18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009
http://mssanz.org.au/modsim09

The Development of an Integrated Modelling Framework for Assessing the Impacts of Land Use Change on Corner Inlet

Adams, R. [1], **Western, A.W.** [1] **Law, S**[2]**., Andersen, S**[2]**.**

[1] *Department of Civil and Environmental Engineering, The University of Melbourne, Parkville, VIC*
Email:rada@unimelb.edu.au
[2] *Water Technology Pty Ltd, Notting Hill, VIC*

Abstract:

The E2 modelling system is a powerful software tool developed to enable catchment managers and planners to investigate the interactions of land use, climate, water quality and water quantity. E2 forms the basis of a Decision Support System (DSS) developed for the Corner Inlet catchment in South Gippsland, Victoria. The purpose of the DSS is to inform catchment management, via modelling of the terrestrial and estuarine impacts of scenarios of land use or land management change. This is achieved by linking together an E2 model of sediment and nutrient delivery from the catchment with a model of estuarine water quality impacts derived from detailed 3-D hydrodynamic simulation of the estuarine transport. The model can be used to run scenarios of land use or land management change in the terrestrial catchment (e.g. reforestation) with the results being examined for impacts on the estuary or on the modelled streams.

The underlying hydrodynamic model was developed using MIKE21, and calibrated against gauged tidal records at 5 different locations throughout Corner Inlet and Nooramunga. Model parameters were calibrated in an effort to minimise differences between the measured and modelled water surface elevations and tidal constituents (amplitude and phase angle). The calibrated and measured tidal constituents were also verified against the Australian National Tide Tables and those reported in the literature. The IOS (Institute of Ocean Sciences) method was applied for the decomposition of tidal constituents. The advection-dispersion simulations of the estuary were analysed to develop a statistical link between constituent inflows and transport to important seagrass beds. This transport was treated as conservative due to limited data on nutrient transformations within Corner Inlet. For similar reasons, the State Environment Protection Policy was used to define critical water quality thresholds in Corner Inlet.

The hydrological and water quality models within E2 have been used in this particular E2 application. The SimHyd model was used to simulate the rainfall-runoff response, with calibration against existing stream flow stations and fitting of separate parameter sets for forested and non-forested landuses. Existing monitoring data from various sources were used to parameterize and calibrate "constituent" models within E2 for nitrogen (Total Kjeldahl Nitrogen, NO_x), phosphorus (Total Phosphorus, Dissolved Reactive Phosphorus) and suspended sediment generation. The choice of constituents for this study came about partly over concerns that elevated concentrations of nitrogen in the estuary were causing a decrease in the seagrass population in Corner Inlet. Concern has also been raised for several decades that high levels of phosphorus in coastal waterways in south-eastern Australia may contribute to the development of algal blooms and coastal eutrophication.

A review of the existing data sources found that although the database of weekly and monthly water quality samples was reasonably extensive spatially (especially for Phosphorus) and covered a period of at least ten years of monitoring, the monitoring data lacked sufficient samples taken at high flow periods, classified as runoff events. Evidence from the samples taken during events was that the loads of nutrients and sediments transported during high runoff periods contributed over 90% of the total monitored load. Also, there was a paucity of nitrogen (including nitrate and ammonia) measurements in this particular catchment. Therefore, a monitoring program was devised to collect water quality samples from six streams and rivers at eight locations using automatic samplers. The data collected have been used to improve the calibration of the E2 model, especially for high-flow periods.

Keywords: *Eutrophication, Decision Support Systems, Nutrient Modelling, Hydrodynamic Modelling*

1. INTRODUCTION

Concern has been raised for several decades that high levels of nutrients in coastal waterways in south-eastern Australia may contribute to the development of algal blooms and coastal eutrophication. The Corner Inlet and Nooramunga estuarine complex located north of Wilsons Promontory in Victoria contains areas of significant conservation value, including marine national park and coastal reserves and is a Ramsar site. Environmental values include a representative area of the only extensive *Posidonia australis* meadows in Victoria , high invertebrate faunal diversity, with 390 species recorded, and over 74 varieties of fish (Plummer et al., 2003), which is likely to be an underestimate of actual faunal diversity. This study was motivated partly by concerns that elevated concentrations of nitrogen are causing a decrease in the seagrass population in Corner Inlet (Hindell et al., 2007) and partly as a response to a Gippsland Coastal Board audit of Corner Inlet (CSIRO, 2005), which called for increased monitoring, nutrient and sediment load mitigation and assessment of threats to the biodiversity of the estuary. The Corner Inlet DSS (CI-DSS) was developed to as a tool for the CMA to use in addressing these management needs. This research came about partly through a need to fill in gaps in the understanding of the linkage between land use and the water quality in the estuary.

