |
| Brumbys Creek to South Esk | 4,782 ML | 4,519 ML |

**Table 1. Estimated level of irrigation extraction from the Lake River and lower Macquarie River during the years 1999-2000 and 2000 - 01**

Favourable conditions (rain) during the first two months of the 2000/01 season meant that irrigation extraction did not begin until December. This had the effect of reducing overall irrigation demand on the river and resulted in a probable saving of about 2,400 ML. During recent discussions, the water bailiff also suggested that during the past year there have been significant savings, as releases have been better managed and irrigation extraction practices have been further tightened (improvements to diversion structures, etc). He also suggested that as a worst-case scenario, Hydro Tasmania could reasonably expect future water extraction for agricultural irrigation to reach a maximum of about 75ML per day (for the stretch between Woods Lake and the junction of Brumbys Creek and the Macquarie River). This equates to a total volume of about 13,700 ML per annum, which is very close to the 13,300ML that the earlier Woods Lake modelling suggested could be met without any failure, although no account is taken of additional water releases for environmental purposes.

## Water Quality and Biological Health

The section of the Lake River immediately downstream of Woods Lake flows initially through forested catchment that is subject to extensive logging activity, before entering agricultural land where water is extracted for irrigation purposes. The most extensive dataset on water quality has been collected from Woods Lake, where the Inland Fisheries Service and Hydro Tasmania have been conducting studies for more than 7 years. The frequency of monitoring at the lake has varied between monthly and fortnightly during that time and is currently being monitored as part of the Waterway Health Monitoring Program.

In the Lake River itself, the only significant dataset has been collected at a single site at 'Parknook', in the upper section of the Macquarie Plains reach. Part of this dataset was collected by the Department of Primary Industries and Fisheries (now the Department of Primary Industries, Water and Environment) over three years between 1992 and 1995 under the South Esk Basin 'State of Rivers' reporting program (Bobbi, *et. al*., 1996). This involved monthly sampling at 'Parknook', which is a flow monitoring station. The data from that study were used to compare the quality of water in the Lake River with that from other waterways in the Macquarie River catchment and the wider South Esk Basin.

Since April 2000, Hydro Tasmania has been monitoring a selection of water quality parameters through the installation of remote sensors at 'Parknook'. These include water and air temperature, conductivity, dissolved oxygen, pH and turbidity as well as river level. This station has been installed to provide data for input to this project and will be analysed and commented on alongside catchment 'snapshot' data that has been collected during the current study.

### *Woods Lake Water Quality*

The quality of Woods Lake water is characterised by high nutrient concentrations and frequently elevated turbidity due to wind driven re-suspension of sediments (Crook, 1995). Monitoring of water quality began in late 1989, when the clarity of water in the lake was first raised as a significant issue by anglers and downstream users on the Lake River. In the 1992 Inland Fisheries Service Biological Consultancy Annual Report (Sanger, 1992), it was suggested that inorganic particulate material contributed most to excessive turbidity in the lake. It also suggested that while inflows from Ripple Canal and the upper Lake River may be contributing to elevated turbidity, excessive levels appeared to be primarily derived from sources within the lake.

Baseline turbidity in the lake since the commencement of monitoring under the Inland Fisheries Service Biological Consultancy has generally fluctuated between 20NTU and 40NTU (see Figure 1). A significant deterioration in water quality occurred during the summer of 1995 - 96, when turbidity in the lake exceeded 60NTU for almost 6 months. This corresponded with very low water level (734.75 m above sea level), which allowed re-suspension of sediments from the bottom of the lake.

Improved lake level management in the following four years brought about significant reductions in turbidity, however due to lack of adequate recharge to the lake in the summer of 2000, elevated turbidity was once again recorded.

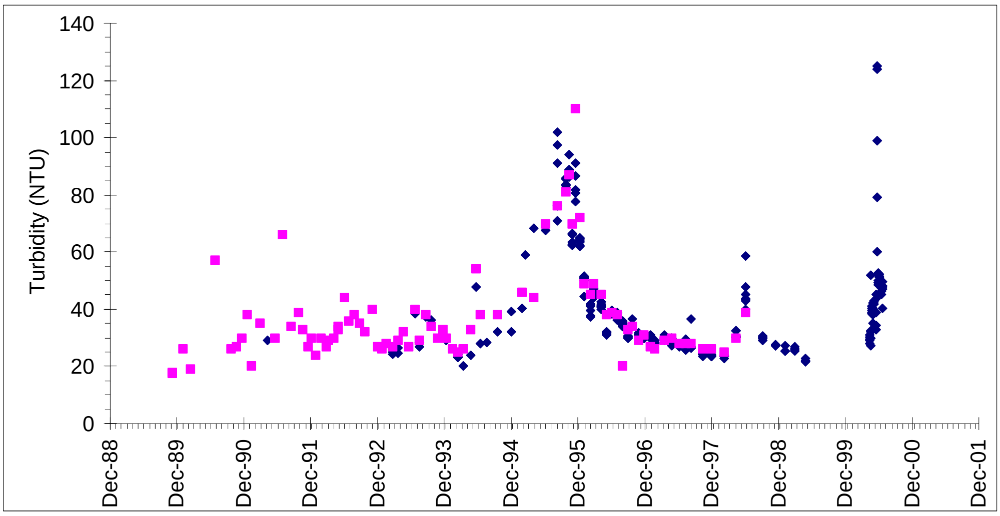


**Figure 1: Turbidity in Woods Lake as monitored by the IFSBC. Two equivalent overlapping datasets are shown. The first is turbidity as measured in the laboratory from water samples while the second are field measurements taken on-site (HACH turbidimeter).**

Very high concentrations of nutrients phosphorus and iron in Woods Lake have also been recorded (0.12mg/L7mg/L respectively) during times of high turbidity (see Table 2). This has led to periodic blooms of algae (as indicated by the chlorophyll data) and a further deterioration in water quality. This storage is one of the most eutrophic water bodies currently managed by Hydro Tasmania and has always been given a high priority for monitoring under Hydro Tasmania's 'Waterway Health Monitoring Program'.

| | Units | Maximum | Minimum | Average |
|---|---|---|---|---|
| Total P | mg/L | 0.12 | 0.031 | 0.086 |
| TKN | mg/L | 1.05 | 0.36 | 0.9 |
| Total Fe | mg/L | 7 | 2.2 | 5.1 |
| Chlorophyll a | g/L | 32.6 | 0.2 | 5.2 |

NB: from Inland Fisheries Service Biological Consultancy Annual Report

**Table 2. Statistics for selected water quality parameters recorded in Woods Lake at the dam (outlet to Lake River)**

As Woods Lake provides the main source for water in the lower Lake River, it is highly likely that water quality changes in the lake have a significant impact on water quality further down the catchment. This is discussed in the following section.

### *South Esk 'State of Rivers' Report*

The South Esk 'State of Rivers' study was initiated in 1992 to provide up-to-date baseline water quality data on rivers throughout the South Esk basin for use in catchment and water resource management (Bobbi, *et. al.*, 1996). As part of the network of sites located in the Macquarie catchment, the Lake River was monitored at 'Parknook'. The site was visited on a monthly basis, with a total of 37 samples being taken. During analysis of these data, records of water quality from Woods Lake were also obtained from the Inland Fisheries Service Biological Consultancy for comparison.

Results from that study suggested that changes in water quality in the lower Lake River broadly reflect changes in water quality within Woods Lake. Although sampling dates at the two locations do not overlap completely, comparison of the time series of changes in the concentration of phosphorus at 'Parknook' and Woods Lake (see Figure 2) suggested that Woods Lake has some influence on concentrations in the Lake River. However it appears that phosphorus concentrations in the Lake River are almost always much less than those in Woods Lake (about 5 times lower). A large proportion of the phosphorus found in the water of both Woods Lake and the Lake River is found attached to particulate material. The lower concentrations that have been measured in the Lake River at 'Parknook' indicates that settling of particulate material and nutrient cycling processes within the river may combine to remove a significant portion of the phosphorus present in the water being released from the lake.

