An assessment of land management practices that benchmark water quality targets set at a Neighbourhood Catchment scale using the SWAT model.

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Abstract: The Great Barrier Reef Marine Park Authority has estimated that pollutant loads discharging into the Great Barrier Reef World Heritage Area have increased 300-900% since c1850, impacting negatively on the health of the reef and its associated industries. The authority has suggested that sediment and phosphorus levels should be halved and nitrogen be reduced by a third by 2011. Under the National Action Plan for Salinity and Water Quality initiative, Regional Strategy Groups need to establish targets to meet salinity and water quality objectives from priority catchments. The Fitzroy catchment is a one such priority catchment and it is estimated that 2.6 million tonnes of sediment on average is discharged annually from the basin into the GBR World Heritage Area. For targets to be met, they need to be translated to upstream catchments and associated properties where decisions on land management practices occur. However, there is little evidence to suggest that measurement and modelling conducted at a large basin scale can inform changes that need to be made in agricultural practices at farm scales to reach agreed targets. Two 'Focus Neighbourhood Catchments', Gordonstone and Spottswood Creek; have been instrumented to measure the impacts of land management practices on sediment and water quality in two key landscapes (Basalt Downs, Dawson River Downs) within the Fitzroy Basin. Preliminary data from the Gordonstone Creek Focus NC (predominately cropping) and a long-term erosion study were used to model a range of management scenarios using the Soil and Water Assessment Tool. Modelling scenarios show that improved cropping practices can reduce sediment loads within streams, but alone are insufficient to reduce loads to half of current levels. Community Neighbourhood Catchments established within similar biogeographical regions by the Fitzroy Basin Association are used to create ownership in Neighbourhood Catchment land management and water quality targets.

Keywords: *Water Quality Targets; Neighbourhood Catchments; Catchment Modelling; Soil and Water Assessment Tool*

1. INTRODUCTION

The Great Barrier Reef Marine Park Authority (GRMPA, 2001) has estimated that sediment loads discharging into the Great Barrier Reef World Heritage Area have increased 300-900% since European settlement in the region c1850, impacting negatively on the health of the reef and its associated industries. Economic analysis by the Productivity Commission (2003) highlights the value of Great Barrier Reef (GBR) based industries, indicating that tourism alone exceeds the Gross Value of production of agriculture within GBR catchments. Land-based agricultural industries have been implicated as the main source of pollutants. This is consistent with predictive modelling by agencies over the last fifteen years; displaying at least a four-fold increase in the delivery of sediment and nutrients to the streams and rivers of the GBR catchment (Baker *et al.*, 2003).

The largest of the GBR catchments is the Fitzroy, with data from GRMPA suggesting that currently an average of 2.6 million tonnes of sediment discharges annually from the Fitzroy River into the GBR World Heritage Area. The authority suggests that sediment and phosphorus be halved and nitrogen be reduced by a third by 2011. The National Action Plan for Salinity and Water Quality (NAPSWQ) requires Regional Strategy Groups in priority catchments (e.g. Fitzroy River) to set targets with a range of timeframes and scales: aspirational (approximately 50 years), condition and trend (10-20 years) and management targets (5-10 years). Monitoring and evaluating target achievement is also a part of the NAPSWQ initiative.

1.1. Effective Target setting

For targets to be achievable specified management strategies need to be actionable on properties in upstream catchments (Baker *et al*., 2003). Current measuring, modelling and communication efforts for target setting have concentrated at a larger basin scale and there is little evidence to suggest that they can identify or communicate the impact of agricultural best management practice (BMP) on pollutant loads at the required property and local stream scale. This paper will outline how the Neighbourhood Catchment modelling approach seeks to address these challenges, through the:

1. Measurement and modelling to set relevant water quality targets at the appropriate scale for landholders to have ownership in,

2. Measurement of tangible change in the adoption of BMP and its impact on water quality, and

3. Extrapolation of results from paddock to progressively larger scales and timeframes.

The Gordonstone Creek Focus Neighbourhood Catchment was chosen as a case study to run the Soil and Water Assessment Tool (SWAT) (Neitsch *et al*., 2001), simulating a range of land management scenarios at a local catchment scale.

2. NEIGHBOURHOOD CATCHMENT'S

2.1. Definition

A Neighbourhood Catchment (NC) (typically 300 km^2) consists of a group of properties that are located in a common catchment, hence the term 'Neighbourhood'. This NC scale is then used as a building block to create ownership of land and stream management issues at a sub-catchment scale and larger.