2. CORNER INLET CATCHMENT AND DATA

The catchment of Corner Inlet comprises several large rivers (from east to west: Bruthen Creek, Tarra, Albert and Jack, Agnes, and Franklin Rivers), each with catchment areas of several hundred square kilometres (the total area modelled in this study was approximately 1900 km^2). These rivers flow mainly from north to south from the forested headwaters of the Strzelecki Range (elevation up to 500m above sea level), through cleared plains mostly comprising pastoral lands to the sea. Several small, usually ephemeral creeks drain the western part of the catchment south of the township of Foster. Until 2008 all these western creeks were ungauged. Rainfall varies from west to east, with the eastern catchment being much drier, and also by topography with the Strzelecki Range that forms the watershed for most of the catchment receiving more than twice the rainfall on the coastal plain. Annual average rainfall for 1961 – 1990 varied from 700 mm to 1500 mm within the catchment. Previous monitoring of freshwater streams and rivers in the area has focussed mainly on phosphorus, which was assumed to be to the limiting nutrient supplied to the estuary, both through a ten-year Waterwatch monitoring partnership between the West Gippsland CMA (WGCMA) and the local community (Waterwatch, 2007), and the existing state-funded Victorian Water Quality Monitoring Network (VWQMN). The VWQMN has monitored 4 sites in the catchment situated on the larger rivers from the early 1990s to date. Only the VWQMN data contained concentrations of sediment and nitrogen species (oxidised nitrogen and Total Kjeldhal nitrogen). During winter 2008 a catchment monitoring program was carried out which involved sampling streams and rivers at 8 locations using both automatic and grab sampling. The autosamplers were set up to collect samples during events where water levels in the stream exceeded a predefined threshold value, estimated where possible from the historical gauge data. Samples were analysed for the nutrients listed above and suspended sediments, and in-situ water quality measurements (conductivity, pH, turbidity) were taken. The results from this program provided additional data for model calibration, particularly for EMC estimates, where historical samples from Waterwatch and VWQMN from events were limited in number.

3. THE CORNER INLET DSS

The purpose of the CI-DSS is to inform catchment management, via modelling of the terrestrial and estuarine impacts of scenarios of land use or land management change. This is achieved by linking together an E2 model of sediment and nutrient delivery from the catchment with a hydrodynamic model of estuarine water quality impacts. E2 can be used to run scenarios of land use or land management change in the terrestrial catchment (e.g. reforestation) with the results being examined for impacts on the estuary. The E2 modelling system is a powerful software tool developed to enable catchment managers and planners to investigate the interactions of land use, climate, water quality and water quantity (Argent et al., 2005). E2 forms the basis of the CI-DSS, and was chosen for this role partly because of successful applications to other Australian river basins, more specifically the nearby Western Port and Port Phillip Bays catchments (Argent et al., 2007). The node and link structure of the CI-DSS is shown in Figure 1 with subcatchments denoted by the coloured polygons. There are fifteen outlet links that represent discharges from the rivers into the estuary at different locations – note that Figure 1 shows all the links converging on one location for computational simplicity. E2 employs Functional Units (FUs) to describe areas within subcatchments that are likely to have similar hydrological response (e.g. runoff generation) and nutrient generation characteristics.