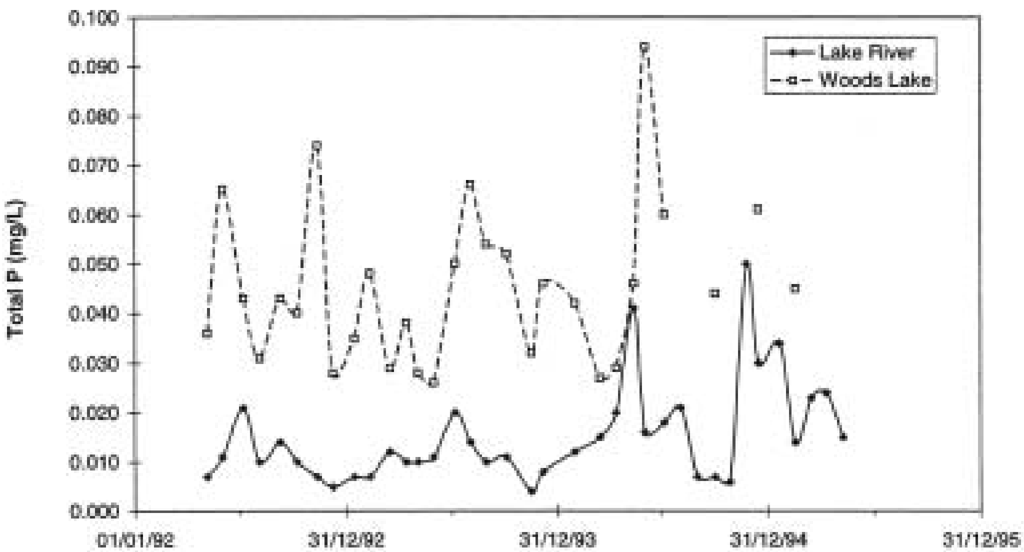


**Figure 2: Changes in total phosphorus (Total P) concentrations in the Lake River at 'Parknook' and in Woods Lake between 1992 and 1995 (Taken from Bobbi, *et. al.*, 1996).**

| | Units | Sample No. | Maximum | Minimum | Average |
|---|---|---|---|---|---|
| Flow Range | $m^3/s$ | 37 | 24.5 | 0.544 | 3.71 |
| Conductivity | S/cm | 36 | 222 | 51 | 85 |
| Dissolved Oxygen | mg/L | 10 | 12.4 | 8.4 | 10.5 |
| Turbidity | NTU | 16 | 27.5 | 3.67 | 15.2 |
| TDS | mg/L | 4 | 93 | 56 | 75 |
| Total P | mg/L | 37 | 0.05 | 0.004 | 0.015 |
| Total N (by calc.) | mg/L | 12 | 0.471 | 0.065 | 0.278 |
| Total Fe | mg/L | 4 | 2.6 | 0.73 | 1.52 |

**Table 3: Statistics for selected water quality parameters recorded in the Lake River at Parknook by the then Department of Primary Industries and Fisheries between 1992 – 95 (Taken from Bobbi, *et. al*., 1996).**

Other data from the South Esk 'State of Rivers' study (see Table 3) show that water in the Lake River is characterised by low conductivity and healthy dissolved oxygen concentrations, has slightly elevated turbidity (which increases dramatically during storm events) and moderate nutrient levels when compared to data from sites on the Macquarie River system. While the concentrations of total dissolved solids are well within guidelines for ecosystem health and irrigation use, iron levels may occasionally be high enough to present problems.

The data from the South Esk study suggest that there is some moderation of water quality as it travels downstream from Woods Lake, with most parameters decreasing in concentration between Woods Lake and Parknook. While some of this can be attributed to settling out or filtration of particulate material (leading to improvements in turbidity and iron levels), it is likely that biological processes in the stream are also utilising some of the nutrients being discharged from Woods Lake.

### *Biological Health*

Communities of aquatic fauna are being widely utilised as indicators of the health of stream ecosystems around Australia. Under the National River Health Program new techniques for rapid sampling of macroinvertebrates has enabled more costs-effective sampling to be undertaken and this technique has been employed to sample aquatic fauna at several sites in the Lake River.

Previous surveys using National River Health Program sampling protocols have been carried out under the Hydro Tasmania funded Electricity Supply Association of Australia project (spring 1995 and autumn 1996) and assessed using combined season models (Davies, *et. al*., 1999). The Department of Primary Industries, Water and Environment has also sampled several locations as part of the National River Health Program schedule (spring and autumn of 1998), the data from these being assessed using single season riffle and edgewater models. None of the locations sampled under either program coincide.

It is also important to note that assessment of samples varies between the two programs. Samples collected by the Department of Primary Industries, Water and Environment were assessed using only a presence/absence model while a second (rank abundance) model was also used to assess samples collected under the Electricity Supply Association of Australia project. This is important, as the latter model incorporates relative impacts arising from flow alterations.

Woods Lake Dam is managed as a riparian release structure and the hydrology of the river downstream is different from natural (Davies, *et. al.*, 1999), as base flows are increased between October and April to provide for irrigation demand. Davies (1999) concluded that the O/E scores from both sites he sampled reflect this, falling into the 'A' and 'X' bands respectively (see Table 3). From these data, he concluded that the macroinvertebrate communities of the Lake River are essentially unmodified downstream of Woods Lake (using both presence absence and rank abundance models) although O/E values in the 'X' band may indicate potential organic enrichment. 'X' bands are defined as being potentially biodiverse or indicative of slight organic enrichment. Given the water quality review in the section above, these data support the hypothesis that nutrient enriched water from Woods Lake is having some affect on instream biota in the Lake River.

The Department of Primary Industries, Water and Environment results from the spring and autumn sampling rounds of 1998 are also presented in Table 4. In both seasons, riffle habitats at all sites were found to be unimpaired (A banding) or more diverse than reference (X banding). During the spring survey, edgewater habitats at two sites (Lake River at Woods Lake Road and Lake River at Little Den) were classified as slightly to moderately impaired. This is likely to be as a result of high flows during the spring of 1998 as neither index for O/E interpretation (OE50 and OESIGNAL) indicates potential water quality or habitat degradation. Edgewater macroinvertebrate communities are reasonably vulnerable to disturbance from fluctuating flows and can be affected by floods.

In summary, both studies indicate that sites sampled in the Lake River are largely unimpaired although there may be some evidence that macroinvertebrate communities are subject to slight organic enrichment as a result of elevated nutrient concentrations in Woods Lake. As recent comprehensive biological data already exist for the Lake River, sampling of sites on the Lake River using National River Health Program protocols is not necessary under the current technical study to establish biological condition. Sampling of sites in the lower Lake River close to the confluence with the Macquarie and in the Macquarie River upstream of Brumby's Creek would complement existing data, however this area has been subject to considerable modification in recent times (riparian vegetation removal and instream habitat disturbance). It is felt that assessment of biological condition using rapid assessment techniques would not yield representative data and any low scores that are likely to arise would simply reflect habitat disturbance and not flow related effects.

| Lake River | Program | North | East | Date | Riffle (P/A) | Edgewater (P/A) | Riffle (RK) |
|---|---|---|---|---|---|---|---|
| Lake River @ Woods Lake Road | MRHI | 5342500 | 503800 | Mar 1998 | X | A | - |
| Lake River @ Woods Lake Road | MRHI | 5342500 | 503800 | Nov 1998 | A | B | - |
| Lake River @ Little Den | MRHI | 5354700 | 508400 | Mar 1998 | A | X | - |
| Lake River @ Little Den | MRHI | 5354700 | 508400 | Nov 1998 | A | B | - |
| Lake River @ Macquarie Road | MRHI | 5374100 | 508000 | Mar 1998 | A | A | - |
| Lake River @ Macquarie Road | MRHI | 5374100 | 508000 | Nov 1998 | A | * | - |
| Lake River @ Big Den | ESAA | 5353700 | 505300 | Combined | A | - | A |
| Lake River @ "Parknook" | ESAA | 5368700 | 506600 | Combined | X | - | X |

X – More diverse than reference; A – Equivalent to reference; B – Less diverse than reference (Modified); * Outside of experience of model. PA = Presence/Absence; RK = Rank Abundance.

