Developing a Catchment Model for a Rural Dominated Catchment in North West Tasmania

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Keywords: *Water quality modelling; Model simulation, Dairy catchments, Catchment modelling*

EXTENDED ABSTRACT

The catchments in north west Tasmania tend to be dominated by rural industries such as grazing and dairying, native forest, logging and plantation forestry. The dairy industry had been identified a major contributor of nutrients to the Montagu River in north-west Tasmania (Horner et al 2003). In response, a project was initiated to measure the impact of land management changes on water quality using a catchment model

The E2 catchment model (eWater CRC 2007) was applied to the 295 km^2 Montagu River catchment. The model delimited subcatchments in which land uses included dairying (16%), dairy runoff pastures (3%), beef cattle pastures (4%), eucalypt and pine plantations (6%) and native forests including reserves (71%).

E2 is a catchment modelling framework, rather than one model or group of models. It allows the modeller to choose the most appropriate component model with which to describe a part of the catchment hydrology, and links these together through a typical node-link style modelling interface. The application of E2 is growing in Australia, however it had not been previously applied in the Tasmanian region and there were some concerns as to whether the specific characteristics of the Montagu River catchment, especially with regards to rainfall and runoff, could be adequately predicted. The SimHyd rainfall-runoff model was able to be calibrated and validated within the catchment and showed good agreement with previous estimates. In addition, the application of the model and the required parameterisations needed to obtain suitable calibration results increased the overall understanding of the Montagu catchment's hydrological processes.

Several model scenarios were developed and run to test a range of potential management actions and land use changes. The results, in conjunction with estimates of relative loads and flows from the base case scenario, provided valuable insights not only into the catchment response, but in the application of a catchment model in this scenario and the opportunities and constraints of adapting a daily model to a typical river catchment.

The results showed that dairying dominated the nutrient loads being exported from the catchment, but also demonstrated that the model was limited in the ability to account for temporally dynamic pollutant generation, such as that associated with seasonal fertilizer application. It also demonstrated that daily models are limited in their ability to represent in-stream routing and pollutant decay in catchments of this size, where the majority of in-stream processes are likely occurring over several hours during events.

Fundamentally, the application of the model demonstrated that other measures of catchment loads and concentrations can provide critical data with which to validate model outputs, especially where detailed data sets are few.

1. INTRODUCTION

The use of predictive tools to estimate the effects of land use change and management on water quality has increased over the last several years with the development of catchment modelling tools through groups such as the former CRC for Catchment Hydrology and its successor, the eWater CRC. These tools, once they are developed and calibrated, allow for rapid assessments of the impacts of land use change, best management practices (e.g. on-farm practices, buffer strips etc), climate variability and climate change on catchment response in terms of constituent loads and runoff.

Environmental problems are often identified at catchment scale but solutions are mostly targeted at farm and paddock scale. The difficulty at this scale is that there are limited data with which link the environmental target at the bottom of the catchment with the proposed solutions on the farm. Therefore, the development of a catchment model can be used as a first step in evaluating the relative impact at catchment scale of reductions in contaminant loads by adoption of best practices by dairy farmers.

To assist in this, the E2 modelling framework was applied to the Montagu River catchment in which the dominant land uses are dairying and beef cattle grazing, eucalypt plantations, commercial native forest management and reserves of native vegetation.

E2 is a group of model elements that can be built into a catchment model within a consistent model framework that allows rapid and transparent parameterisation, and provides visual and temporal contextualisation of model outputs. It was developed as a successor to the Environmental Management Support System – EMSS (Chiew et al 2002) and provides modellers with a flexible tool to apply to a wide variety of catchment contexts.

The E2 catchment model allowed prediction of the contributions of contaminants from dairying (which have been quantified and verified at paddock scale) with respect to other land uses in the catchment.

2. CATCHMENT CHARACTERISATION

The Montagu River Catchment, in North West Tasmania, covers an area of approximately 295 km^2, though the actual catchment boundary is slightly ambiguous due to the very flat terrain across much of the catchment. Previous estimates were around 330 km^2 but in this study the northern extent of the catchment is taken to be the Tasmanian Department of Primary Industries and Water (DPIW) flow gauging station at Stuarts Rd (about 2km from the river mouth) since this is an obvious location to which flows (and constituent concentrations and loads) can be assessed.

The catchment boundary was manually delimited from aerial photographs and verified with some field checking because the DEM for this area had insufficient resolution to allow software to adequately identify the catchment boundary.

The Montagu River valley runs south to north for about 45km and is bounded in the west by Bonds Tier and in the east by Christmas Hills both composed predominantly of Cambrian fine-grained sediments. The valley floor is underlain by Cambrian dolomite on which up to 6m of Quaternary colluvial, alluvial and aeolian sediments (Seymour and Baillie 1992) exist. Fixters Creek is a tributary of the Montagu River which drains the Brittons Swamp catchment.

