Nutrient Loads from the Macalister Irrigation District

Outcomes of the Specialist Workshop held at Monash University on the 14 April 2000

Barry T Hart

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Technical Report 5/2000

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1 INTRODUCTION

1.1 Background

The Gippsland Lakes experience algal blooms almost every year, with major implications for tourism and more recently for the fishing industry.

The State Environment Protection Policy (SEPP) - Waters of Victoria: Schedule F5, Latrobe and Thomson River Basins (Vic Government Gazette, 1996), addresses the nutrient loads entering Lake Wellington and some of the key nutrient sources. Environmental quality objectives in the policy are established for a median stream flow year. In particular, the SEPP requires at least a 40% reduction in the annual phosphorus loads from irrigation drains in the Macalister Irrigation District (MID) by 2005, with the baseline load determined on the basis of total annual phosphorus loads discharged during the years 1994, 1995 and 1996.

There has been considerable controversy about the baseline total phosphorus (TP) load from the MID, with claims and counter claims about the best estimate (many different methods have been used, and all have problems because of a lack of adequate data).

The Environment Protection Authority (EPA) requested that the CRC for Freshwater Ecology (CRCFE) facilitate a specialist workshop, attended by many key stakeholders, to resolve the issues regarding the estimation of loads from the MID. The purpose of the workshop was to seek agreement on a "best" methodology and a "best" available data set, and if needed to define what additional data needs to be collected. The Workshop program and a list of participants are provided in Appendix A and B respectively. A Discussion Paper was produced by EPA to provide essential background for the Workshop (see Appendix C).

A map of the region and the MID drainage system is given in Figure 1.

1.2 Workshop objectives

A workshop was held on the 14^{th} April 2000. The objectives of the workshop were:

- To review available data and methodologies being used to estimate the annual loads of phosphorus discharged from irrigation drains in the MID.
- To agree on an appropriate method for calculating these loads and on the "best" available data set needed for this purpose.
- To agree on a baseline annual phosphorus load discharged during the years 1994, 1995 and 1996 (or if this is not possible agree on a method and data set required to estimate such a baseline load).

1.3 Workshop output

The purpose of the workshop was to agree on a "best" methodology and a "best" available data set to estimate the baseline TP loads from the MID.

The outputs from the Workshop have been arranged below in three sections:

1. Best available data set;
2. Agreed method to estimate the baseline TP load from the MID; and
3. Future activities.

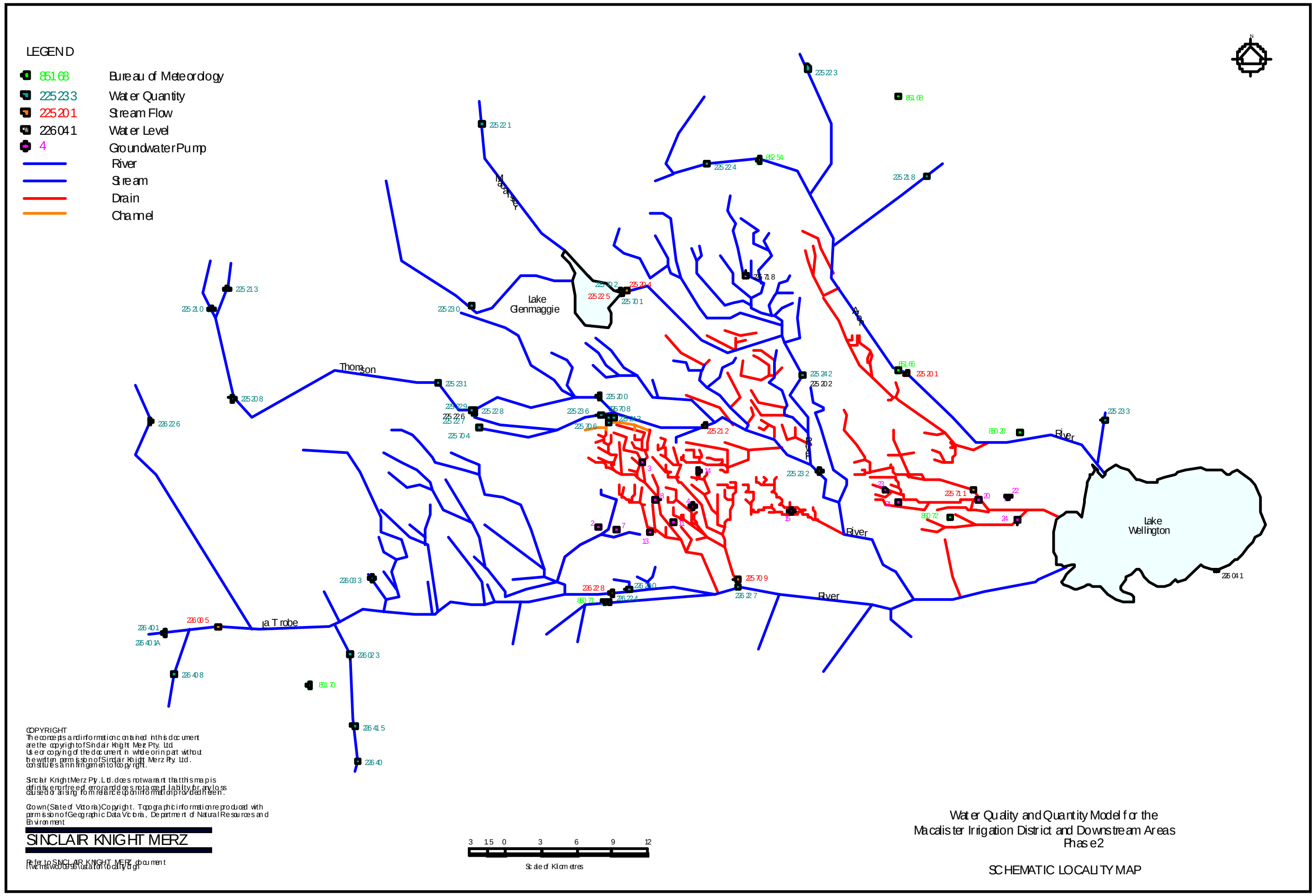

Figure 1: Schematic locality map

2 BEST AVAILABLE DATA SET

A summary of the main points made by each of the workshop presenters is presented in Appendix D, while the discussion of the three workshop groups that were formed to consider approaches to TP load calculation is included in Appendix E.

The Workshop participants identified a number of constraints to EPA's requirement that a baseline TP load is estimated for a "median" year, using the loads discharged during the years 1994, 1995 and 1996. These constraints are:

- There is no adequate water quality data for the years 1994-96.
- Water quality and flow data are available for two MID drains for the period 1997-99, but there are no well-accepted methods for extrapolating these data to the whole MID nor to the desired period (1994-96).
- The period 1994-96 was relatively wet while 1997-99 was very dry.
- There may have been changes in land use or irrigation practice during the period between the two dates (although the participants from the MID region believe that any changes have been relatively minor).
- The drought period of 1997-99 would have affected water allocations during this time because of the changes in irrigation practice forced by lack of water.

The Workshop concluded from this discussion that there were uncertainties associated with each of the methods for estimating the baseline TP load from the MID at this stage. It will, therefore, be important that the method adopted be transparent so that any limitations in the results will be clear.

2.1 Quality of available data

The existing sampling site distribution and frequency of sampling undertaken by Southern Rural Water (SRW) is summarised below (see Figure 1 for locations):

- Two drains (drains (Central Gippsland Drain No. 3 (CG3) and Lake Wellington Main Drain (LWMD)) have been sampled daily since around August 1997 - these two drains account for around 25% of the total flow from the MID.
- One additional drain (CG2) has been sampled daily since August 1999
- Sampling in one additional drain (Newry Creek) was commenced in April 2000 (daily sampling)
- Sampling in another two drains (CG4 and Serpentine Creek) is due to commence before June 2000 (daily sampling proposed).

There has been concern over the quality of the TP results for the daily samples taken from the two drains (CG3, LWMD) during the period 1997-99. These samples were analysed by Envirogen, a local consulting analytical laboratory, which has had problems with low level TP analyses during the earlier part of this period.

Workshop participants were presented with a review of the Envirogen data for these drains (not the river samples) and a comparison between the Envirogen data and that of a well-established and highly reputable laboratory (Water Studies Centre, Monash University). This review showed that differences between the Envirogen data and the WSC laboratory have steadily reduced such that since April/May 1999, the differences have been minimal.

Other available data sets include those collected by the West Gippsland Catchment Management Authority (WGCMA) and by Waterwatch. The WGCMA data set includes weekly sampling and continuous flow measurements on river sites upstream and downstream of the MID and on two drains. The Waterwatch data set includes irregular monitoring (often of reactive phosphorus rather than TP) and quantitative or qualitative estimates of flow.

The Workshop concluded that with some exceptions (e.g. TP concentrations below ca. 0.02 mg/L), the Envirogen drains data for 1997-99 was acceptable and could be used for load calculations. In addition, it was concluded that the WGCMA and Waterwatch data sets should be used in "reality check" load estimations.