**Table 4: Biological assessment results from MRHI and ESAA sampling in the Lake River between 1995 and 1998**

# 2. Formulation of Study Objectives

There are two main issues that require attention under this technical study: water quality and the provision of environmental flows. These two issues are important for different reasons. Quantification of the environmental water requirements (environmental flows) for aquatic biota in the lower Lake River is seen as important for management of releases from Woods Lake and will need to be considered during negotiations with irrigators. The pattern and volume of this release also has some implications for the management of environmental and recreational issues within Woods Lake itself, as well as the security of supply of irrigation water downstream. The derivation of an environmental flow can be undertaken through two possible approaches. The construction of a 'natural flow' model will be useful in providing hydrologically relevant options for providing an environmental flow, while field studies using the Instream Flow Incremental Methodology technique (which is more biologically relevant) will yield data to determine the habitat requirements of aquatic biota presently found in the river. Information from both of these components should be useful in deriving an agreed and appropriate environmental flow for the river.

With the advent of Protected Environmental Values and the future requirement to protect these values through Water Quality Objectives, water quality management is also a significant issue for Hydro Tasmania. Although the biological data that have so far been collected through previous studies tend to suggest that water quality in the Lake River may be having minimal impact on the aquatic ecosystem, the Lake River Irrigators see Woods Lake as providing water quality that is substandard, so this is essentially an agricultural water use issue. Additional data on water quality throughout the length of the Lake River below Woods Lake would add substantially to the existing dataset and allow appropriate Water Quality Objectives to be developed for the area when this is undertaken in the future.

# 3. DATA COLLECTION AND ANALYSIS

## Construction of 'Natural Flow' Model

Following the review of the Woods Lake catchment model of McConachy (1998), a 'natural flow' model for the entire Lake River was constructed. This is a 'rainfall-runoff' model that has been constructed using TimeStudio™ and encompasses the entire catchment. The model assumes no storage at either Arthurs Lake or Woods Lake, and approximates flow in the upper catchment as if Woods Lake and Arthurs Lake dams had not been constructed. The model also takes into account the contribution to baseflow from ground water stores in the catchment.

The model was calibrated using winter flow information from the 'Parknook' streamflow monitoring station, when irrigation release does not occur and flow in the Lake River can be assumed to reflect natural pickup from the catchment downstream of Woods Lake. The influence of man-made drainage channels upstream of 'Parknook' on flow magnitude and attenuation is unknown, although it is likely to have significant effects on the hydrology of the river. This could not be explicitly incorporated into the model, however alteration of model parameters (infiltration and recharge) was made to ensure model baseflows better matched actual data.

Analysis of output from the model was carried out for three sites on the Lake River:

- Lake River upstream of Scrubby Den Rivulet (22km d/s Woods Lake);
- Lake River downstream Dabool Rivulet (36km d/s Woods Lake); and
- Lake River at Lake House (3km u/s Macquarie River).

These sites were chosen following examination of the geomorphic characteristics of the catchment and because they are potential locations for biological assessments using the Instream Flow Incremental Methodology technique. Seasonal (summer and winter) datasets for these locations were developed and from these the percentile flows of interest were tabulated (see Table 5 and Table 6). Although the presence of Arthurs and Woods Lakes lowers flood peaks and the general magnitude of flows, the shape and form of the hydrograph during the higher flows of winter is retained. For this study the focus is on minimum flows, therefore the main data of interest are the $80^{th}$ and $90^{th}$ percentile figures, as percentile flows have been used in other studies to assess risks for aquatic biota (Davies & Humphries, 1996).

| Lake River Site | Flow Percentiles ($m^3/s$) | | | |
|---|---|---|---|---|
| | $10^{th}$ | $50^{th}$ | $80^{th}$ | $90^{th}$ |
| Above Scrubby Den Rivulet | 10.0 | 2.2 | 0.7 | 0.3 |
| Below Dabool Rvt (Parknook) | 15.0 | 3.4 | 1.15 | 0.5 |
| At Lake House | 17.8 | 4.0 | 1.45 | 0.7 |

**Table 5: Percentile flows for summer at three sites on Lake River from the 'natural flow' model**

| Lake River Site | Flow Percentiles ($m^3/s$) | | | |
|---|---|---|---|---|
| | $10^{th}$ | $50^{th}$ | $80^{th}$ | $90^{th}$ |
| Above Scrubby Den Rivulet | 22.9 | 7.5 | 3.0 | 1.6 |
| Below Dabool Rvt (Parknook) | 29.8 | 10.2 | 4.2 | 2.4 |
| At Lake House | 33.8 | 11.6 | 4.8 | 2.8 |

**Table 6: Percentile flows for winter at three sites on Lake River from the 'natural flow' model**

For the derivation of minimum flows, another option may be to examine flood recession curves that would occur in an unregulated (i.e. modelled) system to determine a minimum flow that might also have some environmental relevance. This can also be done on a seasonal basis (summer and winter). A 20-day recession analysis has been chosen as a conservative basis for deriving baseflow levels during summer, while a shorter 10-day recession analysis appears to be more appropriate for winter periods when rainfall is more frequent.

Recession analysis was therefore undertaken on modelled data for 'summer' and 'winter' events for the Lake River at 'Lake House'. A range of events were chosen from the summer period varying in peak flow from 10 - 45 $m^3/s$, and recession durations varying from 15 - 40 days. The results are presented in Tables 7 and 8. The average of the three 20-day recession analyses for summer is about 0.32$m^3/s$, while for winter the average of the four 10-day duration analyses is about 1.8 $m^3/s$.

| Event Date | Peak Magnitude ($m^3/s$) | Recession Duration | Flow ($m^3/s$) |
|---|---|---|---|
| November 1993 | 45 | 15 days | 1.68 |
| February 1992 | 10 | 20 days | 0.23 |
| March 1993 | 15 | 20 days | 0.58 |
| December 1998 | 24 | 20 days | 0.15 |
| December 1996 | 14 | 30 days | 0.1 |
| December 1997 | 22 | 40 days | 0.01 |

**Table 7: Recession analysis for summer events at 'Lake House' using modelled data**

| Event Date | Peak Magnitude ($m^3/s$) | Recession Duration | Flow ($m^3/s$) |
|---|---|---|---|
| June 1999 | 45 | 7 days | 2.9 |
| May 1995 | 31 | 10 days | 1.2 |
| May 1995 | 41 | 10 days | 1.6 |
| July 1996 | 24 | 10 days | 2.6 |
| June 1997 | 70 | 10 days | 1.9 |
| July 1998 | 150 | 12 days | 3.0 |
| May 1997 | 45 | 20 days | 1.0 |

**Table 8: Recession analysis for winter events at 'Lake House' using modelled data**

For comparison, relevant data for the current flow regime in the Lake River are highlighted in the following two tables (Tables 9 and 10). These data show that the 90th percentile flows at 'Parknook' (which is equivalent to the site 'Below Dabool Rvt') during the summer of last season was about $0.56m^3/s$, while at 'Lake House' the 90th percentile flow after irrigation extraction was $0.22m^3/s$. The minimum flow recorded at 'Lake House' during the summer of 2000/01 was $0.153m^3/s$. Data from the water bailiff indicate that extraction of water downstream of this point may have further reduced this flow by about 30%, resulting in a likely excess flow to the Macquarie River of about $0.1m^3/s$ (8.9ML/day).