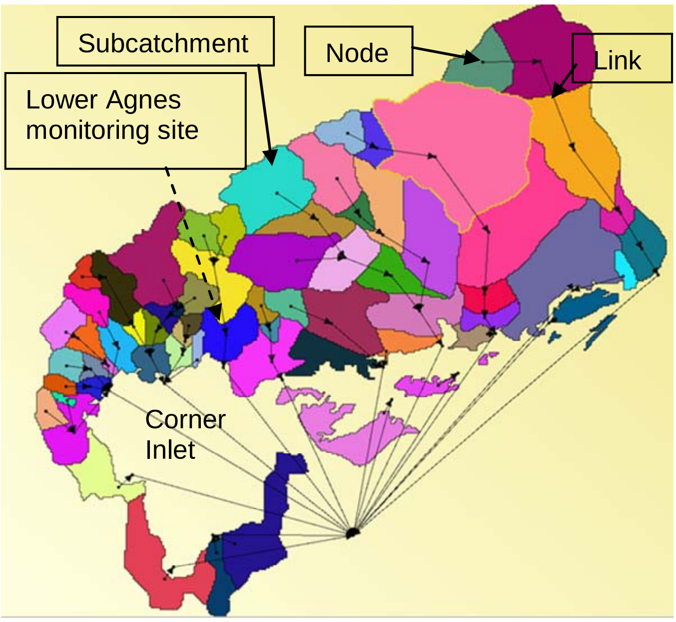

Figure 1 Conceptual diagram showing structure of E2 model forming the CI-DSS

Land use was chosen as the key attribute for defining FUs within this particular E2 model. Thus each subcatchment contained several FUs each corresponding to a different land use. Each FU has model parameter values assigned; the selection of these is discussed below. The scenario representing the existing land use is referred to as the "baseline". These land use data were obtained from the Bureau of Rural Sciences (BRS), and were derived from satellite imagery from the mid-90s. The user can modify the land use distribution either by importing a new map layer or manually re-assigning the areas of each FU. New FUs to represent land use changes such as riparian management or agricultural BMPs (Best Management Practices) can be added to the CI-DSS by the user and several have been developed in this implementation. Eight major FUs representing the dominant (pre-existing) land uses in the catchment were represented in the baseline scenario.

- Dryland Agriculture (including pastoral grazing and some cropping)
- Irrigated Agriculture (including irrigated pasture and crops)
- Reserve (representing nature reserves, wilderness etc of low density vegetation and cover.)
- Production Forest (hardwood and softwood production)
- Forested areas (representing National Parks, wilderness etc of high density vegetation and cover).
- Urban
- Wastewater Treatment Plants (three of these were included)
- Other (land use categories not falling into the above)

3.1. Catchment Model Development

E2 comprises a flexible framework consisting of a series of inter-linked models that can be used to generate and route water and constituents (nutrients, sediments and contaminants) through the river network to the outlet nodes specified by the user. The choice of these models is left to the user and should be made on the basis of: (i) the requirements of the end-user; (ii) the amount of data available for model calibration and verification. In the CI-DSS the SIMHYD hydrological model (a daily lumped parameter model) (Chiew et al., 1994) was used to compute the water balance in each of the sub-catchments. SIMHYD contains only seven parameters and inputs are rainfall and potential evapotranspiration data. In Corner Inlet catchments, daily rainfall data were available from five raingauges for the time period 1987-2006, that cover the east-west and topographically-influenced rainfall patterns in the catchment. Gauge rainfalls were scaled for each subcatchment based on the ratio of subcatchment mean annual precipitation, obtained from a gridded dataset supplied by the Bureau of Meteorology that contained the 1961-90 means, to the gauge (point) mean. Areal potential evapotranspiration data from Sale Airport (50km NE of the catchment) was used in the modelling. Hydrological model calibration was carried out by running model simulations using SIMHYD within the Rainfall Runoff Library (RRL) package (Podger, 2004) and comparing modelled and observed flows (recorded at seven gauging stations in the catchment).

Daily Nash Sutcliffe coefficient of Efficiencies (NSEs) of between 0.15 and 0.57 were achieved using this method, with the poorest NSE values later improved to around 0.5 in the final E2 model. This was achieved by routing flows though the link-node network with delays of up to two days in the larger catchments (Tarra, Bruthen Ck, Agnes and Franklin Rivers). Water balance errors of less than 5% were achieved in the calibration. A regionalisation approach (Chiew et al 2002) was then used to develop parameter sets that could represent both forested and non-forested land uses in both: (i) the drier eastern half of the catchment (the lower Tarra and Bruthen Creek rivers) where streamflow records indicated that there were potential losses to the regional groundwater, and (ii) the remainder of the catchment, where runoff ratios were generally higher. Model calibration runs were carried out in pairs on a group of gauged catchments (the pair representing areas of forested and non-forested land uses in each) using the pattern search optimization algorithm (Chiew et al 2002). In order to generate daily time series of nutrient loads from each subcatchment the EMC/DWC model in E2 was adopted (Argent et al 2005). With this model daily pollutant loads are estimated from each FU to be: Pollutant Load = Surface Runoff x Event Mean Concentration (EMC) + Base flow x Dry Weather Concentration (DWC).