2.2 Spatial representativeness of the data

The two drains for which there is a sufficiently large amount of data available (CG3 and LWMD) represent only 25% of the flow in the MID. Additionally, because they drain efficiently to the rivers, they are not typical of all the drains in the MID. Other drains particularly those in the Maffra region do not drain well and often end in a billabong.

Several options for scaling up from the loads for these two drains to the whole of the MID were discussed. The approach decided upon is detailed in Section 3 below.

3 AGREED CALCULATION METHODS

The Workshop identified problems associated with all the available load calculation methods. A brief summary of the advantages and disadvantages of each method is provided below. Further information can be obtained in the Discussion document and NSW EPA Technical Report 99/73 (1999).

Direct calculation method - This method is simple and transparent in its calculation. However, the method is data intensive requiring data that covers the full range of concentration and flow variation, and would be expensive to apply widely. Currently only two drains have sufficient data for a direct calculation approach and results must be scaled up to cover the whole of the MID, so any variability in TP export from sub-catchments will not be captured. There are also problems associated with extrapolation of results back to 1994-96 period defined in the SEPP.

Estimation from river load calculations - The advantages of this method are its simplicity and ease of calculation (subtraction of upstream from downstream loads calculated from TP-flow regression or direct calculation). Additionally, using data from the rivers sites integrates the inputs from a much greater number of the irrigation drains (about 65% of the area covered). Data already exists for the 1997-1999 period so there is still the problem of extrapolating back to 1994-96 loads. There is doubt about the reliability of some of the low concentration TP analysis that introduces an error into the load calculations especially for the upstream load estimates. In-stream processing of nutrients may also confound the impact of the TP load discharged from the MID. Data was collected on a weekly basis with increased monitoring during high flow events at some of the sites. The EPA calculation prepared for the discussion paper did not use this high flow data (flow data not available then) thus it would have been likely that part or all of the loads carried by large flow events were missed in the preliminary EPA estimate. Additionally, errors in load estimates are amplified by the subtraction of upstream loads from those downstream.

Sinclair Knight Merz (SKM) HYDROL model - The model of TP export from the subcatchments of the MID will be a valuable management tool for guiding nutrient reduction efforts in the future. The model provides a good estimation of drain flows and good spatial coverage. However, modelled loads will be calibrated using data collected directly from the two drains currently monitored, and are likely to produce similar results. The model also assumes that land use and activities have not changed since 1994-96; this requires confirmation. The model will be delivered at the end of June 2000, which may be too late to meet current needs for a defined load from the MID. While the model has many good features, they are not easily communicated to the catchment communities. Total nitrogen (TN) and TP in the irrigation drains is non-conservative, while the model assumes that TP will be conservative. The circumstances leading to remobilisation of TP ‘lost’ along the drains requires further investigation. While the model extrapolates to unmonitored drains, these extrapolations suffer from the same lack of supporting data as the other methods.

After a detailed assessment of each method, the Workshop participants agreed that the direct calculation method should be adopted. It was agreed that while there are a number of uncertainties associated with this method (but no more than with other methods available), it had the advantages of simplicity, transparency (cf. the more complicated models) and used actual water quality and flow data from the MID drains.

The Workshop participants recommended that the following approach be used to estimate the TP loads for three periods: 1997-99, 1994-96 and "median" year:

(a) TP loads for CG3 and LWMD for the period 1997-99

- Use the 1997-99 water quality data for the two drains (CG3, LWMD) to estimate the TP loads and calculate the flow-weighted mean concentrations for this period.

(b) TP loads for the remainder of the MID for the period 1997-99

- Use drain flow data from Mollica (1990) and subsequent flow measurements to estimate 1997-99 flow for the remaining drains.
- Use flow-weighted concentrations calculated in (a) above with these flows to calculate the TP load for the remaining drains.
- It was noted that a linear model could also be used to scale up the load calculated for the two drains to the whole MID (i.e. multiply the load from the two drains by 4 - 25% to 100%). However, this approach is may be too simplistic given the non-uniformity of MID drains.

(c) TP loads for CG3 and LWMD for the period 1994-96

- Use the measured 1994-96 flows for these two drains and the flow-weighted mean concentrations estimated in (a) above to estimate the loads from these two drains for the 1994-96 period.

(d) TP loads for the reminder of the MID for the period 1994-96.

These are to be calculated in two ways:

- Scale the 1994-96 loads for the two drains (estimated in (c) above) to the remainder of the drains above using flow data in the Mollica report (1990) and additional flow data collected since 1990.
- Use the measured 1994-96 flows for these drains and the flow-weighted mean concentrations estimated in (a) above to estimate the loads from these drains for the 1994-96 period.

(e) Median flow loads for the MID.

- Use drain flow data from Mollica (1990) and subsequent flow measurements to estimate median flow.

  There was considerable discussion on the question of "median" flows from the MID. It was noted that the median flow in the Thomson, Macalister or Latrobe rivers was almost certainly NOT a median flow year for the MID. Irrigation flows are not directly related to river flows, e.g. when river flows are high (i.e. wetter year) irrigation flows less; in dry years, irrigation flows are higher.

- Use flow-weighted concentrations calculated above with this median flow to calculate the TP load.

(f) The Workshop participants recommended that two additional calculations be undertaken to "reality" check the TP load calculations.

- Use the available Waterwatch (and other) water quality data for drains in the MID to check the scale up method. These data could be used to estimate the relative differences between the various drains and modify the flow-weighted mean concentrations if needed.

- Use EPA river-based model to recalculate the TP loads contributed by the MID. The data set collected by the WGCMA, including high flow data, providing coverage of around 65% of the MID should be used.

  The Workshop participants recommended that EPA discuss with CEAH the modelling approach to be used.

The Workshop participants recommended that the load estimates be undertaken by EPA (in collaboration with SRW, SKM, Natural Resources & Environment (NRE), Centre for Environmental & Applied Hydrology (CEAH) and WGCMA where necessary) and that the outputs (load for 1997-99; load for 1994-96; load for "median" flow year) be circulated to all workshop participants for comment before they are accepted.

4 FUTURE ACTIVITIES

The following were identified by Workshop participants as important activities for accurately measuring and communicating the P loads discharged from the MID.

4.1 Macalister Irrigation District

- Establish how best to release the load information publicly. Should this be a combined release including all parties or a release by the EPA? Should the release foreshadow what work needs to be undertaken in the future?

4.2 Gippsland Lakes Model

- Evaluate the appropriateness of the river modelling being undertaken by CEAH in determining catchment loads to the Lakes.
- Consider obtaining information for other indicators (e.g. FRP, TN, NO3, NH4, TSS, EC).
- Assess whether P, N or both N and P are drivers of algal growth in the Gippsland lakes [this should be determined from the current modelling project being undertaken by CSIRO].

4.3 Catchment Monitoring

- Assess the spatial representativeness of the current monitoring sites.

4.4 Southern Rural Water

- Consider whether current daily P measurements in drains can be reduced in frequency without jeopardising load calculations. This needs a sensitivity analysis to examine gains available
- The Workshop participants were informed of the following additional monitoring undertaken by SRW: One additional drain (CG2) has been sampled daily since August 1999; Sampling in one additional drain (Newry Creek) was commenced in April 2000 (daily sampling); Sampling in another two drains (CG4 and Serpentine Creek – check?) is due to commence before June 2000 (daily sampling proposed). The Workshop was told that in addition to the above 6 sample sites (from July, 2000), SRW plan to obtain a mobile sampling unit that they will use to obtain "spot" samples from a wider range of irrigation drains over the MID. The Workshop participants supported this approach and recommended that SRW establish a detailed "spot" drain sampling plan for the next 3 years (e.g. which drains will be targeted, for how long will each drain be sampled, etc).
- The Workshop participants addressed the question "Can the present daily sampling at all sites be modified without a loss of information about TP loads from the MID?" The participants recommended that SRW, in collaboration with the WGCMA and EPA, review the objective of the sampling program. For example, if the objective is simply to determine the annual TP load transported from the MID then flow-weighted sampling, where a single cumulative flow-weighted sample is collected over given period (e.g. one week), would suffice. However, if the objective were to use the detailed behaviour of the drains to judge the effect of various management actions within the catchment, then daily sampling or perhaps special intensive studies would be appropriate. The Workshop participants were mindful that any reduction in SRW's costs, for example by reducing the frequency of sampling, would permit the spatial intensity of the sampling to be increased.

- Workshop participants also recommended that SRW undertake a sensitivity analysis of the available water quality data for the two drains to see what sample frequency is required before the load estimates become unacceptable. Workshop participants recommended that the best approach would be to undertake flow-weighted sampling over weekly periods for the agreed number of drains and undertake special studies of the effects of particular management changes where this is required.
- Consider the need for refrigeration of samples collected by the auto-sampler to be purchased by SRW.