| Parknook | Median | 80th Percentile | 90th Percentile | Minimum |
|---|---|---|---|---|
| Summer (1/11/2000 to 1/4/2001) | 0.81 | 0.63 | 0.56 | 0.5 |
| Winter (1/6/2000 to 1/11/2000) | 3.52 | 1.83 | 1.44 | 0.75 |
| Overall (1/6/2000 to 1/7/2001) | 1.56 | 0.75 | 0.64 | 0.5 |

**Table 9: Percentile flows (cumec) in the Lake River at 'Parknook' during the last full year**

| Lake House | Median | 80th Percentile | 90th Percentile | Minimum |
|---|---|---|---|---|
| Summer (1/11/2000 to 1/4/2001) | 0.46 | 0.26 | 0.22 | 0.153 |
| Winter (1/6/2000 to 1/11/2000) | 2.85 | 1.77 | 1.27 | 0.63 |
| Overall (1/6/2000 to 1/7/2001) | 1.42 | 0.46 | 0.29 | 0.153 |

**Table 10: Percentile flows (cumec) in the Lake River at 'Lake House' during the last full year**

It is also interesting to note that during the winter period when there was no extraction from the system, flows measured at 'Parknook were higher than those recorded at 'Lake House' (median of 3.52 $m^3/s$ at 'Parknook' compared with 2.85 $m^3/s$ at 'Lake House'). The lowest reaches of the Lake River have been largely modified through flow diversions and river works to improve drainage, and it is likely that these are the major reasons for this apparent loss of flow. There is a diversion through the 'Formosa' property upstream of Lake House that bypasses the 'Lake House' gauging station and during higher flows in winter this channel may be responsible for diverting significant amounts of water. Site characteristics at the 'Lake House' flow station also limit the accuracy of monitoring at higher flows.

The natural flow model assumes a single channel for the lower reaches of the Lake River, and is therefore not affected by these issues.

The results from recession analysis tend to indicate that in an unregulated system, baseflows would be likely to drop well below the 90$^{th}$ percentile during both summer and winter. Assuming that the 20-day summer recession figure may represent a potential 'threshold' below which stress to the system may begin to occur, adopting a 90$^{th}$ percentile figure as a minimum 'environmental' flow appears to be a conservative approach to protecting the aquatic environment.

If the 90$^{th}$ percentile were adopted, this would compare very favourably with the 0.6$m^3/s$ that has been proposed for the Macquarie River between the Elizabeth River and the Lake River (Davies & Humphries, 1996). Indeed it appears very likely that as at one time the lower Macquarie River was named the Lake River, the majority of flow in the lower reaches of what is now called the Macquarie River may once have come from the Lake River.

While this information is useful and will help in the derivation of hydrologically appropriate environmental flows for the lower Lake River, none of the options presented above are biologically relevant. Additional field studies are required to determine what flows may be required to sustain aquatic life in the long-term.

## Biological Assessment of Environmental Water Requirements

Detailed instream investigations were carried out between December 2001 and March 2002. This involved the collection of instream habitat information and data on the biota within these habitats, using the Instream Flow Incremental Methodology (IFIM). The biological investigation of flow requirements was restricted to the section of river between Woods Lake and the Cressy-Longford Road. This was mainly due to the extreme level of disturbance further downstream that has been caused by willow removal and other river works, which have resulted in extensive instream modification. It was therefore deemed inappropriate to undertake an IFIM-style investigation in this floodplain area. Other factors that also contributed to this decision were the difficulty in accurately understanding water flows in this area (as water is diverted via a number of channels and canals and the low gradient makes flow gauging difficult and inaccurate), and the extreme level of siltation within the main river channel.

The approach taken for the biological assessment has therefore been to derive environmental flows that will maintain environmental values in the upper river (Woods Lake to Cressy Road), where water extraction is limited and the instream environment is relatively unimpacted. This is the best practice method for conducting IFIM assessments, and aims to give priority to protecting values of higher conservation value.

However, recognition must also be given that there may be environmental values in the lower river that should be protected, and some attempt was made to consider these.

The detailed results of the IFIM environmental flow assessment are contained in a separate document (Gregory, 2002), and only a summary will be presented and discussed here. The environmental flow report presented two possible minimum flow targets for the Lake River. One set of values was derived using unregulated 'natural' flows as the 'reference flow' against which the biological risk assessment was carried out. This technique is widely used by the Department of Primary Industries, Water and Environment to derive the monthly minimum flow requirements of biota in rivers elsewhere in Tasmania. For the Lake River, unregulated monthly median flows were derived from the 'Natural Flow Model' constructed to estimate flows in the Lake River in the absence of Arthurs Lake and Woods Lake (Taylor, 2001).

The second approach that was employed was to use the pattern of flow in the river for the recent past as the reference for the biological risk assessment. The premise for taking this approach is that existing flows in the river have not deleteriously affected biological communities in the river and that to maintain existing environmental conditions as the minimum, at least the present flow patterns should be maintained. There is some justification for taking this approach, as a similar argument has been used during a recent assessment of the environmental flow requirements for the Derwent River below Meadowbank Dam (Davies, *et. al.*, 2002).

The results of these two different approaches are discussed below.

### *'Natural Flow Model' as Reference Flow*

Using the 'natural flow model' to give an unregulated flow that can be used as the reference flow for the biological risk assessment, the following monthly minimum flows (at 'Parknook') were suggested (Table 11). This shows that during the irrigation season (typically November to April) minimum flows to preserve aquatic ecosystems should be between 1.2 – 1.45$m^3s^{-1}$. If this were to be implemented, this would result in a considerable increase in water released from Woods Lake and would impact significantly on security of the supply to meet downstream demand.

| Month | Discharge (Cumecs) | Month | Discharge (Cumecs) |
|---|---|---|---|
| January | 1.45 | July | 1.45 |
| February | 1.20 | August | 1.45 |
| March | 1.45 | September | 1.45 |
| April | 1.45 | October | 1.45 |
| May | 1.45 | November | 1.45 |
| June | 1.45 | December | 1.45 |

**Table 11: Suggested minimum environmental water requirements ('No Risk' flows) for the Lake River above 'Parknook' using 'natural flow model' as the reference**

These data are presented graphically in Figure 3, along with the 'Moderate Risk' monthly flow level and the existing median and 80$^{th}$ percentile flows at 'Parknook'. It is clear from this graph that both the 'No Risk' and 'Moderate Risk' flow options for summer are likely to be unacceptable to stakeholders, as this flow will impact significantly on the security of supply from Woods Lake.

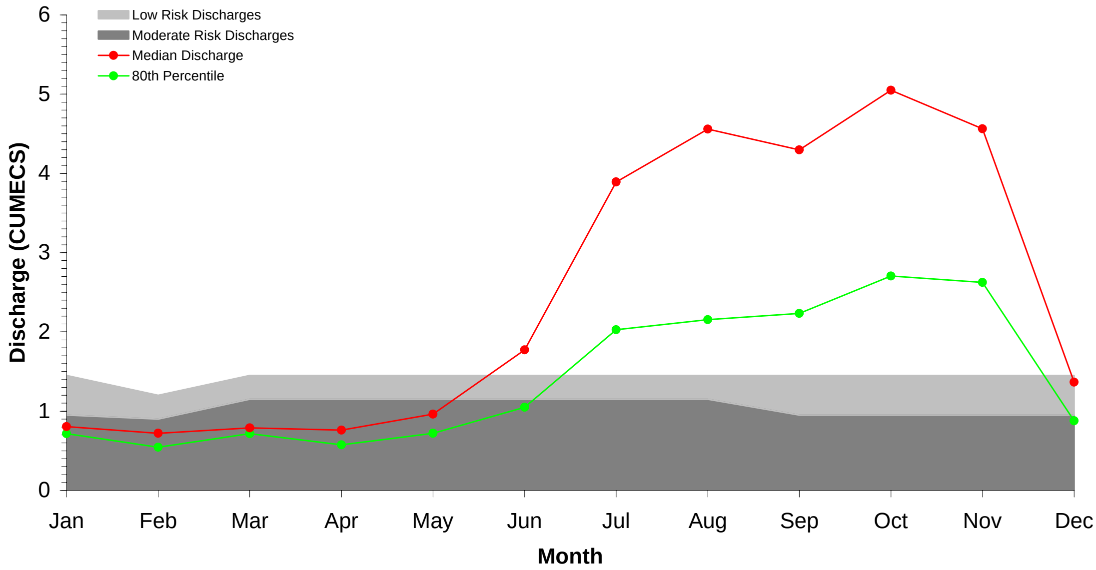


**Figure 3: 'Low Risk' and 'Moderate Risk' minimum environmental flows suggested for the Lake River upstream of 'Parknook' using unregulated flow statistics as the reference**