When first settled, the Montagu River valley contained several large wetland areas, specifically in the Togari and Britton's Swamp districts. As farming activities progressed, these areas were drained and the river realigned in certain sections with long stretches being channelised to promote better flow and drainage.

Land use within the catchment is dominated by native forest and reserves (71%), with 6% of the catchment area utilised for eucalypt and pine plantations. Dairying activities represent the most intensive use of land in the catchment and occupy nearly 20%. Beef cattle grazing occurs on 4% of the catchment.

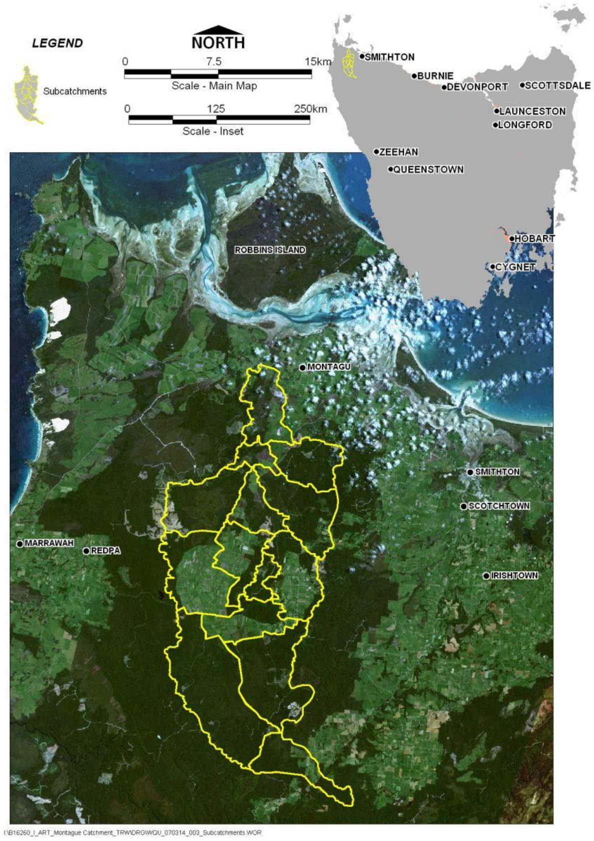

Figure 1 Montagu River Catchment

3. METHOD

The E2 catchment modelling framework was chosen to be used on the Montagu River basin as it had a high degree of flexibility in the individual model elements used to describe each of the catchment processes (i.e. rainfall-runoff, constituent generation, constituent transformation, and flow routing). While this framework had not been applied previously to a Tasmanian catchment, some of the individual model components, especially the rainfall-runoff and constituent generation models are relatively common and undoubtedly would have been applied previously within the region.

E2 (eWater CRC 2007) is a framework in which the modeller has the flexibility to select a range of component models to describe particular parts of the overall catchment hydrology. For example, it may be found that a particular rainfall-runoff model is more appropriate to the catchment being studied than one previously used in other areas. Using E2, the modeller can quickly select the new model, and even run comparative scenarios using each component model. Similar techniques can be used for flow routing, constituent generation and transport and in-stream processes.

In developing the E2 model of the Montagu River catchment, it was imperative that a proper understanding of the catchment behaviour was known . Fortunately, previous studies of the area, in particular the "Eindeloos" field study subcatchment (Holz 2007), gave valuable insights into both the hydrology and constituent generation processes likely to dominate.

The SimHyd hydrologic model (see Figure 2) was used to describe runoff generation in the catchment. SimHyd had not been previously applied in the Tasmanian context, however it has been applied at numerous scales on the mainland, and appeared to have sufficient capacity to encompass the groundwater functions expected

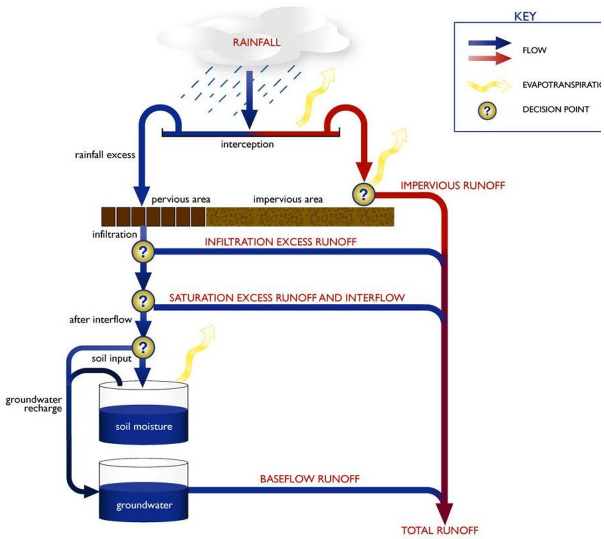

Figure 2 SimHyd (Chiew et al 2002)

The results of flow gauging of the "Eindeloos" catchment over three years showed that due to extensive surface modification using a "hump and hollow" drainage (see Figure 3), 33-45% of rainfall was converted to runoff during winter rainfall events.