The EMC represents the flow-weighted average nutrient concentration in the quick flow component over a storm event. The DWC is the nutrient concentration as measured during dry weather (low flow). DWC concentrations in E2 models generally correspond to those measured in samples collected from rivers during low flow periods. The following constituents were modelled in the CI-DSS:

- Total phosphorus (TP)
- Dissolved Reactive Phosphorus (DRP)
- Oxidised Nitrogen (nitrate+nitrite) (NO_x)
- Total Kjeldhal Nitrogen (ammonia + organic N) (TKN)
- Suspended Sediments (SS)

The EMC/DWC model used output from the hydrology model flow components; each constituent's concentration was assumed to be constant for a given land use. It required estimates of concentration under both high and low flow conditions for each constituent and each land use. A combination of winter 2008 event, VWQMN and Waterwatch data in addition to the estimates from a literature review were used to estimate these concentrations depending on the data availability for each constituent.

4. THE HYDRODYNAMIC MODEL OF NOORAMUNGA / CORNER INLET

The hydrodynamic model was developed using the MIKE 21 (HD) hydrodynamic modelling system (DHI Group). MIKE 21 (HD) is a modelling system for simulating water level variations and flows in response to a variety of forcing functions in rivers, lakes, estuaries and coastal areas. It solves the vertically integrated equations for the conservation of continuity and momentum over a rectangular grid (in this application) covering the area of interest. Key inputs include the model bathymetry, bed resistance coefficients, wind conditions, and boundary conditions.

4.1. Hydrodynamic Model Calibration and Testing

The numerical model developed specifically for Corner Inlet includes the Inlet and Nooramunga waters extending a short distance up each estuarine river reach and out into Bass Strait. The model was developed using a combination of bathymetric data (dating back to the 1980s) and tidal boundary conditions based on the official tidal constituents published in the Australian National Tide Tables (DoD, 2006) relevant to the study area. Once the numerical model was configured such that successful simulation runs were executing in a stable fashion, model output was compared against the tide gauge data and data reported by Dennis (1994). Measured

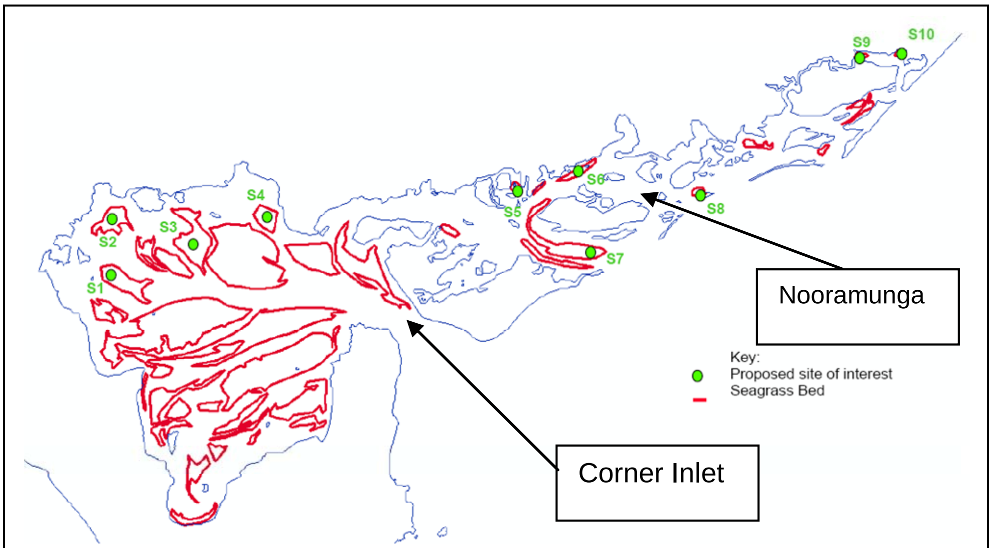

Figure 2. Map of Corner Inlet and Nooramunga estuaries indicating sites of interest.

and modelled tidal variations were decomposed into tidal constituents using the IOS method (Foreman, 1977) using an algorithm included in the MIKE 21 package. A key advantage of the IOS method is that it is able to decompose non-continuous tide records, i.e. combining several tide records into one longer record, leaving gaps at breaks between the records.