It must also be recognised that:

- The primary objective of the minimum flow regime is to maintain the species diversity and productivity of the aquatic community that presently exists in the Lake River. Given that past and recent data on the biological health of the Lake River suggest that the river is not currently impacted to any significant degree under the current regime, there appears to be little value in augmenting the present flows.
- An increase in the pattern of discharge in the Lake River has the potential to de-stabilise the existing channel form and morphology of the Lake River, as the river re-fits itself in response to the greater volume of water it would carry. This in turn may result in channel migration and sediment movement, and re-distribution of instream habitat. This would have the potential to substantially impact on the productivity and biological diversity of the system, which would be counter to the stated aims of an environmental flow release.

### *Current Flow Pattern as Reference Flow*

Recognising the factors outlined above, the IFIM assessment was re-run, using current flow statistics as the 'reference' for the biological risk assessment. As expected, this resulted in a significantly lower minimum environmental flow (Table 12 below). When these data are compared with existing monthly flow statistics (Figure 4), it is clear that the summer flows for the environment are much more likely to be met by current water management practices.

| Month | Discharge (Cumecs) | Month | Discharge (Cumecs) |
|---|---|---|---|
| January | 0.70 | July | 1.45 |
| February | 0.60 | August | 1.45 |
| March | 0.60 | September | 1.45 |
| April | 0.60 | October | 1.45 |
| May | 0.80 | November | 1.45 |
| June | 1.30 | December | 1.05 |

**Table 12: Suggested minimum environmental water requirements ('No Risk' flows) for the Lake River above 'Parknook' using current flow patterns as the reference**

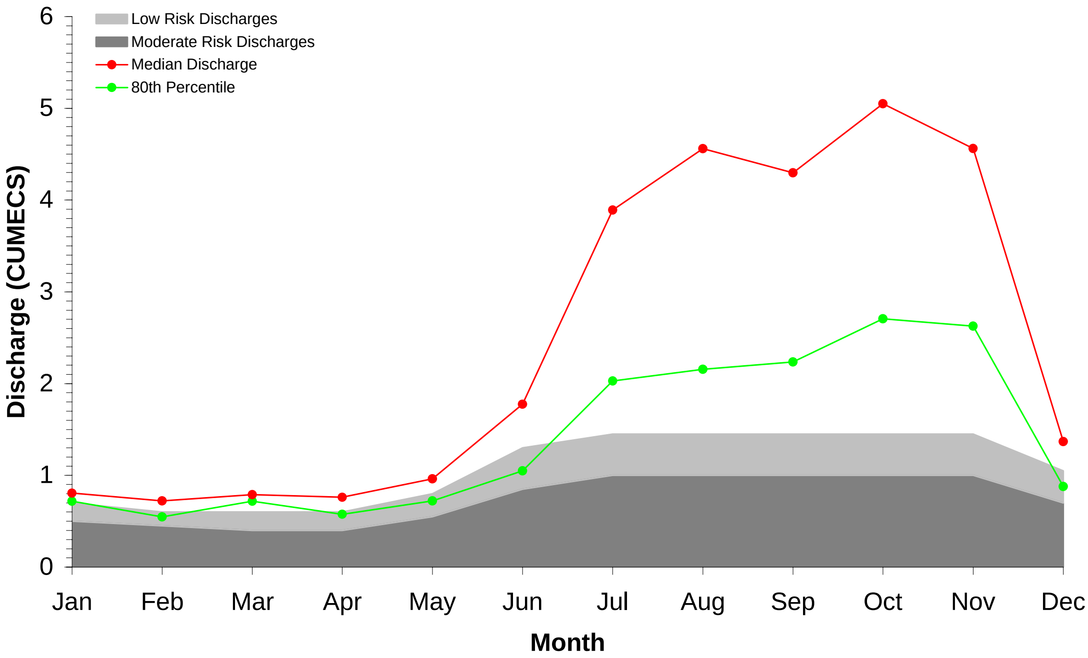


**Figure 4: 'Low Risk' and 'Moderate Risk' minimum environmental flows suggested for the Lake River upstream of 'Parknook' using existing flow statistics as the reference.**

## Water Quality

Additional water quality data have been collected during the present study to increase the level of knowledge regarding changes in water quality at the catchment scale, including the longitudinal variation within the Lake River from the headwaters (Woods Lake) to Brumbys Creek. The location of sites that were sampled during the present study is shown in Figure 5.

Water releases from Woods Lake for irrigation purposes commenced on December 7th, 2000 and concluded on March 23rd, 2001 (Figure 6). At the start of the irrigation release, discharge from Woods Lake was about 1.2$m^3s^{-1}$, however by the end of February this had declined to about 0.57 $m^3s^{-1}$. During the final month of irrigation release, discharge was once again raised to about 0.85 $m^3s^{-1}$ before concluding towards the end of March.

The overall effect of these irrigation releases resulted in a drawdown in lake level over the period of about 0.85m. The final lake level at the end of the irrigation period was 735.81 m above sea level, which is about 0.4 m above the minimum lake level for the protection of water quality in Woods Lake.