Figure 3 "Hump and Hollow" Drainage

This "hump and hollow" drainage was created to convert previous extensive wetlands of the Montagu Swamp in the Togari district of the catchment into viable farming land. During winter months, up to 80% of rainfall is converted to runoff. Watertables are at or near the soil surface for several months each year. The "hump and hollow" drainage is created using an excavator to build a volume of soil above the watertable and thereby improve surface drainage.

Approximately 25% of the dairying pastures use the "hump and hollow" technique, including those of the Togari (formerly Montagu Swamp) and Brittons Swamp districts, so being able to account for this behaviour was seen as desirable to ensure that the model predicted flows well. The remaining dairying areas, while not using the same drainage technique, still were in areas with high groundwater, and it was anticipated that they would exhibit similar behaviour and were parameterised as such.

For the hydrologic model, the forested areas were expected to have considerably different response to the agricultural areas due to higher interception by the canopy and greater moisture storage in the leaf litter and forest floor detritus and greater depletion of soil water storage over summer. Estimates using annual rainfall and evapotranspiration and the curves of Zhang et al. (2001) adapted by Leon Bren (pers.comm.), suggested that the annual runoff from the wet sclerophyll forests would be expected to be around half of that measured from the pastures in this region.

Climatic information used in the model was originally obtained from point rainfall for three stations in the catchment, approximately representing the bottom, middle and top thirds of the catchment. It was found however that this rainfall did not adequately represent the rainfall gradient present in the catchment and gridded data obtained from the national SILO database (QDNRW 2007) was used.

4. RESULTS

4.1 Model Calibration

The model was able to be calibrated only to outlet flows at the Stuarts Road gauging station using parameters derived from the gauging at the "Eindeloos" field catchment. Previous work completed in the catchment by DPIW (Horner et al 2003) included monthly concentrations of a number of analytes. Annual flows (1965-2006) at the Stuarts Rd gauging station, calculated the mean annual runoff was approximately 123,000ML. Using the a longer dataset than used in the DPIW study, the E2 model yielded similar results, predicting flows in the order of 125,000ML. This was expected however as model parameterisation and calibration aimed to reproduce flows of a similar magnitude to the previous study, but it also validates the assumptions made regarding parameterisation of the agricultural and forested land use hydrology.

4.1 Model Outputs

The application of the E2 model allowed individual land use contributions to be compareded across the catchment. In particular, one of the aims of the project was to quantify nutrient loads from varying land uses. Using the spatial contextualisation of the model, results showed that the highest nutrient loads came from subcatchments in the centre of the catchment, corresponding to the dairying areas which had both high runoff generation and constituent concentrations (see Figure 4).

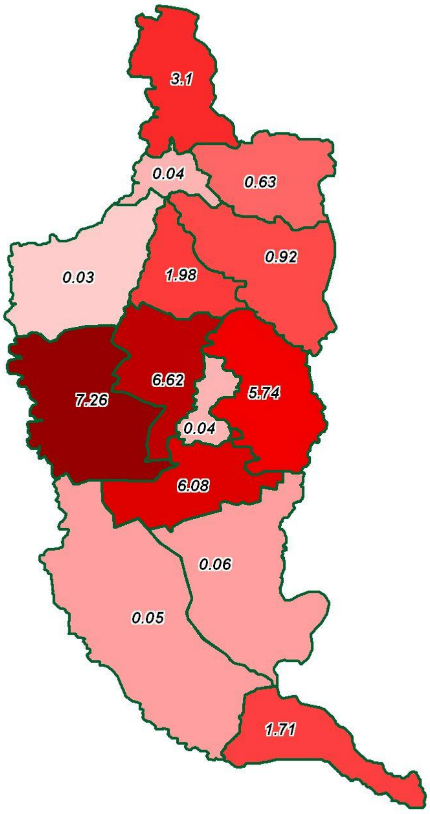

Figure 4 Total Phosphorus Loads (kg/ha/yr)

The model was also used to derive individual land use loads as shown below.