The hydrodynamic model was run for 32 days starting from the 1st of March, 2008. Thus the simulation period overlapped with the period from the 6th – 28th of March where measured tide records were retrieved from five water level sensors deployed at the ports and beaches, allowing direct comparison of the predicted water surface variation with measured variation. Model parameters were iteratively adjusted in an effort to minimise differences between the measured and modelled water surface elevations and constituent values (amplitude and phase angle). Adjustments were made in the first instance by varying the ocean boundary condition to reflect the fact that most tidal constituents were known to change between Wilsons Promontory and McLoughlin's Beach (Hinwood and Wallis, *unpubl*). It was found that the changes in tidal constituents were mainly in a N-S direction, hence a uniform boundary condition was applied at the Southern boundary, while a varying boundary condition was applied on the Eastern boundary. Generally, the tidal amplitudes decrease northwards, closer to McLoughlin's Beach. Part of the calibration process was to determine appropriate constituents for the Eastern boundary.

4.2. Linkages between the Terrestrial and Hydrodynamic Model Components

For the purposes of the CI-DSS, seagrass was determined to be the best indicator of ecological health. Seagrass growth can be affected by salinity and light (e.g. growth can be reduced by high turbidity or excess phytoplankton growth, induced by increased nutrient levels, can adversely effect seagrass growth). Seagrasses are associated with the intertidal mudflats, and the dominant beds are located within Corner Inlet rather than Nooramunga. CSIRO (2005) reported approximately 149km^2 of Seagrass beds within Corner Inlet. Water quality standards for Victorian coastal waters and rivers are defined by SEPP (State Environment Protection Policy) limits and these were used in the absence of more detailed local understanding of water quality thresholds. The combined hydrodynamic and catchment models were run over a typical year (1998 was chosen) to determine the maximum extent of influence for each river. A tracer of concentration 1000 mg/L was added to the modelled river inflows at the start of the simulation period to assess the percentage reductions in concentrations observed over one year. The maximum extent of each tracer provides the zone of influence for each river inflow. Where high tracer concentrations were correlated with seagrass beds it was assumed that there was potential to influence the ecological health of these beds. Ten points were selected based on the highest tracer concentrations which co-located with the seagrass beds (Figure 2).

The hydrodynamic model was run offline to develop a relationship between the catchment and seagrass beds, without having to run it for each scenario. Instead the E2 outputs were linked to the hydrodynamic model through an integration spreadsheet (using MS Excel™ software) containing a look-up table. The concentration at the seagrass beds is readily calculated as the input concentration from E2 multiplied by the reduction in concentration between the catchment outlet and the seagrass bed (determined from the hydrodynamic tracer simulations). In these simulations it was found that concentrations at the seagrass beds were variable both over time and space (due to varying inflows, tides and circulation of contaminants throughout Corner Inlet). As such a direct correlation between the inflow concentration of the tracer (constant at 1000 mg/L) and the concentration at the seagrass beds could not be formed. Instead the 75th percentile concentrations were calculated at both the E2 model catchment outlets and the seagrass beds, since the SEPP limits relate to the 75th percentile concentration values (see Table 1 for the limits). This method provides not only a comparison between inflows and the seagrass beds, but also determines if the SEPP limits were exceeded and therefore the seagrass beds were under ecological stress. Since limited literature or guidelines exist for sediments, this value was based on the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). For nitrate and TKN, the two components that make up total nitrogen (TN), it was assumed that if either nutrient exceeded the SEPP limit for TN the seagrass bed would be under stress.

5. RESULTS

5.1. Catchment Water Quality Modelling

In this section results from the lower monitoring site on the Agnes River for the baseline scenario (see Fig. 1) are shown as an example of the output from the CI-DSS. Land use above the monitoring site is mixed, with approximately 61% forest and 39% mostly dryland agriculture. Figure 3 shows the results in terms of modelled and observed constituent concentrations. Observed concentrations were sourced from the VWQMN data from

1997 to 2006. Modelled concentrations were sourced from daily E2 model output (the entire 10 year period was used to compute the statistics).