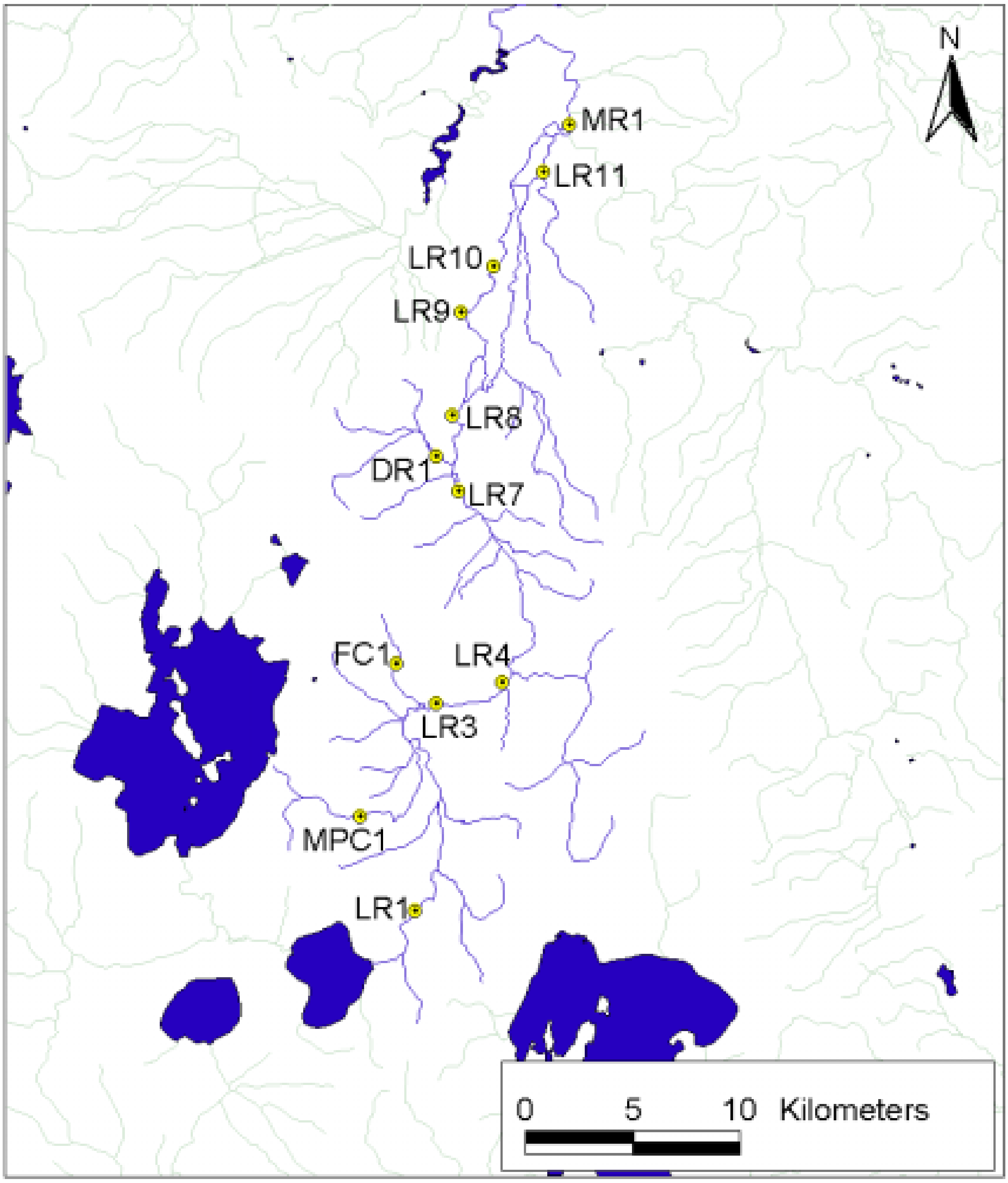


**Figure 5: Map showing the location of sites sampled in the Lake River catchment during the present technical study**

**LEGEND:**

| | | | |
|---|---|---|---|
| LR1 | Lake River downstream Woods Lake | LR 7 | Lake River at Boomer Bottom |
| MPC1 | Mount Penny Creek | LR 8 | Lake River at 'Parknook' |
| FC1 | Flash Charlies Creek | LR 9 | Lake River at 'Rockford' |
| LR3 | Lake River at Big Den | LR 10 | Lake River at 'Little Forest' |
| LR 4 | Lake River at Little Den | LR 11 | Lake River at 'Lake House' |
| DR 1 | Dabool Rivulet | MR1 | Macquarie River at Westmoor Br |

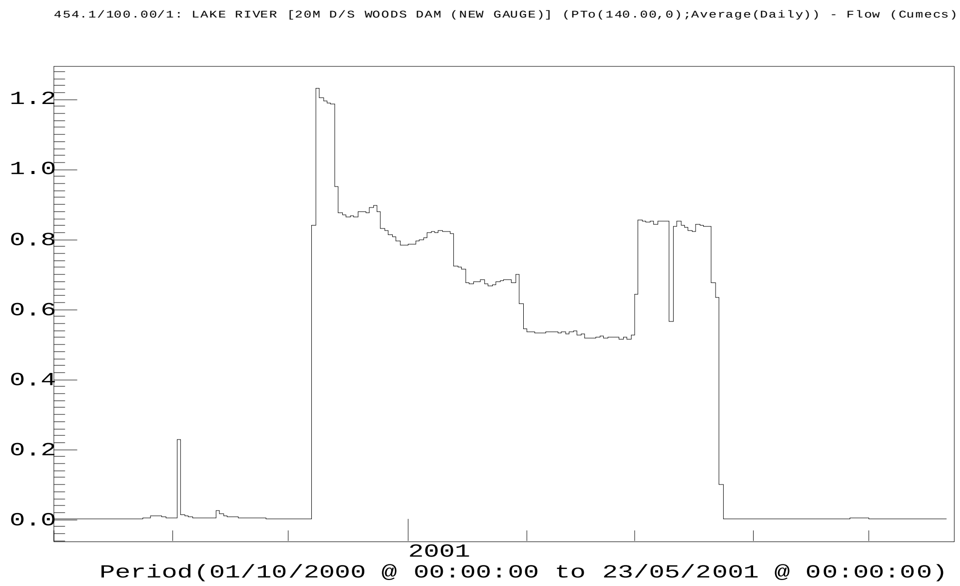


**Figure 6: Flows released from Woods Lake for irrigation purposes during the summer season 2000/2001. Plot shows daily average flows in cubic metres per second**

The commencement of water release from Woods Lake produced a noticeable change in some of the baseline water quality characteristics in the Lake River downstream. This was most clearly seen in the continuous data recorded at 'Parknook' (see Figure 7), where baseline turbidity increased markedly in early December from about 4NTU to over 10NTU. Although turbidity levels tended to decline gradually between December 2000 and February 2001, turbidity at 'Parknook' was still elevated at the time irrigation releases ceased. It is also interesting to note that when discharge from the Woods Lake was increased during March, this produced a corresponding increase in turbidity at 'Parknook', which may indicate the degree to which increased flow velocity allows particulate material to be carried further downstream.

Upon the restoration of natural flows in the river, turbidity levels once again dropped down to a baseline of about 4NTU. Spikes that occur throughout the period of record are a clear indication of the effect of catchment runoff below Woods Lake during rainfall events.

The conductivity data from 'Parknook' also shows the effect of releases from Woods Lake (see Figure 8), though this is less different than what might be expected in an unregulated river. Although conductivity levels did increase over the irrigation period, this increase was less rapid than what may have occurred in the river under natural conditions (compare with April and May) and was still within the normal range expected for rivers in the area.

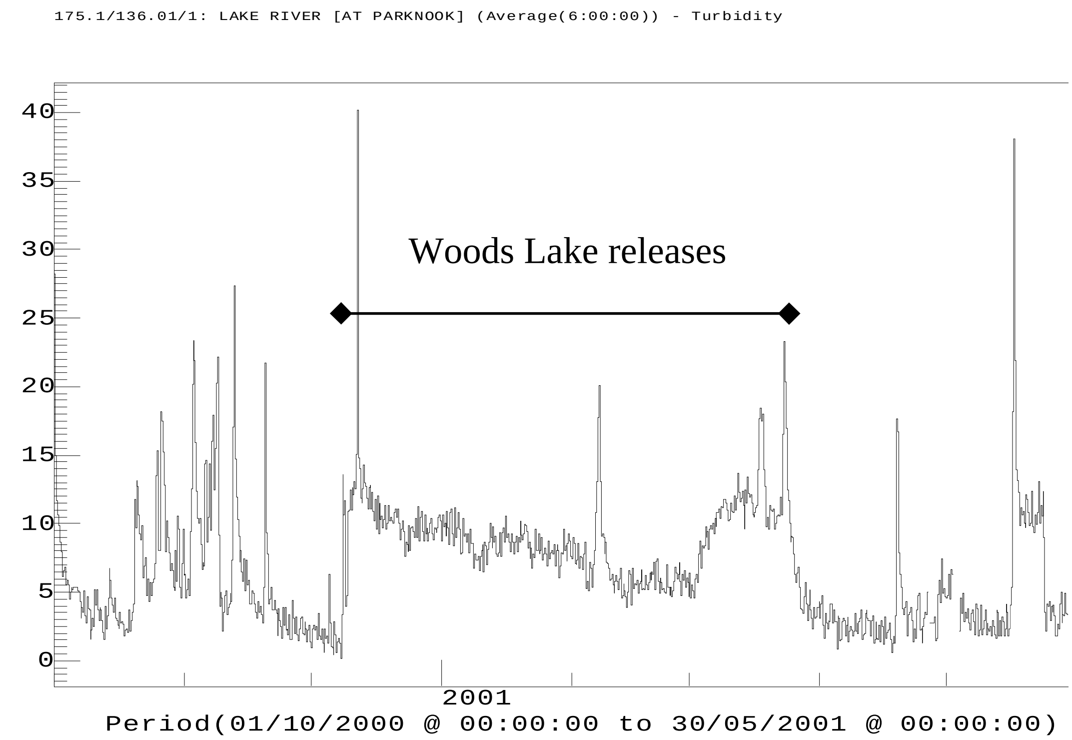


**Figure 7: Time series plot of turbidity at 'Parknook' on the Lake River between Oct 2000 and May 2001. Turbidity units are in NTU's**