5 CONCLUSIONS

The Workshop participants concluded the following:

- That there were uncertainties associated with each of the methods used for estimating the baseline TP load from the MID at this stage. It will, therefore, be important that the method adopted be transparent so that any limitations in the results are clear.
- That with some exceptions (e.g. TP concentrations below ca. 0.02 mg/L), the Envirogen drains data for 1997-99 were acceptable and could be used for load calculations. It was also agreed that the WGCMA and Waterwatch data sets should be used to "reality check" load estimations.
- That the 'direct calculation method' be used as the basis for estimating the P loads discharged from the MID for 1994, 1995 and 1996.
- That the calculation of loads be undertaken by EPA (in collaboration with SRW, SKM, WGCMA, the Department of Natural Resources & Environment and the Centre for Environmental & Applied Hydrology where necessary) and that the outputs (load for 1997-99; load for 1994-96; load for "median" flow year) be circulated to all workshop participants for comment before they are accepted.
- That there were a number of activities that would assist with the development of accurate P loads from the MID and the communication of these results. These would be considered further by the organisations represented at the Workshop.

Appendix A: Workshop Program

Time	**Activity**
0930-1000	Registration and coffee
1000-1015	Introduction: Issues, purpose of workshop & expected outputs (Dennis Monahan)
1015-1025	EPA Discussion Document - Summary of main points (David Robinson)
1025-1040	The MID (Brett Millington)
1040-1200	Review of current work modelling in progress:
	(a) EPA modelling (Kim Shearman)
	(b) SKM/Southern Rural Water – MID modelling (Rohan Barling)
	(c) CRCCH – Thomson/Latrobe modelling (Andrew Western)
	(d) CRCFE – Canberra modelling (Ian Lawrence)
	(e) CSIRO – Gippsland lakes modelling (Brett Wallace)
	(f) Discussion
1200-1245	LUNCH
1245-1415	Split into 3 small groups each to address:
	• strengths and weaknesses of each method used to estimate the P loads from MID;
	• identify any constraints (e.g. poor data sets);
	• specify what needs to happen for these constraints to be addressed
1415-1430	Afternoon tea
1430-1500	Each group report back
1500-1615	General discussion to get agreement on main points:
	(g) “best” calculation method
	(h) “best” available data set
	(i) agreed baseline P load from MID (if possible), or agreed method and data set to use to determine the baseline load
	(j) any additional work needed
1615-1630	Summarise main points and agreement (Barry Hart)
1630	Workshop conclusion

Appendix B: Workshop Participants

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Appendix C: EPA MID Discussion paper

ESTABLISHING BASELINE PHOSPHORUS LOADS FOR THE MACALISTER IRRIGATION DISTRICT

David Robinson and Kim Shearman
Environment Protection Authority, Victoria

ESTABLISHING BASELINE PHOSPHORUS LOADS FOR THE MACALISTER IRRIGATION DISTRICT

INFORMATION PAPER

Introduction

The CRC for Freshwater Ecology has been asked by EPA to assist in determining baseline phosphorus loads discharged from the Macalister Irrigation District. The establishment of the baseline is an important part of a statutory policy requirement aimed at reducing nutrient inputs to Lake Wellington.

To facilitate this process, a specialist workshop ‘Nutrient Loads from the Macalister Irrigation District’ will be conducted by the CRC for Freshwater Ecology and EPA 14 April 2000.

The workshop objectives are to:

- Review available data and methodologies used to estimate the annual loads of phosphorus contributed to the Thomson, Latrobe and Macalister rivers by the Macalister Irrigation District.
- Agree on an appropriate method for calculating these loads and on the ‘best’ available data set for this purpose.
- Agree on a baseline annual phosphorus load discharged during the years 1994, 1995 and 1996 (or if this is not possible agree on a method and data set required to estimate a baseline load).

This paper has been prepared to provide background information to support the workshop and covers the following areas:

1. Policy Context
2. Establishment of a Baseline Load for the Macalister Irrigation District
3. Techniques for Load Estimation
4. Data Types
5. Available Data Sets for Phosphorus Load Estimation
6. Limitations of the Data for Load Calculation
7. Current Approaches to Nutrient Load Estimation in the Macalister Irrigation District, Lake Wellington, the Gippsland Lakes, and elsewhere
8. Summary of Issues

1. Policy Context

State environment protection policies (SEPP's) are statutory policies that express in law the community’s expectations, needs and priorities for using and protecting the environment. They provide a framework for environmental decision-making and a clear set of publicly agreed environmental objectives and management actions that all sections of the community must work together to achieve.

Across Victoria, water quality is protected through an ‘umbrella policy’ – *State Environment Protection Policy (Waters of Victoria) 1998*. Regional policy schedules are now developed within this framework.

The original Latrobe SEPP, which came into effect in 1981 as a stand-alone policy, was revoked in October 1996. It was replaced by a variation to the Gippsland Lakes Schedule (Schedule F3) and insertion of a new Schedule F5 to the Waters of Victoria SEPP. The Latrobe/ Thomson Schedule F5 covers the whole catchment of Lake Wellington and the adjoining Merriman's Creek.

The revision of the original Latrobe SEPP involved a lengthy period of public consultation. Reduction of nutrient inputs from the Lake Wellington catchment was identified as essential in reducing the risks of algal blooms in Lake Wellington. (EPA Publication 516 Policy Impact Assessment: Protecting Water Quality in Central Gippsland).

Analysis of the impact of nutrients on chlorophyll *a* levels in Lake Wellington determined that at least a 40% reduction of phosphorus inputs to the Lake was required to move Lake Wellington from a eutrophic to a mesotrophic state. A 40% reduction would result in an annual input load of115-tonnes / year on the basis of a baseline total input load to Lake Wellington of approximately 190 tonnes for a median flow year. (EPA Publication 460).

Specific objectives were established in the policy to guide nutrient reduction within the catchment:

- Schedule F3 - 'By the end of the year 2005 phosphorus inputs to Lake Wellington must be less than 115 tonnes/ year for a median annual streamflow or its standardised equivalent and must be at a level to ensure that -
  (1) the annual median concentration of chlorophyll *a* in Lake Wellington shall be no greater than 0.008 mg/L; and
  (2) the median concentration of chlorophyll *a* in Lake Wellington during the months of January to June inclusive shall be no greater than 0.005 mg/L'.

- Ambient nutrient concentration limits for rivers within the areas covered by the Latrobe/ Thomson Schedule (F5) which are approximately 40% lower than levels recorded in these rivers in early 1990s.

The policy also establishes an Attainment Program that outlines activities for sound environmental management practices required to achieve the policy’s objectives. A key attainment program measure for nutrient reduction in the MID requires the preparation of a Nutrient Reduction Plan to reduce the annual load of phosphorus discharged from irrigation drains in the MID by at least 40% by the year 2005.

The 40% phosphorus reduction is primarily aimed at improving agricultural practices from a situation where there is little active management of phosphorus discharge to one where measures are employed to counter the phosphorus enrichment from irrigated agriculture. A 40% reduction is considered to be the level of improvement that can be achieved through the adoption of commonly available measures for phosphorus reduction.

2. Establishment of a Baseline Load for the Macalister Irrigation District

To enable the assessment of whether the MID nutrient reduction target is achieved, it is essential to set an appropriate baseline load. The policy stipulates that the establishment of the baseline load is to be determined on the basis of an assessment of phosphorus loads discharged during the years 1994, 1995 and 1996. However, this has proven difficult.

The systematic collection of accurate data upon which any assessment could be based did not commence until 1997. While there is data available for the years 1997, 1998 and 1999, there is the problem of using a different period for the baseline to that specified in the policy. This may be an issue if phosphorus loads during 1997-1999 are thought to differ significantly from those in 1994-1996 and/or if changes to management practices had already been implemented that reduced nutrient export from farms in the period 1997-1999.

The approaching target date of 2005 for the achievement of the MID target loads and the on-going changes to farm management taking place preclude any further extension of the period for collection of data for baseline load assessment.

Questions about the quality of phosphorus analyses have also been raised which casts uncertainty upon the validity of some data that has been collected and its use in load calculations. Due to this uncertainty, various parties have sought to obtain their own data and widely varying estimates for the load discharged from the MID have been made. This has resulted in wide concern and confusion over what the appropriate number for the baseline load is, as well as casting doubt on the validity of the work being done to assess the baseline.

Additionally, there is the issue of the spatial representativeness of the sites being monitored in the available data sets. All data sets only monitor a portion of the MID and the question of how scaling of any load estimates to account for the whole of the MID area must be addressed.

3. Techniques for Load Estimation

An excellent review and assessment of techniques for load estimation is given in a technical report by NSW EPA (report no EPA 99/73, October 1999). It provides a comprehensive review of available methods and tests them against a data set from the Richmond River in northern NSW. A major conclusion of this review was ' there is no single optimal sediment and nutrient (direct) load estimation technique. Selection of an appropriate load estimation technique depends not only on the availability of concentration and discharge data, but also on the hydrological characteristics of the catchment being considered, the desired accuracy of the estimates and the preferred complexity of the load estimation technique. All techniques considered were found to have disadvantages in certain situations.'