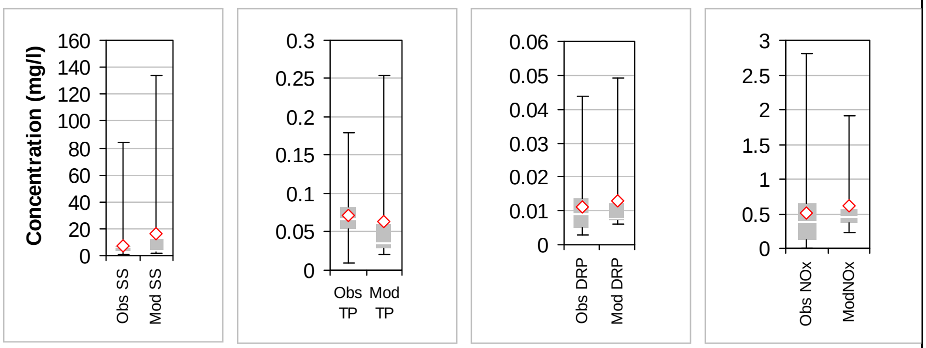

Figure 3 Modelled and Observed Constituent Concentrations – Baseline Scenario Lower Agnes (red diamond indicates mean concentration, grey shading 25th and 75th percentiles)

Model results indicate that the higher concentrations of some constituents are not predicted as well as others, particularly TP and TKN at this particular site. Also noticeable was that the inter-quartile range of the observed nutrient concentrations was generally greater than the modelled range. This is partly because the EMC/DWC constrains concentrations so they range between the EMC (at high flows) and the DWC (at low flows). Various factors that could affect nutrient concentrations such as seasonally-varying nutrient export, either due to fertilizer applications or intermittent grazing periods are not represented in this model. The exception to this was suspended sediments where the greater spread in model results may reflect that the suspended sediment EMC for production forest was increased following monitoring of a forested headwater catchment that generated high concentrations of sediments during three winter 2008 events included in the calibration data set. Results from three other VWQMN monitoring sites in the catchment from the same time period are shown in Table 1 in the form of observed and simulated median concentrations. The model has reproduced the observed median concentrations for some constituents very well.

Table **1**. Modelled and Observed Median Concentrations at VWQMN Sites

Constituent	Tarra (Yarram)		Tarra (Fischers)		Franklin River	
	Modelled (mg/L)	Observed (mg/L)	Modelled (mg/L)	Observed (mg/L)	Modelled (mg/L)	Observed (mg/L)
SS	5.4	6.0	3.6	4.0	7.7	7.5
Nitrate + nitrite	0.37	0.44	0.43	0.44	0.36	0.36
TKN	0.37	0.40	0.21	0.20	0.54	0.52
DRP	0.01	0.01	0.01	0.01	0.01	0.01
TP	0.04	0.05	0.03	0.03	0.05	0.05

5.2. Integrated Hydrodynamic and Catchment Models

The concentrations of the constituents in the E2 river link representing the discharge from the mouth of Agnes River, and the estuary at Site S4 (the estuarine site nearest to the mouth) are shown in Table 2 with the corresponding SEPP limits. Model outputs are available at the 10 sites highlighted in green in Fig.2 but only the closest site to the Agnes River is shown here for brevity. Note that for nitrogen species, the SEPP limit of 0.3 mg/L applies to total nitrogen, but if the concentration of either species in the river or estuary exceeds this value then a flag is set to indicate this.

Table **2**. Modelled Concentrations and SEPP 75th percentile limits in Agnes River and Estuary (S4)

Constituent	SEPP (75th percentile concentrations ≤) (mg/L)	Modelled (River) (mg/L)	Modelled (S4) (mg/L)
SS	10.0	10.7	1.8
Nitrate + nitrite	0.3	0.56	0.1
TKN	0.3	0.61	0.1
DRP	0.005	0.017	0.003
TP	0.03	0.085	0.014

At the site (S4) on the estuary, concentrations of constituents were well below SEPP limits under the baseline scenario however in the river the concentrations of all constituents except suspended sediments exceeded the SEPP limits by between 1.8 and 3.4 times. At all ten estuarine sites the concentrations of all constituents were predicted to be significantly reduced at the seagrass beds to less than the SEPP standards except: (i) locally high phosphorus concentrations at sites S1-S3 associated with catchment loads from the creeks draining into the western side of Corner Inlet (ii) elevated concentrations of DRP associated with discharges from the Toora and Foster wastewater treatment plants.