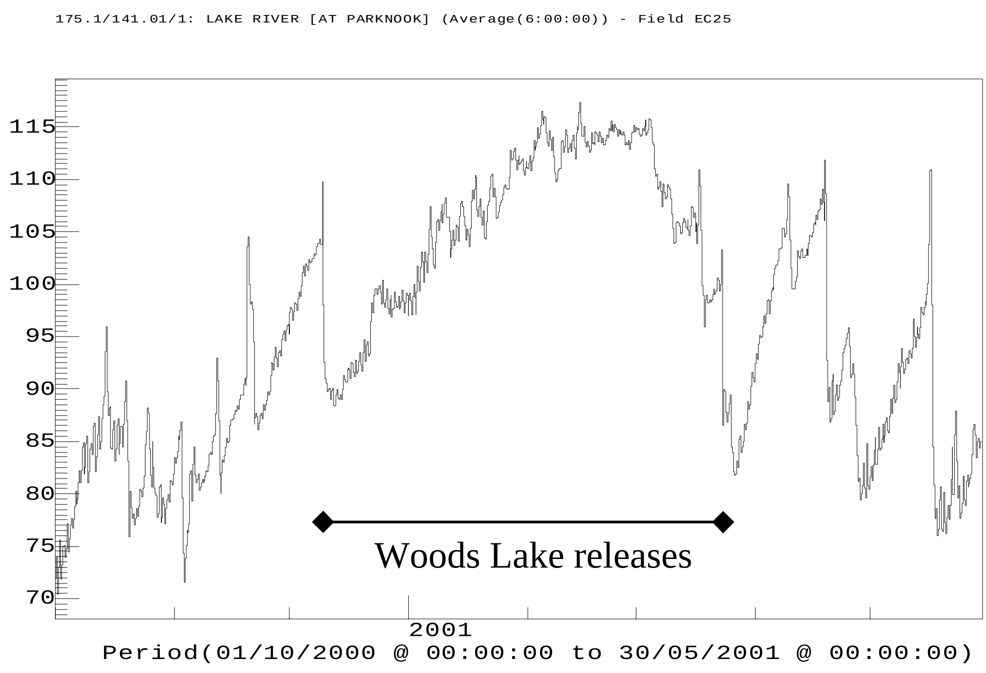


**Figure 8: Time series plot of conductivity at 'Parknook' on the Lake River between Oct 2000 and May 2001. Conductivity units are in μS/cm**

Longitudinal sampling down the length of the Lake River in March (see Figure 9) showed there is a steady reduction in turbidity between the Woods Lake outlet and the Macquarie River, with the greatest changes occurring between LR4-LR7 and LR10-LR11. This pattern of change is mirrored by total phosphorus concentrations (see Figure 10), indicating that the large majority of the phosphorus in the river is bound to particulate material that settles out of the water column during its passage down the length of the river.

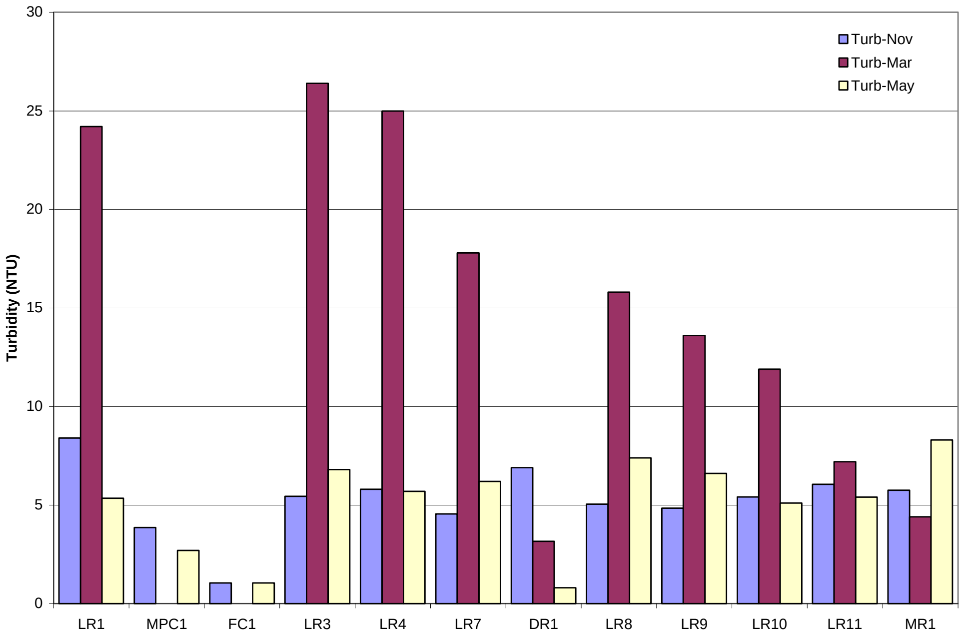


**Figure 9: Longitudinal plot of turbidity from the headwaters of the Lake River to below the junction with the Macquarie River**

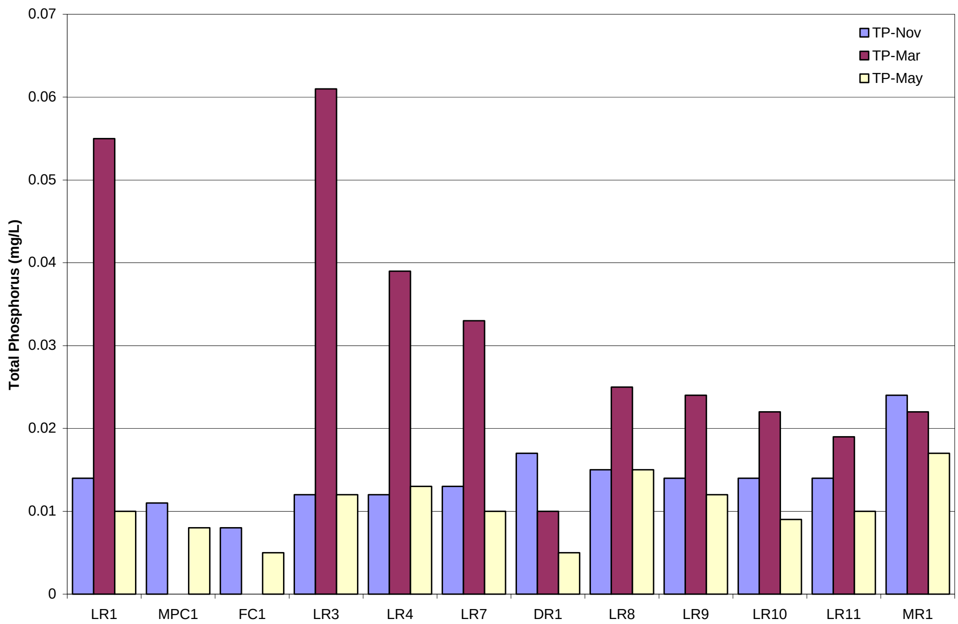


**Figure 10: Longitudinal plot of total phosphorus from the headwaters of the Lake River to below the junction with the Macquarie River**

The pattern of change of faecal coliform concentration down the length of the Lake River is very different to that for nutrients (see Figure 11). Water emerging from Woods Lake contains very low levels of faecal bacteria. On all sampling occasions faecal bacteria increased substantially towards the bottom of the catchment, with the greatest increase occurring at LR7 (Boomers Bottom) where extensive stock access to the river has resulted in the direct deposition of faecal material into the bed of the river. Although this general pattern was found on all sampling occasions, levels across all sites were lowest during May 2000, when no site exceeded 100 fcu/100 mL. During the March survey most sites below LR3 exceeded the guideline value of 1000 fcu/100 mL as outlined in National Water Quality Guidelines for the protection of stock health (ANZECC, 1992), and all exceeded the more stringent trigger value of 100 fcu/100 mL that is now being considered (ANZECC, 2001). These sites also pose significant health risks for recreational use by the public (swimming and bathing).