2.2. Focus Catchments

Within the Fitzroy Basin, two 'Focus Neighbourhood Catchments', Gordonstone (260 km^2) and Spottswood Creek (270 km^2) both upland ephemeral catchments have been instrumented with water quality equipment in key biogeographic regions, as defined by Thackway *et al*. (1995). Gordonstone Creek is located in the Basalt Downs landscape and Spottswood Creek is located in the Dawson River Downs (Figure 1). Pollutant transport is monitored in the Focus NC's using a nested methodology measuring sediment, nutrient and pesticide loads at scales from 15 ha up to the NC scale (30 000 ha). The monitoring program aims to fill NC scale knowledge gaps and to quantify the impact of agricultural BMP on stream pollutant loads within each landscape.

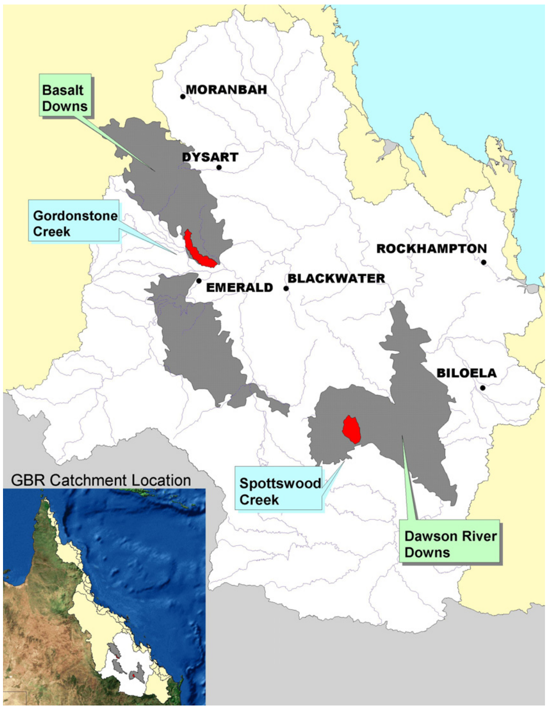

Figure1. *Location of Gordonstone and Spottswood 'focus' Neighbourhood Catchments.*

Preliminary data from the monitoring project indicates that significant reductions in pollutant loads are identifiable at a NC scale from changes in surface cover (Carroll *et al.,* 2001). The amount of surface cover retained in a cropping system is in turn influenced by land management practices undertaken by the landholder. The impact of changes in agricultural land management practice on water quality can thus be 'sensed' through monitoring at a NC scale. Hence, it is reasonable to expect that targets could be set and measured within instrumented areas over long timeframes. However, it is not realistic to instrument the whole Fitzroy and the required timeframe is too long to allow timely feedback on progress.

3. MODELLING THE IMPACT OF BMP

To measure the impact of the adoption of BMP at larger scales, "focus catchment" data needs to be extrapolated through modelling over longer timeframes and larger areas.

3.1. Model Description

SWAT (Soil and Water Assessment Tool) is a spatially explicit, continuous time step, watershed scale model developed by the USDA Agricultural

Research Service. It was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch *et al.*, 2001).

3.2. Experimental design

The Gordonstone Creek Focus NC was used to model the impact of land management practices on runoff and soil erosion. The catchment boundary was derived from a digital elevation model, and overlaid with current land use. The catchment has an area of 26,129 ha, which is partitioned into three sub-basins, based on existing water quality monitoring sites (Figure 3). The major land use within the catchment is dryland cropping (51% of area; predominantly wheat, sorghum and sunflowers).

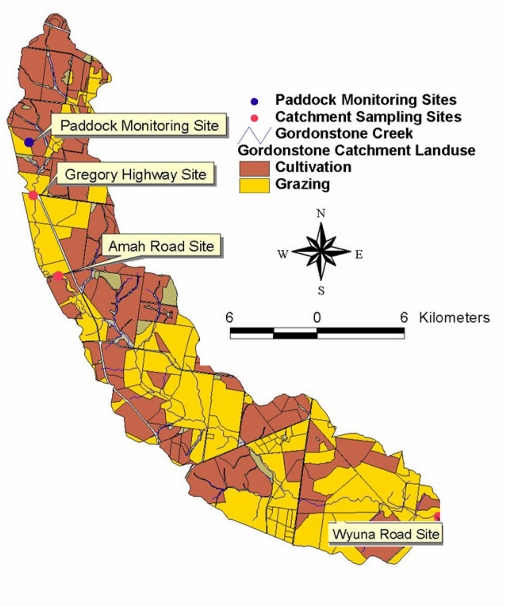

Figure 3. Gordonstone Creek "Focus Catchment"

The cropping landuse was split into three categories to reflect current management practices – conventional tillage, reduced tillage and zero tillage. Soil parameters were adapted from relevant soil surveys and past research data (e.g. Carroll *et al.,* 1997; Irvine, 1998). BROWSER (McClymont *et al.*, 2001) was used to visualise modelled outputs with measured data.