6. CONCLUSIONS

A successful implementation of the E2 modelling system to the catchments surrounding Corner Inlet has been described in this paper. The EMC/DWC method of computing nutrient loadings according to land use was used. Since there are only two parameters to this method there are some limitations to the model's ability to predict fluctuations in nutrient concentrations due to agricultural activities or seasonal variability. A full 3-D hydrodynamic model of the Corner Inlet-Nooramunga estuary was also developed and used to identify sites where high concentrations of nutrients and sediments delivered from the catchment could have a detrimental effect on the seagrass population. An interface between the models allows the effects of land use change in the terrestrial catchment on the estuary to be investigated by running scenarios and this forms the backbone of the CI-DSS. Current "baseline" monitoring and model results suggest that the SEPP guidelines are exceeded in some of the rivers, these are unlikely to transfer into SEPP exceedances in the estuary, except from some local "hotspots" of high phosphorus loads that originate either from agricultural (pastoral) land uses in the catchments and/or wastewater treatment plants.

ACKNOWLEDGMENTS

The support and funding of the West Gippsland Catchment Management Authority is acknowledged (Project Manager: Michelle Dickson). The project benefited from the contributions of Robert Argent, Brett Anderson, Andrew McGowan and James Rennie and a Technical Advisory Group of state and local agencies.

REFERENCES

ANZECC (2000), Chapter 3 – Aquatic Ecosystems, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines. Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra, ACT.

Argent, R. M., Grayson, R. B., Podger, G. D., Rahman, J. M., Seaton, S. P., Perraud, J.-M. (2005), E2: A flexible framework for catchment modelling, In Proceedings of MODSIM 05, Modelling and Simulation Society of Australia. p 594-600.

Argent, R.M., Pexton, H.M., McAlister, A.B. (2007), The PortsE2 Decision Support System – An Application of E2. In Proceedings of MODSIM 2007. Modelling and Simulation Society of Australia. p 896-901.

Chiew, F.H.S. and McMahon, T.A. (1994), Application of the daily rainfall-runoff model MODHYDROLOG to twenty eight Australian catchments. *Journal of Hydrology*., 153: 383-416

Chiew, F.H.S., Scanlon, P.J., Vertessy, R.A.. and Watson, F.G.R. (2002), Catchment scale modelling of runoff, sediment and nutrient loads for the South-east Queensland EMSS *Cooperative Research Centre for Catchment Hydrology*, Report 02/1, 59 pp.

CSIRO (2005), Corner Inlet Environmental Audit. CSIRO Land and Water Client Report for the Gippsland Coastal Board. Prepared by D. Molloy, S. Chidgley, I.Webster, G. Hancock and D. Fox.

Dennis L.R. (1994), Intertidal Vegetation and Tidal Patterns. Unpublished PhD thesis. Department of Mechanical Engineering, Monash University, Clayton, Vic. 335 pp.

DoD (2006), Australian National Tide Tables 2004. Australian Hydrographic Publication 11.Commonwealth of Australia.

Foreman (1977), Manual for Tidal Heights Analysis and Prediction. Pacific Marine Science Report 77-10. Victoria, BC., Canada, Institute of Ocean Sciences. 101 pp.

Hindell, J., Ball, D., Brady, B., and Hatton D. (2007), Establishment of a monitoring program to assess estuarine water quality and its effects on seagrass health in Corner Inlet. DPI, Queenscliff, Vic., Report No. WG0506.10.28 54 pp.

Plummer, A, Morris, L, Blake, S and Ball, D (2003), Marine Natural Values Study, Victorian Marine National Parks and Sanctuaries. Parks Victoria Technical Series No. 1, Parks Victoria, Melbourne. http://www.parkweb.vic.gov.au/resources/19_1031.pdf (checked 24/2/09) 348 pp.

Podger, G (2004) Rainfall Runoff Library User Guide. *Cooperative Research Centre for Catchment Hydrology*,110 pp.

Waterwatch (2007), Waterwatch West Gippsland 1997-2006 Ten Year Report: Nooramunga Corner Inlet Project. Prepared by J. Vella, West Gippsland, Catchment Management Authority. On CD-ROM.