A number of techniques exist for the estimation of load from field data. Load is not measured directly but is estimated as the product of pollutant concentration and discharge for a given time interval, and the load over a period of time (eg. a year) is the sum of all such load estimates made for successive time intervals during that period of time.

$$L = \sum_{i=1}^{T/\partial t} CiQi$$

L = load over time period T, C = concentration, Q = discharge,

When the sampling interval is very short, that is approaches the concentration variability with flow, the method of linear interpolation can be used to generate real loads as described by the following equation.

$$\sum_{i=1}^{n+1} \sum_{ti<t\leq ti+1}^{i} q_t \frac{C_{t_i}(t_{i+1}-t)+C_{t_{i+1}}(t-t_i)}{t_{i+1}-t_i}$$

Although flows are usually measured on a continual basis, in most situations the frequency of measurement of pollutant concentrations falls far below this ideal situation. The use of linear interpolation to calculate loads is likely to become inaccurate as the sampling interval increases to the point where it does not accurately capture variations in flow and concentration. The ideal sampling interval will depend upon the system being studied with larger rivers requiring less frequent sampling than smaller systems such as irrigation drains. In most situations where the sampling interval is not ideal some technique is required to estimate pollutant concentration for the period between sampling occasions. These techniques fall into two categories: 1) time averaging techniques, and 2) modelling techniques where a relationship between discharge and concentration is used (usually regression or ratio estimators) to estimate concentrations from discharge measurements.

Time averaging techniques can provide accurate estimates of load but are subject to bias if there are correlations between discharge and concentration and the sampling program does not provide data from the entire range of discharge and concentration variability.

Modelling techniques have the potential to re-create an ideal data set using the continuous flow record. They can also be subject to bias and imprecision if the relationship between flow and concentration used is poor, or the data used to derive the relationship does not cover the full range of flow variation present during the period for which estimates are being derived.

The choice of technique will depend upon the type of data available and the type of system being studied with it being desirable to employ a number of techniques to give an indication of the reliability of the estimates.

4. Data Types

Data for load estimation can be classified into a number of categories or types (NSW EPA 1999):

1. Stratified or flow weighted data
2. Routine data with spot sampling during flood flows

3. Routine data

Stratified or flow weighted data
This is the best class of data as it characterises concentration over the entire range of flow conditions. To collect this type of data usually requires some form of automation, for example, auto samplers activated by changes in flow. Estimation of load would normally be by linear interpolation or some averaging technique.

Routine data with spot sampling
Data collected on a routine basis (eg. daily, weekly, and monthly) with spot sampling during flood events is the next best class of data. Accurate calculation of load is greatly assisted by the availability of continuous discharge data.

Routine data
The most common sampling interval for routine collection is monthly which is too long an interval to capture variations in flow unless the system has very low variability because of drought or is a stream reach below an impoundment. Direct calculation methods of load are not recommended with this type of data. If a continuous flow record is available then loads can be estimated using some sort of technique to estimate concentration from discharge. In this instance it is important to have concentration data that covers the range of flow variation in the period of assessment or at least an assessment of the representativeness of the concentration data.

5. Available Data Sets for Phosphorus Load Estimation

Many sites are monitored within the Gippsland Lakes catchment but for the purposes of this paper only those sites in the lower reaches of the Latrobe, Thomson and Macalister rivers that can be used to assess loads from the MID area are considered. Table 1 lists these sites and provides a summary of the data collected.

There are three organisations currently involved in the collection of water quality and flow data in the lower reaches of these three rivers. These are 1) West Gippsland Catchment Management Authority (WGCMA), 2) Southern Rural Water (SRW) and the 3) Department of Natural Resources and Environment (DNRE) as a part of its Victorian Water Quality Monitoring Network (VWQMN). Waterwatch also undertakes sampling at many locations in the area, but only measure dissolved phosphorus and do not take flow measurements, which means that their data cannot be used for estimating loads of total phosphorus.

West Gippsland Catchment Management Authority
The WGCMA monitors eight sites on rivers and two on drains in the MID area (Table 1). Monitoring is on a weekly basis with continuous flow monitoring at some of the river sites. The WGCMA has also undertaken some flood event monitoring at some of the key river sites. This data could be classed as routine data with some spot sampling during flood flows and is potentially useful data for load estimation. There are however some gaps in the data, which could create problems for load calculation.

Southern Rural Water

Southern Rural Water have monitored two irrigation drains since 1997 (Table 1) with additional monitoring stations recently installed on Newry Creek and Central Gippsland Drain 2. Flow monitoring is continuous with daily collection of samples (by auto sampler) for nutrient analyses. Increasing flows can also activate the auto samplers to sample at a higher frequency. This data is potentially very useful data as it falls into the category of flow weighted data with a high frequency of sample collection. The spatial representativeness of the data is however limited with only two drains being monitored over the period of interest and techniques will be required to scale up the estimates for the whole of the MID.

Department of Natural Resources and Environment

The Department monitors two sites (Table 1) in the area, one each on the Latrobe and Thomson rivers as part of the Victorian Water Quality Monitoring Network. Sampling is monthly for a large range of parameters including both nitrogen and phosphorus. Flow monitoring is continuous. The VWQMN is the only program of systematic data collection prior to 1997.

Table 1 Summary of data collection on the lower Latrobe, Thomson and Macalister Rivers

Site	Monitoring Data				Flow Data			Comments
	Responsible Organisation	Laboratory	Dates	Frequency	Responsible Organisation	Dates	Frequency	
Latrobe @ Swingbridge	West Gippsland CMA/Theiss	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx. weekly. No data for 12/97 to 3/99	None - tidal	-	-	
Latrobe @ Scarnes Bridge	West Gippsland CMA/Theiss	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx. weekly. No monitoring data for 11/97 to 1/98.	WGCMA/Theiss/ Envirogen		Continuous	Some flood monitoring.
Latrobe @ Kilmany South	West Gippsland CMA/Theiss	Envirogen/CMA/NRE Ellinbank/WSC Monash	6/97 - 12/99	Approx. weekly. No monitoring data for 11/97 to 1/98.	WGCMA/Theiss/ Envirogen		Continuous	Some flood monitoring.
Latrobe @ Rosedale	VWQMN/NRE	AWT	3/84 - present	Monthly	DNRE/VWQMN	1900 - present	Continuous	
Thomson @ Swingbridge	West Gippsland CMA/Theiss	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx. weekly. Very little monitoring data between 6/97 and 3/98	None - tidal	-	-	

Site	Monitoring Data				Flow Data			Comments
	Responsible Organisation	Laboratory	Dates	Frequency	Responsible Organisation	Dates	Frequency	
Thomson @ Bundalaguah	West Gippsland CMA/Theiss	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx. weekly. No data for 4/97, 5/97, 1197, 12/97 and 1/98. Patchy data 6/98 - 8/98	WGCMA		Continuous	Some flood monitoring.
Thomson @ Cowwarr Weir	West Gippsland CMA	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx. weekly. No data for 5/98 - 8/98				Samples taken from weir. Water from weir may be discharged through Rainbow Creek or Thomson River. Flow taken as a summation.
Thomson d/s Cowwarr Weir					SRW/ Envirogen	No flow data before 7/97	Continuous	
Rainbow Creek d/s Cowwarr Weir					SRW/ Envirogen	No flow data before 7/97	Continuous	
Thomson @ Wandocka	VWQMN/NRE	AWT	10/76 - present	Monthly	SRW	At least 1/75 - present	Continuous	
Macalister @ Glenmaggie Weir	WGCMA	Envirogen/CMA/NRE Ellinbank/WSC Monash			SRW		Continuous	

Site	Monitoring Data				Flow Data			Comments
	Responsible Organisation	Laboratory	Dates	Frequency	Responsible Organisation	Dates	Frequency	
Macalister @ Riverslea	WGCMA	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx weekly. No data for 11/97 - 1/98	Thiess	9/97 - 8/99	Approx. weekly. Gauge board only. Is not rated for floods.	
Macalister @ Licola	VWQMN/NRE	AWT	1/90 - present	Monthly. Infrequently before 1990		At least 1/97-present	Continuous	
Central Gippsland Drain No. 3	WGCMA	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx weekly. Data thin from 2/97 - 1/97	Thiess/ Envirogen	1/97? - present	Continuous?	
Central Gippsland Drain No. 3	Southern Rural Water	Envirogen	7/97 - present?	Daily	Envirogen	7/97 - present	Continuous	Some flood monitoring?
Lake Wellington Main Drain	WGCMA	Envirogen/CMA/NRE Ellinbank/WSC Monash	2/97 - 12/99	Approx weekly. No data for 7 - 8/97 and 7 - 8/98	Thiess/ Envirogen	1/97 - present	Continuous?	
Lake Wellington Main Drain	Southern Rural Water	Envirogen	8/97 - present	Daily	Envirogen	7/97 - present	Continuous	Some flood monitoring

6. Limitations of the Data for Load Calculation

West Gippsland Catchment Management Authority

The main limitation of the WGCMA data is the weekly monitoring frequency, which means that some high flow events will have been inadequately sampled or missed. This particularly applies to the monitoring on the irrigation drains, which would exhibit much more rapid rises and falls in flow than the rivers. Flood event monitoring was undertaken by WGCMA on some of the river sites, but probably not enough to allow direct calculation of loads from the data. A modelling approach to load calculation or a combination of direct calculation with modelling of high flow events that were not sampled would probably work best with this data. A further limitation is that the monitoring points used do not cover the whole of the MID, requiring some scaling up of the estimates. Another limitation is that the MID loads are not being measured directly but rather by the difference in loads between upstream and downstream sites on the rivers. This has the effect of compounding the errors of estimation at each site.