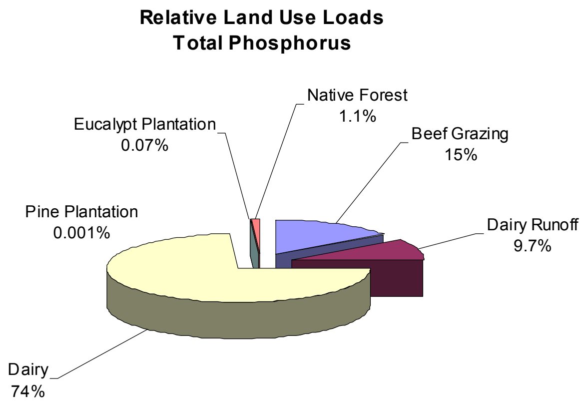

Figure 6 Land Use Contributions of Phosphorus

As can be seen in Figure 6, while the dairying activities in the catchment only account for 20% of the landuse area, contributions to catchment P loads are approximately 74%. Also of note is the low relative contribution of forestry activities, which appears to be simply due to the low runoff volumes from these areas in comparison to the agricultural uses.

5. DISCUSSION

The E2 component models available did not allow specific representation of catchment, stream and/or plot scale time dependent processes. The models are limited in that they only allow constant values for model parameters to be used over the entire climatic record.

The "lumped-conceptual" approach used (where the numerous details of subcatchment geospatial and climatic information are lumped together as a single node) can describe the response of the subcatchment to these processes, for example, constituent generation and export from specific land uses. This approach works well when longer-term outputs (eg., mean annual loads) are required, however, it does not adequately represent shorter term variations due to factors such as season or within event variations related to flow rate.

In the Montagu River for example, there is a spike in nitrate concentrations at the beginning of each runoff season (see Figure 7).

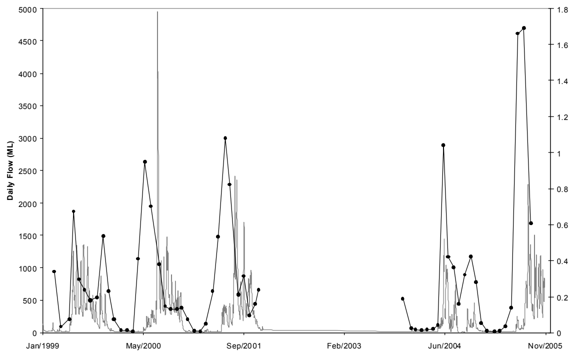

Figure 7 Nitrate Concentrations and Flow – Montagu River

The Event Mean Concentration (EMC) approach (Chiew et al 2002) only allows one value to be used in this case, and of necessity, this needs to be a value that represents an average of the seasonal variation if accurate mean annual loads are to be determined. That being said, it does allow for differences between land uses and is typically used in the majority of catchment models developed within Australia.

Considerable difficulty was also experienced in appropriately simulating both flow routing and constituent decay using the E2 framework as the lag in each link of the node-link network could only be set as low as 12 hours. Given that the total lag time of flows from the top to the bottom of the catchment as shown by comparison of rainfall and flow records was less than two days, using the routing available would have yielded catchment lags of greater than three to four days and potentially overestimated the decay in constituent concentrations.

It was also obvious from assessing the constituent concentrations at the catchment outlet in comparison to those derived off the 12ha field study catchment at "Eindeloos", that significant decay and/or dilution of constituents occurs from that observed at the farm scale. As this constituent decay within the model relies on the lag time of the flow within a link to calculate the processing time for decay, when no flow routing was enabled, the constituent decay models were disabled.

Estimates of catchment P loads were available from Horner et al (2003) and the E2 estimates of catchment loads were similar if the decay functions were disabled, however when the decay models were enabled, the P loads were only 50% of that previously estimated. This exercise highlighted the value of credible bottom of catchment constituent load estimates with which to validate model outputs. In addition, in the case of the Montagu River, where there is little sediment, the river bottom is mostly exposed dolomite and banks are fully vegetated, there may be little decay in P concentrations. That is, parameterising the model to be consistent with bottom of catchment estimates may reveal important aspects about the behaviour of constituents in the system. An issu to be resolved is that of "circular reasoning", but in this case there are reasonable external arguments to support the position presented.

6. CONCLUSION

The E2 modelling framework allowed the prediction of catchment flows and constituent loads on both a spatial and temporal resolution that assisted in identifying and validating land use contributions at the catchment outlet.

While model limitations were identified, these did not hamper the overall calculation of these flows and loads over longer time frames (e.g. mean annual loads), however they showed that further development of the modelling framework would assist in improving the development of E2 models that were able to describe catchment processes at shorter temporal and spatial scales.

It also indicated that the component models selected were appropriate to the modelling of predominantly rural catchments and could be applied to catchments in the Tasmanian region.

7. ACKNOWLEDGEMENTS

Dairy Australia and University of Tasmania provided funding to the overall Montagu River studies, of which the E2 modelling was a component. Their support is gratefully acknowledged.

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