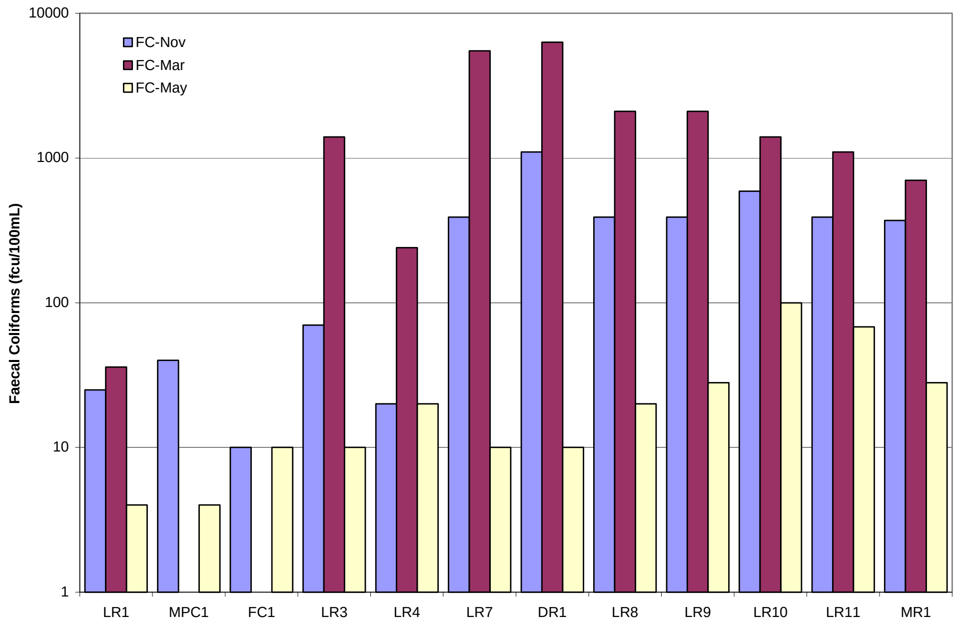


**Figure 11: Longitudinal plot of bacteria from the headwaters of the Lake River to below the junction with the Macquarie River**

Dissolved oxygen at most sites was found to be indicative of a healthy environment, although levels at the lowest site (MR1 - Macquarie River at Westmoor Bridge) were markedly lower than all other sites and are indicative of a mildly degraded environment (oxygen saturation levels of 59-84%). The lowest level measured in the Lake River was at LR10 and LR11, both of which are in reaches of the river where low bed gradients prevent oxygenation of the water.

It is clear that the quality of water within Woods Lake is a major determinant of water quality further down the river, with the notable exception of faecal bacteria. Stock access to the river clearly causes significant contamination of the river and may have consequences for animal health, especially young animals that may be more susceptible to infectious diseases.

Nutrient concentrations in the upper reaches of the river during the irrigation season are obviously governed by conditions within Woods Lake, however towards the bottom of the catchment concentrations are likely to be nearer to what would occur under an unregulated flow regime.

# 4. Environmental Management Options for the Lower Lake River

## Options for Allocating Water for the Environment

There appear to be three potential options for setting minimum environmental flows for the section of the Lake River between Woods Lake and 'Parnook'.

The first of these options might be to continue the existing system of managing flows in the river. There is some justification for taking this option, as various assessments of biological health recently and in the past have shown that the aquatic community is reflective of a very 'healthy' ecosystem.

Using only the statistical output from the constructed 'natural flow model', a minimum flow based on recession curve analysis (20-day during summer and 10-day during winter) is likely to provide sufficient water to protect the aquatic environment. This is predicated on the fact that slightly greater discharge than is currently maintained in this section of the river (from 'Parknook' data), and that any additional flow is not likely to impact negatively on the 'health' of biotic communities in the river, which is presently good.

Using the biologically relevant Instream Flow Incremental Methodology approach, the only viable option from this assessment appears to be the second option, where 'existing flows' have been used as the reference flow (see Table 13). This has resulted in a summer minimum flow of 0.6 $m^3s^{-1}$ and a winter minimum flow of about 1.45 $m^3s^{-1}$. The table below (Table 13) presents the options for direct comparison. Options that have been deemed 'not viable' are those that will require a substantial increase in the volume of water released from Woods Lake, and have been found to significantly impact on the ability of Woods Lake to meet irrigation demands from year to year.

| | Summer Minimum Flow (cumec) | Winter Minimum Flow (cumec) |
|---|---|---|
| Recession Curve Analysis (20-day summer; 10-day winter) | ~0.26 (22.5ML/day) | ~1.44 (124.5ML/day) |
| $90^{th}$ Percentile Flow | 0.5 (43.2ML/day) | 2.4 (207ML/day) |
| 'Natural Flow' as Reference for IFIM | 1.45 (125.3ML/day) | 1.45 (125.3ML/day) |
| 'Existing Flow' as Reference for Instream Flow Incremental Methodology | 0.6 (51.8ML/day) | 1.45 (125.3ML/day) |

**Table 13: Options for 'minimum environmental water allocations' for the Lake River – figures presented are for the Lake River at 'Parknook'**

The implementation of any of these three potential options should be considered within the broader context of water use and management in the Lake River. Until issues of water use are resolved, it may not be appropriate to change from the current system of water release from Woods Lake.

## Options for Water Quality Management

The water quality information gathered during earlier studies and complemented by additional data collected during this project, supports conclusions that baseline turbidity and to a lesser extent nutrient concentrations in the Lake River are driven to a large degree by conditions in Woods Lake. Much poorer water quality (as indicated by turbidity levels) tends to be a result of local rainfall events that result in runoff from the middle catchment, where logging activities are likely to have substantially increased sediment delivery to the river). Options for managing water quality in the Lake River are outlined below.

*Options*

- Manage water levels in Woods Lake to minimise impact upon turbidity levels in water being discharged to the Lake River downstream.
- Undertake no active management of water levels in Woods Lake to protect water quality.
- Construct and maintain a large wetland downstream from Woods Lake to act as a polishing pond to improve clarity of water discharged from Woods Lake.
- Look at potential rehabilitation of parts of the Lake River that may be contributing to degradation of water quality below Woods Lake during runoff events.

Some aspects of the water quality issue are intimately tied to water level management within Woods Lake. Unfortunately, management of this storage may be influenced by issues other than water quality (i.e. threatened species), but any decisions regarding water level management must take into account the potential impacts on water quality for downstream users in the Lake River.

It is also important that Hydro Tasmania is involved in the Water Quality Objective setting process for this area, so that expectations by the public and Government Agencies are not unrealistic. In this process there must be some recognition that turbidity within Woods Lake is likely to be a historical fact, though low lake levels may cause intermittent problems. Options to protect or ameliorate water quality within Woods Lake should be seen as having a ‘moderate’ level of priority.

It is also clear from the data that heavy, localised rain events (which are characteristic of this area) result in excessive sediment entering the river from forestry activities in the catchment below Woods Lake. Sampling in the catchment following heavy rains showed that roads established for logging purposes in the upper catchment were leading to high turbidity levels in tributaries of the Lake River, and this is likely to have longer-term consequences for water quality and geomorphology in the river. Any plans to mitigate turbidity in the Lake River must take this activity into account.

The management objective for this issue in the Lake River is therefore to provide water from Woods Lake of sufficient quality so that the concerns of downstream users are met and that will meet or exceed the Water Quality Objectives set to ensure that the Protected Environmental Values are maintained. Having regard for this, and the importance of environmental issues within the lake itself, the first option is most favourable.

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