Southern Rural Water

The high frequency of sample collection and continuous flow monitoring means that direct calculation of loads, with very low errors, is certainly possible from the data. There are some concerns with the practice of emptying the auto samplers on a weekly basis, which means that some samples will have been sitting in the sampler for up to a week before collection. This raises the possibility of changes to the samples occurring either through contamination or physico-chemical changes taking place in the samples. There are also concerns with the time representativeness of the samples if there is a regular diurnal variation in concentrations as the auto samplers generally sample at the same time every day. Spatial variation in concentration within the drains is also a potential problem. The other difficulty with the Southern Rural Water data is that only two of the irrigation drains are monitored requiring one to scale up the load estimates for the whole of the irrigation area.

Department of Natural Resources and Environment

Because of the long sampling interval for water quality parameters (monthly) this data should not be used for direct load calculation, but the availability of continuous flow data makes the estimation of load through a modelling technique possible. The other major limitation with use of the VWQMN data is that only two sites are monitored, and one of the sites (the Latrobe River at Rosedale) is poorly situated in relation to the MID as it picks up one irrigation drain but misses most of the irrigation input to the lower Latrobe.

Quality of the data

Concerns have been raised concerning the quality of the total phosphorus measurements made by the laboratory (Envirogen) used by SRW and WGCMA. In particular, measurements made during 1997 and 1998 are of uncertain quality (Appendix 1). WGCMA became aware of the problem in 1998 and changed laboratories as well as attempting to get some data together to produce cross comparisons between Envirogen and other laboratories. However, some of their data is still affected and they do not appear to have recorded the exact times when laboratories changed, making it difficult to know which laboratory was responsible for which readings. WGCMA's sampling of the irrigation drains is potentially useful for cross comparisons between the analytical results of Envirogen with another laboratory and may be useful for developing a correction factor for Envirogen's data if analysis shows it is needed.

SRW have continued to use Envirogen and consequently their data on the drains which is potentially very good data may require some correction before it can be used.

EPA became aware of problems with Envirogen's data for total phosphorus in 1998 after receiving results for phosphorus analyses contracted out to Envirogen. EPA subsequently submitted split samples of known and unknown concentrations to a number of laboratories (including Envirogen) and found the results of analyses from Envirogen to be inadequate. Following this, EPA undertook an audit of Envirogen's methods and recommended some changes to procedures. The results of trials and audits are given in Appendix 1, as well as some analysis of cross comparisons of data analysed by Envirogen with analyses of other laboratories.

Representativeness of the baseline period

Because of the lack of data for the baseline period specified in the SEPP it is necessary to considered establishing the baseline using the years 1997, 1998 and 1999. There are potential problems with this if management practices to reduce nutrients discharged from the MID had already started to take effect by 1997. Another consideration is that the years 1997, 1998 and 1999 have all been drought years in this region as well as much of the rest of Victoria, and taken together represent a very dry three-year period. This raises a very real problem of how to extrapolate the data for a median flow year, especially as the available data does not cover median flow conditions.

Long-term flow statistics are available for the Latrobe at Rosedale and, to a lesser extent, the Thomson River at Wandocka. Total annual flows for the years 1994, 1995, 1996, 1997, 1998 and 1999 for the Latrobe at Rosedale and the Thomson at Wandocka were compared to the long-term data and percentile rankings are presented in Table 2.

Table 2 Latrobe and Thomson Rivers – approximate percentile rank of Total annual flows for the years 1994 - 1999

Latrobe River at Rosedale		Thomson River at Wandocka	
Base data period 1900 - 1999		Base data period 1977 - 1999	
Year	Percentile Rank	Year	Percentile Rank
1994	53%	1994	62%
1995	91%	1995	81%
1996	80%	1996	71%
1997	3%	1997	38%
1998	5%	1998	57%
1999	1%	1999	10%

7. Current Approaches for Nutrient Load Estimation in the Macalister Irrigation District, Lake Wellington, the Gippsland Lakes and elsewhere

Most of the current efforts in nutrient load calculation are aimed at producing estimates of loads to the Gippsland Lakes and the estimates produced are not directly applicable to the MID. However as the MID is in the Gippsland Lakes catchment the data sets required for load calculation for both the Lakes and the MID are usually from the same sources and of the same type, and thus the techniques developed for one are likely to be applicable to the other.

EPA - MID

EPA used monitoring data collected by the WGCMA for the period 1997-1999 from sites on the Latrobe, Thomson, and Macalister Rivers and on Lake Wellington Main Drain (LWMD). There were two sites each on the Latrobe and Thomson Rivers at approximately the upper and lower boundaries of the MID. LWMD drains directly to Lake Wellington. The SRW data for the two irrigation drains was not used because of uncertainties about the reliability of the phosphorus concentration data. This data is being compared to WGCMA data on the same drains (using a different analytical laboratory) to see if a correction factor can be developed.

The general approach was to estimate the load for the sites near the upstream and downstream MID boundaries on the Latrobe and Thomson Rivers and the load from LWMD. The load due to the MID was assumed to be the difference between the upstream and downstream loads plus the load from LWMD. In practice, these sites do not fully capture the MID load. The down stream sites on each river, Kilmany South and Bundalaguah, are each approximately 20 km upstream of the boundary of the MID. The upstream site on the Latrobe River, Scarne's Bridge, is also substantially upstream of the MID. Nuntin Creek and Heart No. 2 Drain are not captured by any monitoring points. Consequently, the final estimated load was factored to account for land area not captured by the monitoring points and for land incorporated by the monitoring which is not part of the MID. This scaling assumed that all fractions of the MID emit phosphorus at the same rate.

Loads were calculated from monitoring data (collected approximately weekly) and daily flow data. The populations were assumed to be lognormal and each site was examined for a correlation between log flow and log concentration. A correlation was assumed to exist if the $r^2 > 0.05$ and the p-value < 0.05. For the sites where a correlation existed, the relationship between flow and concentration was used to simulate daily concentration from the daily flow data. This simulated daily concentration was used in the load estimation. For the sites where no correlation existed, the mean annual concentration was used for the load estimation.

The estimates derived from this approach and their associated errors are as follows:

Estimated load for the MID = 88 tonnes P/yr

Upper bound = 120 tonnes P/yr

Lower bound = 63 tonnes P/yr

It must be noted that data for some high flow events monitored by the CMA has not yet been used due to the time available to do the preliminary calculations. The method for estimating concentrations from the daily flow record is only as good as the data put into it. If the relationship between flow and concentration changes significantly with increasing flows, which is very likely, then the estimates for flows that fall outside the range for which we have concentration data could be very biased (probably low). Thus the estimate above, including the upper and lower bounds, could well be biased and is not considered to be the final estimate.

Sources of error:

- The single largest source of error is the use of daily flow to predict daily concentration. The prediction errors are large owing to the low values of r^2 which indicate that the relationships used to predict concentration from flow explained only a small amount of the variability in concentration. More work on the relationships between flow and concentration, possibly using seasonal corrections and antecedent flows has the potential to considerably improve these relationships. Furthermore, the errors are compounded by the method of obtaining the load by the difference in load estimates for two sites.
- It may not be possible to extrapolate from 1997-99 to 1994-96, in which case this method is likely to substantially underestimate the MID load for a median flow year.
- The SEPP requires the calculation of load discharged from the agricultural drains. Using receiving water loads may underestimate the drain loads because of assimilation processes within the rivers.
- This method uses CMA monitoring data. The quality of some of this data is not clear because of uncertainties about the identity of the analysts and the exact dates when laboratories were changed.

West Gippsland Catchment Management Authority - MID

Monitoring data was analysed in-house at the CMA from the period November 1998 to October 1999. Mean concentrations of total phosphorus at sites on the Latrobe River upstream (Scarnes Bridge) and downstream (Kilmany South) of the MID were calculated. The percentage increase in mean concentration was used to scale up the load estimate for the Latrobe River taken from a 1978 report on the Gippsland region by Graham et al. “Input Streams Assessment”. The resultant load estimate was 62 tonnes/year for that river reach.