3.3. Paddock scale calibration

Nine years of runoff and soil erosion data were used from an historical long-term study at Capella to calibrate SWAT at the paddock scale (Sallaway *et al.*, 1988a and 1988b, Carroll *et al.*, 1992, and Carroll *et al.*, 1997). Runoff and soil loss data were measured from nine contour bays (approximately 10 ha), with three crop sequences (wheat, sorghum or sunflower) and three tillage treatments (zero, reduced, conventional).

Runoff

The SCS curve number method was used to calibrate runoff. Optimised curve numbers were generated using PEST (Doherty, 2002), a non-linear parameter estimation package.

Interrogation of the measured and observed annual runoff (Figure 4) indicates errors in prediction under low intensity rainfall events (e.g. cyclonic depressions). SWAT generates rainfall intensity to calculate peak runoff rate, however this is randomly calculated for a given day from maximum monthly intensity parameters. Model performance could potentially be improved with the addition of measured half hour intensity data.

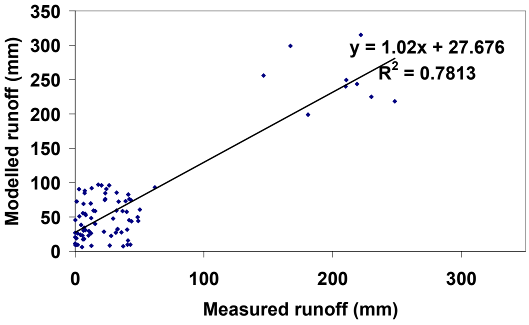

Figure 4. Annual measured and modelled runoff for nine contour bays, 1983-1991. Curve number = 73.

Erosion

SWAT uses the Modified Universal Soil Loss Equation (MUSLE), a modified version of the Universal Soil Loss Equation (USLE) to calculate soil erosion. Erodibility parameters used in the calibration were the same as those used for the calibration of the PERFECT (Productivity Erosion Runoff Functions to Evaluate Conservation Techniques) model (Littleboy *et al.*, 1999) (Table 1), which was calibrated on the historical study area.

MUSLE Parameters	***Parameter Values***
Soil erodibility (K)	0.40
Support Practice Factor (P)	0.6
Topographic Factor (LS) Slope Length	120 m
Topographic Factor (LS) Slope	1%
Rock in First Layer	1%

Table 1.Paddock scale erodibility parameters used in calibration.

A low correlation for annual soil erosion (Figure 5) may be attributed to the over estimation of runoff in low intensity years resulting in the over estimation of erosion.

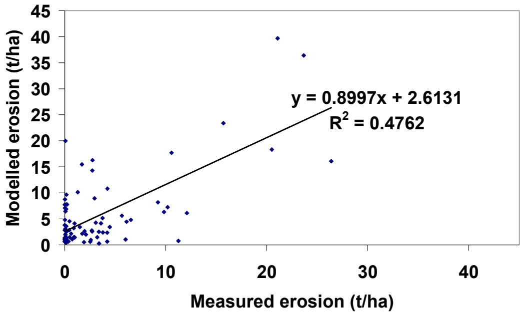

Figure 5. Annual measured and modelled soil erosion for nine contour bays, 1983-1991.

3.4. Catchment scale calibration

Using the parameters derived from the paddock scale calibration, the model was then calibrated at the catchment scale. Soils data used were from the calibrated paddock scale data, and from measured farm scale data (Irvine, 1998). This information was then merged and applied as a single soil across the entire Gordonstone Creek catchment. Modelled hydrology was matched to the measured hydrology of the three monitoring sites. Data from 1999-2000 were used as a combination of low and high cover, and dry and wet years.

Gordonstone Creek is an ephemeral stream that experiences significant transmission losses. These losses reduce runoff volume as the flood wave travels downstream. Transmission losses from surface runoff are assumed to percolate into the shallow aquifer. Hydraulic conductivity of the main channel was therefore used to calibrate hydrology at the catchment scale. Data from the catchment was measured and modelled from daily flows for Gregory Highway and Amah Road (Figure 6). Modelled data for Wyuna Road is not as accurate, possibly due to variability in cropping practices and rainfall.

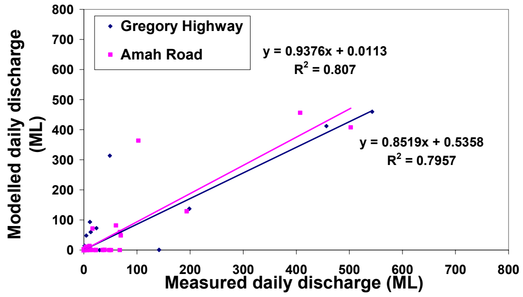

Figure 6. Measured and modelled daily flow for Gregory Highway and Amah Road, 1999-2000

An edge-of-field filter strip was applied to all cropping scenario's to simulate the effect of waterways, riparian zones, etc. A strip width of 10 m gave a modelled soil load of 1352 t (measured 1275 t) for Gregory Highway, and 1340 t (1910 t measured) for Amah Road. The width was arbitrarily applied to give a best fit for erosion.