Sources of error:

- The most obvious problem with this load calculation is that it is based purely on concentration and takes no account of correlations between flow and concentration.
- The total phosphorus load for the Latrobe River was taken from a report which is now 22 years old and the estimate was for a single twelve month period for the Latrobe River at Kilmany South not Scarnes Bridge.

Southern Rural Water - MID

For the preparation of the Nutrient Reduction Plan for the Macalister Irrigation District SRW produced an estimate of 27 tonnes/ year of phosphorus from the MID. This was on the basis of Waterwatch data, which was used to produce an estimate of mean concentration for irrigation drainage water and estimates of annual flows for the years 1994, 1995 and 1996. Again this calculation takes no account of possible correlations between flow and concentration. Furthermore, it relies on Waterwatch data, which is for dissolved phosphorus and not total phosphorus.

Sinclair Knight Merz: MID Surface Water Quality and Quantity Model

In May 1999, Sinclair Knight Merz (SKM) was commissioned to develop a surface water quality model for the MID and the catchment downstream to Lake Wellington. The Department of Natural Resources and Environment (DNRE), Southern Rural Water and the National Heritage Trust (NHT) jointly funds the project.

The project has two main objectives:

- To estimate the current salt and nutrient loads discharging from the MID to Lake Wellington; and,
- To construct a computer simulation model which can be used to assess the impact of changing management practices on the flow, salt and nutrient loads leaving the MID.

The computer model package selected for the project is referred to as “HYDROL”. The model was developed by the Tasmanian Hydro-Electric Corporation (HEC) to model the time dependent behaviour of systems. The model comprises of a series of “nodes” and “links”. Nodes are used to represent objects and inputs to the system such as groundwater pumps, drain diverters, rainfall, evaporation, channel outfalls, etc. Links are used to represent river reaches and drainage networks. Nodes and links are connected together to form a network which mimics the natural system.

The model specifically focuses on the following parameters:

- Flow (ML/d);
- Salinity (µS/cm (EC));
- Total Nitrogen (mg/L (TN)); and,
- Total Phosphorus (mg/L (TP)).

In addition to the river and drainage network, the model will encompass Lake Wellington. However, given the overlaps with the “Gippsland Lakes Model” (being developed by CSIRO) and the complexities associated with modelling nutrients in the Lake, only changes to salinity concentrations in the Lake will be modelled at this stage.

The model is to be run over a 20-year “Plus” timeframe from 1 January 1978 to 30 June 1999.

A trial model focusing on the Avon River sub-catchment and Central Gippsland Drain No. 3 has been constructed, calibrated and tested. Currently work is continuing on the construction and calibration of the model encompassing the MID. The entire project will be completed by the end of June 2000, however preliminary load estimates from the MID are expected by mid to late April. The modelling work being undertaken by SKM has strong links with the Gippsland Lakes Model currently being constructed by the CSIRO. Both teams are keeping in touch on a regular basis to ensure that the greatest benefit can be derived from both projects.

EPA - Lake Wellington

EPA Publication 460 documents the results for load calculations for input streams to Lake Wellington. These estimates are based upon data for six twelve-month periods ranging from 1977 to 1990. The sampling frequency varied from weekly with flood event sampling to routine monthly sampling. The method of calculation was the interval concentration and discharge method in which the data set is broken down into intervals for which estimates of concentration and discharge are used to calculate the load for each interval. The loads for all successive intervals in a twelve-month period are summed to produce estimates of annual loads. This method can produce very accurate estimates of loads when the interval is short but is likely to become much less precise when the sampling interval increases. Thus the estimates for the two twelve month periods that were only sampled at a monthly frequency would be less precise, although both these twelve-month periods were very dry with lower than normal variation in flow. The estimated total annual input load of phosphorus to Lake Wellington was 191 tonnes P/yr. The results of these load estimates were used to develop the target loads in the Latrobe/Thomson policy, although the percentage reduction in load required was developed from an analysis of phosphorus-chlorophyll *a* relationships in Lake Wellington.

Centre for Environmental Applied Hydrology, University of Melbourne - the Gippsland Lakes

The Centre for Environmental Applied Hydrology (CEAH) at the University of Melbourne has undertaken to produce estimates of daily loads of total suspended solids (TSS), total phosphorus and total nitrogen for all of the rivers flowing into the Gippsland Lakes for the years 1997, 1998 and 1999. This work is being carried out to provide input to the CSIRO/ Coastal Board study of the Gippsland Lakes. During this period the temporal spacing (monthly) of available water quality sampling was too large to consider any direct calculation load. CEAH has chosen to use a modelling approach based on regression relationships between flow and concentration, allowing the use of the extensive continuous flow records available for the rivers flowing into the Gippsland lakes. CEAH has been able to improve the relationships between flow and concentration by including parameters that represent seasonality and antecedent flow conditions. CEAH are still determining the optimum combination of variables for each site, although preliminary indications are that they have been able to greatly improve the r^2 values by use of these additional parameters as compared to relationships between flow and concentration only.

CSIRO Gippsland Lakes Environmental Audit

The CSIRO gives figures for loads to the Gippsland Lakes in a review of the water quality status of the aquatic ecosystems of the Gippsland Lakes prepared for the Gippsland Coastal Board in October 1998. These estimates are taken from an earlier report (Graham et al 1978). Their method of calculation was a time averaging technique with some stratification of the data into flow periods. This technique would be expected to produce biased estimates of loads (usually low) because of correlations between flow and concentration, although the stratification of the data could be expected to improve this bias. The load of total P estimated by Graham et al for all of the Lake Wellington inputs was 284 tonnes P/yr.

Other approaches: application of the AQUALM Model in prediction of phosphorus exports

Water quality monitoring in the ACT over the late 1970s and early 80s indicated that some 90% of catchment pollutant export occurred during significant rainfall and discharge events. In view of the significant climatic variability across the region, it was recognised that it was imperative that an ‘event based pollutant export’ model be developed. In 1983, regression analysis was undertaken of ‘event discharge – pollutant exports’ relationships

(R^2 values of 0.6 to 0.8) for intensive water quality monitoring of runoff events across urban, rural and forested catchments in the upper Murrumbidgee Catchment. Water quality constituents analysed included TP, TN, & SS.

Building on Water Balance Models (Boughton), runoff predictive models for a range of soils and land uses were developed for the catchment. Analysis of the daily runoff predictions provided by the models against gauged discharges indicated a significant (at the 5% level) correlation between predicted and gauged values.

In 1987/88, WP Software incorporated the algorithms into a graphic user interface software package (AQUALM) to provide a more efficient and accessible model for general use by government agencies and consultants. The model enables the integration of diverse sub-catchments in terms of land uses, soil types and rainfall, with application:

- of the rainfall-runoff model to yield daily runoff estimates for each 'soil – land use rainfall'category, and application
- of the appropriate 'discharge – pollutant export' regressions

to yield a whole of catchment daily discharge and pollutant export estimate. The integrated package includes provision for the inclusion of point-source discharges, and for in-stream losses and re-suspension, as a function of flow and channel morphology.

The software incorporates the ACT algorithms as default values, but allows the user, via user friendly graphical devices, to enter soil profiles and pollutant regression relationships more appropriate to local conditions, as well as the local catchment configuration.

Using historic rainfall data across the catchment, the model is typically used to provide a profile of discharges and pollutant exports over time, and for a range of land use and management practice scenarios. Often, application is on the basis of an average rainfall year, together with a wet and dry year (20%ile and 80%ile rainfalls) to provide an indication of range in values. The model may be applied either by application of rainfall, or using gauged discharge data.

Over the last 5 years, there has been a substantial increase in published 'event based discharge – pollutant export' relationships for a range of land uses across the nation. While these regressions indicate a minor increase in the export gradient with increased rainfall, they demonstrate the accuracy and reliability of the model assumptions.

The 'physical pathways' focused water balance model provides a robust basis for estimating pollutant export, in terms of the overflow (surface) and interflow (seepage) discharge pathways and associated mobilisation of pollutants. The CRC for Freshwater Ecology has now extended the analysis of these pathways to the forms of nutrient discharge. In a similar way, the application of organic fertilisers could be accommodated in the model.

Ideally, its calibration relative to local conditions is tested by application of the model for periods for which some discharge and pollutant event based export data is available.

It is now the most widely used pollutant export predictive model across Australia, NZ & SE Asia, with rapid growth in application in the US and Europe. In 1994, the model was adopted as the basis of analysis of land use and management ‘futures’ in the joint Commonwealth, NSW, ACT & Local Government ‘ACT & sub-region Planning Strategy.

Independent testing and comparison of the model predictions with other models has been published by Chiew and Jakeman. These studies have demonstrated accuracy and robustness of the AQUALM model and its potential application to the MID requires consideration.

8. Summary of Issues

Representativeness of the baseline period
The period that will need to be used for the baseline (1997, 1998 and 1999) differs to that specified in policy (1994, 1995 and 1996). This could be an issue if management actions to reduce nutrients discharged had started to take effect by 1997.

The period 1997-1999 was very dry and the targets in policy are referenced to median flow conditions. This requires adjustment of the loads for the baseline period to median flow conditions.

The approaching target date of 2005 for the achievement of the MID target loads and the on-going changes to farm management taking place preclude any further extension of the period for collection of data for baseline load assessment.

Spatial Representativeness of the data
All of the available data sets face the problem of only covering part of the MID and scaling up the resultant load estimates for the whole of the MID will be required.

Quality issues with the analyses for total phosphorus
Issues will be difficult to resolve because of the small amount of good data for the purposes of cross comparison. Some correction factors may be needed for some of the data. How can these be developed?

Techniques for load estimation
There are numerous techniques available for load estimation, each with advantages and limitations. A number of techniques should be used to give an indication of the reliability of estimates. These need to be appropriate for the type of data available.

There is a need to take into account the errors involved in estimation and to quantify those errors. The sources of error need to be identified and minimised as much as possible.

APPENDIX 1

Compilation of data indicating problems with Envirogen's phosphorus analyses in 1997 and 1998.

EPA became aware of potential problems with Envirogen's data for total phosphorus in 1998 after receiving results for phosphorus analyses EPA had contracted out to Envirogen.. EPA had commissioned a study to investigate the variation due to sampling position within a stream, thus the sampling design incorporated both transverse and longitudinal transects, with replicates at each point on the transect.

During the statistical analysis of the results a problem with excessive levels of variability for the sets of replicates for the total phosphorus analyses was found (note the other indicators, TKN, NOx and suspended solids did not appear to be suspect) and levels of phosphorus were generally surprisingly low.

A compilation of some of these results which illustrate our concerns with the data are presented in Table 1 below. In particular, note the results for the Campaspe River at Rochester which was sampled on the same day as the VWQMN program. The Envirogen results for this site are all mostly below the detection limit of < 0.02 mg/L whereas the VWQMN sampling, on the same day, had a value of 0.076 mg/L.

Table 1: Data from EPA's spatial variation study

Site name	Date	Habitat	Transect type	Transect position	Replicate	Total phosphorus mg/L	
Barwon River at Kildean	14/04/97	Pool	Transverse	1	1	0.060	
Barwon River at Kildean	14/04/97	Pool	Transverse	1	2	<0.02	
Barwon River at Kildean	14/04/97	Pool	Transverse	1	3	<0.02	Note variability amongst replicates
Barwon River at Kildean	14/04/97	Pool	Transverse	2	1	0.300	
Barwon River at Kildean	14/04/97	Pool	Transverse	2	2	0.020	
Barwon River at Kildean	14/04/97	Pool	Transverse	2	3	<0.02	
Barwon River at Kildean	14/04/97	Pool	Transverse	3	1	<0.02	
Barwon River at Kildean	14/04/97	Pool	Transverse	3	2	<0.02	
Barwon River at Kildean	14/04/97	Pool	Transverse	3	3	0.070	
Site name	Date	Habitat	Transect type	Transect position	Replicate	Total phosphorus mg/L	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	1	1	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	1	2	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	1	3	<0.02	Note variability amongst replicates
Barwon River at Kildean	14/04/97	Pool	Longitudinal	3	1	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	3	2	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	3	3	0.070	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	5	1	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	5	2	0.030	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	5	3	<0.02	
Barwon River at Kildean	14/04/97	Pool	Longitudinal	Composite	1	1.300	

Site name	Date	Habitat	Transect type	Transect position	Replicate	Total phosphorus mg/L	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	1	1	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	1	2	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	1	3	0.080	Note variability amongst replicates
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	3	1	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	3	2	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	3	3	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	5	1	0.020	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	5	2	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	5	3	<0.02	
LaTrobe River at Kilmany South	28/04/97	Bend	Transverse	Composite	1	<0.02	

Site name	Date	Habitat	Transect type	Transect position	Replicate	Total phosphorus mg/L	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	1	1	0.170	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	1	2	0.060	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	1	3	0.310	Note variability amongst replicates
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	3	1	0.080	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	3	2	0.060	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	3	3	0.100	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	5	1	0.140	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	5	2	0.070	
Barwon River at Pollocksford	6/11/97	Pool	Longitudinal	5	3	0.090	

Site name	Date	Habitat	Transect type	Transect position	Replicate	Total phosphorus mg/L	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	1	1	0.020	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	1	2	<0.02	VWQMN data for the same day
Campaspe River @ Rochester	21/10/97	Straight	Transverse	1	3	<0.02	21/10/97 was 0.076 mg/L
Campaspe River @ Rochester	21/10/97	Straight	Transverse	2	1	<0.02	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	2	2	<0.02	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	2	3	0.020	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	3	1	<0.02	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	3	2	<0.02	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	3	3	<0.02	
Campaspe River @ Rochester	21/10/97	Straight	Transverse	Composite	1	<0.02	

Concerns with this data, together with issues raised by the West Gippsland CMA regarding Envirogen's phosphorus analyses at that time, prompted EPA to conduct a limited interlab comparison using split samples with spikes of known concentration added.

EPA interlaboratory comparison May 1998

Replicate water samples from two sites on the Campaspe River were collected with the following labelling and treatments applied:

Location of sample	**Label**	**Pre treatment**
Campaspe at Rochester	Drain 1	None
Campaspe at Redesdale	Drain 2	None
Campaspe at Redesdale	Drain 3	None
Campaspe at Redesdale	Drain 4	Spiked at 0.15 mg/L P
Distilled water	Channel	Spiked at 0.15 mg/L P

The samples were prepared including the additions of the phosphorus spikes at EPA's Environmental Chemistry laboratory. The spikes were a phosphorus salt added to raise the concentration of phosphorus in the sample by 0.15 mg/L. The sample water was collected on 30/4/98, the samples and spikes were prepared on 1/5/98. The samples were frozen immediately after the spikes were added, and none of the laboratories knew that the samples were being used in a trial. The samples were submitted to the laboratories on 4/5/98 (WES and WSC) and on 5/5/98 (Envirogen).

Table 2 Interlaboratory Comparison

Laboratory	**Drain 1**	**Drain 2**	**Drain 3**	**Drain 4**	**Channel**	**Spike (4-ave 2,3)**
Envirogen	0.03	<0.02	<0.02	0.1	0.1	0.08?
WES	0.02	0.038	0.035	0.19	0.16	0.154
WSC	0.029	0.039	0.037	0.18	0.17	0.142

WES = Water EcoScience now AWT
WSC = Water Studies Centre
Results expressed in mg/L.

We see in these samples (Table 2) that agreement between WES and WSC is very good, including the measurement of the spikes. The only sample that Envirogen appears to have measured accurately is Drain 1. The other Envirogen samples returned results that are significantly lower and would indicate that Envirogen's analyses at that time were not adequate to measure phosphorus in water at typical environmental levels.

The West Gippsland CMA also conducted some interlab trials of its own, the results of which appear in the tables below.

Table 3: Comparison between Envirogen and State Chemistry Laboratory (SCL)

Site/ date	Parameter	SCL (mg/L)	Envirogen (mg/L)
Latrobe River at Kilmany South 22/10/97	Total P Total N	0.12 0.71	0.03 0.3
Macalister River at Maffra 22/10/97	Total P Total N	0.04 0.24	<0.02 <0.2
Thomson River at Bundalaguah 22/10/97	Total P Total N	0.10 0.46	<0.02 0.3
Latrobe River at Kilmany South 2/12/97	Total P Total N	0.18 1.1	0.05 0.4
Macalister River at Maffra 2/12/97	Total P Total N	0.04 0.42	0.04 0.3
Thomson River at Bundalaguah 2/12/97	Total P Total N	0.10 0.46	<0.02 0.3
Latrobe River at Kilmany South 9/12/97	Total P Total N	0.16 1.2	<0.02 0.4
Macalister River at Maffra 9/12/97	Total P Total N	0.03 0.24	<0.02 <0.2
Thomson River at Bundalaguah 9/12/97	Total P Total N	0.09 0.43	<0.02 0.3
Latrobe River at Kilmany South 16/12/97	Total P Total N	0.17 1.2	0.10 0.6
Macalister River at Maffra 16/12/97	Total P Total N	0.05 0.33	<0.02 0.2
Thomson River at Bundalaguah 16/12/97	Total P Total N	0.08 0.41	0.11 0.5
Latrobe River at Kilmany South 22/12/97	Total P Total N	0.20 1.3	0.10 0.6
Macalister River at Maffra 22/12/97	Total P Total N	0.06 0.3	0.04 0.3
Thomson River at Bundalaguah 22/12/97	Total P Total N	0.09 0.41	0.07 0.3
Latrobe River at Kilmany South /01/98	Total P Total N	0.18 1.2	0.04 0.8
Macalister River at Maffra 6/01/98	Total P Total N	0.05 0.3	<0.02 0.2
Thomson River at Bundalaguah 6/01/98	Total P Total N	0.11 0.55	0.03 0.3
Macalister River d/s Glenmaggie 6/01/98	Total P Total N	0.11 0.54	<0.02 <0.2

Generally, Envirogen's results for both nitrogen and phosphorus are much lower, particularly for phosphorus. For total phosphorus, there is one instance where Envirogen measured higher and one, possibly two, instances where Envirogen is in close agreement with SCL.