As with discharge for Wyuna Road, sediment yield was much higher than measured (measured 612 t, modelled 1142 t). Although modelled discharge and sediment yield are higher than measured, the sediment concentration is more closely matched (measured 0.39 t/ML, modelled 0.45 t/ML). The sparsity of measured data and storm variability limits the accuracy of model outputs and resultant calibration. However this should improve as more events generate more data.

3.5. Land management simulations and results

Three land management scenarios were run on Gordonstone Creek Focus NC to demonstrate the impact on meeting GRMPA targets. A nine year period was simulated (1983-1991) using daily rainfall from the Capella historical study. The cropping land management treatments were:

1. Conventional tillage, where crop stubble is incorporated into the soil and there is low surface cover. This was the situation over 20 years ago before the development and widespread adoption of stubble retention in the region.

2. Current practice (zero and reduced tillage) within the catchment where 70% of the cropping in the catchment undertakes stubble retention practices and surface cover is >30%.

3. Full stubble retention (zero tillage), where all cropping properties within the catchment retain crop residue on the soil surface.

The simulation shows that, should current practice (30% conventional tillage, 70% stubble retention) change to 100% stubble retention, a 13% reduction of sediment loads could be achieved from the catchment (Figure 7). It can also be seen that since the adoption of stubble retention in the catchment over 20 years ago, there has been a 40% reduction in sediment loads in Gordonstone Creek. However to reach GRMPA targets other management practices not considered in these scenarios are required (GRMPA targets calculated as half of present management).

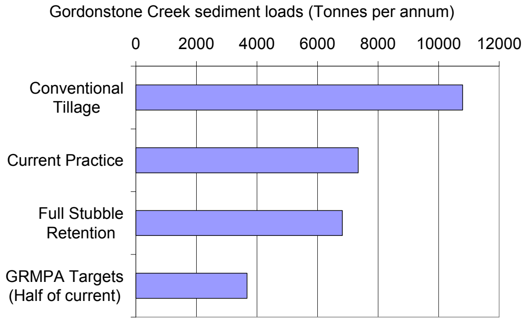

Figure 7. Land management practice sediment loads simulated by SWAT in Gordonstone Creek.

3.6. Ownership of targets

These results indicate that large reductions in sediment loads have been achieved and that these reductions can potentially continue. However this information needs to be communicated to landholders to allow ownership and feedback. The Fitzroy Basin Association (FBA) have adopted the Neighbourhood Catchment extension methodology (Millar, *et al.* 2001) for delivering devolved Natural Heritage Trust grants to achieve change in land and vegetation management. Catchments formed through the devolved grant process are termed Community Neighbourhood Catchments.

There is a two-way relationship in information exchange between Focus Neighbourhood Catchments and the Community Neighbourhood Catchments (Figure 8). The instrumented Focus NC's, fill catchment scale knowledge gaps, and measure, quantify and model land management scenarios that can be used to inform relevant target setting. Outcomes can be extrapolated to Community NC's in the same biogeographical regions. In addition, landholders in those Community NC's and regions can help develop scenarios and have ownership in the agreed targets that are set.

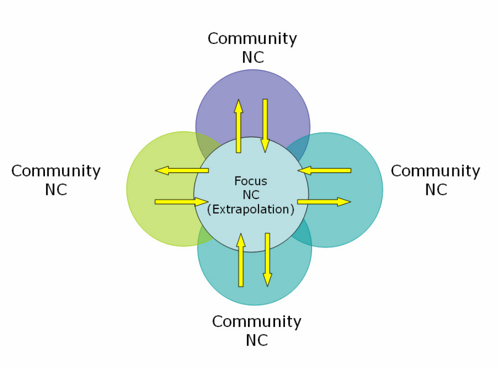

Figure 8. Relationship diagram of NC information exchange.

4. CONCLUSIONS

Detailed data at a paddock and a catchment scale from Gordonstone Creek focus Neighbourhood Catchment enabled the SWAT model to effectively simulate land management scenarios. Without this level of information SWAT would have been unable to be calibrated. Outputs from the simulations suggest that sediment loads can be improved if the remaining 30% of conventional tillage changes to stubble retention. However to reach GRMPA targets other measures need to implemented.

5. ACKNOWLEDGMENTS

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