The WGCMA also conducted another trial on 16th March 1998 using a greater number of laboratories including analyses conducted in-house at the CMA

Table 4: Split laboratory samples 16th March 1998

	Envirogen	WES	WSC	WSL	SCL	CMA
CGD No 3						
Total N mg/L	0.04	0.46	0.5	0.65	0.3	0.486
Total P mg/L	0.4	1.0	1.1	1.9	0.5	
CGD No 4						
Total N mg/L	0.02	0.35	0.34	0.5	0.22	0.377
Total P mg/L	1.0	1.4	1.3	3.4	1.3	
Thomson River @ Wandocka						
Total N mg/L	<0.02	0.057	0.087	0.12	0.03	0.081
Total P mg/L	0.4	0.92	0.36	1.4	<0.5	
Macalister River @ Maffra Weir						
Total N mg/L	<0.02	0.071	0.064	0.12	0.04	0.074
Total P mg/L	0.4	0.34	0.30	0.85	<0.5	
Latrobe River at Scarnes bridge						
Total N mg/L	0.08	0.053	0.048	0.12	0.03	0.077
Total P mg/L	0.4	0.57	0.57	0.95	<0.05	
Latrobe River at Kilmany South						
Total N mg/L	<0.02	0.094	0.086	0.18	0.05	0.088
Total P mg/L	0.7	0.74	0.7	0.95	<0.05	
Moe Drain at Trafalgar east						
Total N mg/L	0.09	0.094	0.092	0.18	0.06	0.091
Total P mg/L	0.4	0.74	0.7	1.5	0.7	

Notes: Samples were collected and delivered to Envirogen in the company of the State Chemistry Laboratory Manager, Bruce Shelley.

Identity of the samples:
Latrobe at Scarnes Bridge: actual sample
Latrobe River at Kilmany South: one actual sample and one labelled as Moe Drain
Thomson River at Bundalaguah: one sample labelled as Maffra Weir and one sample labelled as Wandocka.
CGD 3: actual sample
CGD 4: actual sample.

Considering the results for total phosphorus only in the above table, we observe the following:

- The results for WES and WSC are in close agreement.
- SCL seem a little low by comparison to WES and WSC.
- WSL seem somewhat high by comparison to WES and WSC
- CMA in-house measurements are in fair agreement with WES and WSC.
- Envirogen results are generally very low when compared to WES and WSC, although there is one result that is in close agreement and one which is higher.
- When one considers the actual samples that are duplicates (Kilmany South/ Moe Drain and Maffra Weir/ Wandocka) we see that the agreement was generally very good between samples for each laboratory for the Kilmany South water except for Envirogen (<0.02 and 0.09). For the Thomson River water, although apparently more variable, agreement between duplicates is fair, but Envirogen's results stand out as being very low.

Appendix D: Summary of presentations

EPA Discussion Document - Summary of main points (David Robinson)

Key technical issues:

- Representativeness of the baseline period
- Spatial representativeness of the available WQ data
- Quality of the WQ data
- Range of calculation methods used

SRW Overview (Brett Millington)

- SRW undertakes TP monitoring in response to the MID nutrient management plan, which covers 52,500 hectares and 500 km of irrigation drains.
- Monitoring is being expanded from the two existing sites, to a total of six sites that covers approximately 50% of the MID by June 2000.
- Statistical comparisons indicate no significant differences between the data collected by SRW and WGCMA since 1997.

EPA modelling (Kim Shearman)

- WGCMA monitoring data from the Latrobe, Thomson Rivers and Macalister Rivers and the Lake Wellington Main drain was used to calculate loads from the MID (subtraction approach).
- Loads were calculated using regression models of flow and concentration data following log transformation.
- The approach did not capture all of the MID load; some factoring was undertaken to account for MID area left out or non-MID area included in load estimates at river sites.
- This method estimated an average of 88 tonnes P discharged from the MID annually. Errors were very large due to the low r^2 values from the regression models.
- Some high flow loads have yet to be estimated (awaiting flow data from Thiess).

SKM/Southern Rural Water – MID modelling (Rohan Barling)

- SKM are using the Hydrol model to estimate the TP loads from 21 sub-catchments in the MID. So far, two sub-catchments have been modelled, with the rest of the sub-catchments expected to be modelled by June 2000.
- An assumption of the model is that irrigation tailwater is 20% of the water delivered.

- Both TN and TP are not conservative (TN and TP concentration declines along irrigation drains); it is not clear where the some of the load goes.
- TN and TP concentrations are not normally driven by flow; however, there is seasonal variability in concentration in the drains.

CRCCH – Thomson/Latrobe modelling (Andrew Western)

- CEAH have investigated TP, TSS and TN loads entering the Gippsland Lakes to help drive the ecological components of the CSIRO lakes model.
- CEAH used EPA data from six sites to develop six TP (plus 6 TSS and 6 TN) regression models using different attributes of flow and time of year (e.g. flow, log flow, baseflow, log baseflow, baseflow index, antecedent flow, seasonality).
- Ten of the eighteen models had a coefficient of efficiency (analogous to R^2) $E>0.5$; fourteen had $E>0.3$.
- Where different models had similar performance, the simpler of the models were used for input into the CSIRO model.
- Log transformed data were corrected to account for retransformation bias using a residual, smearing technique.
- Serial correlation was reduced but not eliminated by incorporation of data for additional (other than total flow) predictors .

CRCFE – Canberra modelling (Ian Lawrence)

- The ACT experience shows that large reductions in TP load can be achieved (e.g. Canberra achieved a 98% and 70% reduction in point and diffuse source loads respectively.
- In the case of the MID, is the concern reductions in P generation and transport at the farm level, or reduction of P in drains and entering the Gippsland Lakes?
- Modelling approaches are generally used to calculate loads as direct measures are too costly. Examination of water cycles and pollutographs suggest that a lot of sampling is required to capture the variability of various forms of P (and other pollutants).
- An empirical model could be developed to compare the baseline TP load from the MID with that of 2005. However, changes in landuse etc. are likely to invalidate the model in the future. A process model is required to accommodate changes in land use.
- The ACT approach included development of regression models relating runoff depth to TP loads for various landuses.

CSIRO – Gippsland lakes modelling (Brett Wallace)

- The Gippsland Lakes model is comprised of hydrodynamic and ecological components.
- P is modelled as dissolved inorganic P, dissolved organic P, particulate P and TP.
- Particle reactivity is critical to the behaviour and modelling of P (e.g. sorption/desorption of P to the Fe-O-OH coating of a particle is relatively fast; diffusion of P to the particle core is relatively slow).
- The model depends on information on DIP, TP, Chl-a and TSS inputs to the lakes.

Appendix E: Brief reports for each workshop group

Group A

- The 1997- 1999 data sets for drains were considered satisfactory for TP load calculation with the application of a correction factor (e.g. removal of outliers)
- The river loads approach was considered inappropriate given the non-conservative nature of N and P and doubt about the accuracy of P measurements at low concentrations.
- The merit of direct assessment method was recognised, but this had limited spatial scale and it was expensive (unsustainable) in the long term.
- The process model approach of SKM was preferred, as it had good spatial coverage that could be improved further over time. Flow estimates appeared accurate, which would greatly assist load calculations.
- The calculation of TP loads from 'median years' required further discussion.

Group B

- Although simple in nature, the river loads approach was not appropriate given non-conservative N and P and doubt about P measurements at low concentrations.
- The process model of SKM has good potential and is valuable given its links with management practices.
- The direct calculation method is ideal but there is the difficulty of extrapolating back to 1994-96.

Group C

- The group preferred the direct calculation method, although recognising problems with scaling up and extrapolating back to 1994-96. Additional data sets (e.g. Waterwatch) were available that would assist with scaling up and provide a better temporal and spatial coverage of the MID.
- The SKM process model was useful for management, was comprehensive and flexible. However, it did not account for the non-conservative nature of P and would not be ready until June 2000. The model would also require recalibration in 2005, and the future version may not be comparable to the current version, potentially leading to misleading interpretation.
- Correlation models (river loads approach) were easy, but there was poor correlation between flow and TP, and the question over the accuracy of P measurements at low concentrations remains.

Summary

The Workshop ultimately agreed that the direct calculation approach would be used to gain a rapid appreciation of TP loads leaving the MID. Flow weighted concentrations would be applied to flows from 1994-96 to estimate loads for this period of interest. Additional monitoring and evaluation would be undertaken in the future to refine the load calculations.