Tully Murray Water Quality Monitoring Strategy

For the FNQNRM
Tully Water Quality Improvement Plan

FNQ NRM LTD

ACTFR Report No. 07/18

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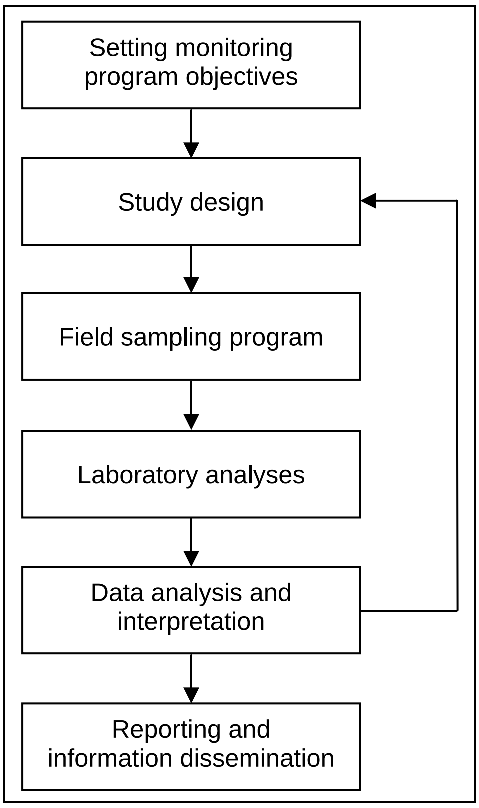
1. Introduction

Since 2005 the Australian Centre for Tropical Freshwater Research (ACTFR) has conducted a Water Quality Event Monitoring Project for FNQNRM in the Tully Murray basin. This project has targeted the collection of baseline sediment and nutrient samples from major and minor sub-catchment waterways stratified on the basis of land use.

Water quality information collected through this baseline water quality monitoring program will assist the Coastal Catchment Initiative (CCI) in the development of this Water Quality Monitoring Strategy designed to measure changes in water quality as a result of the implementation of on-ground land management actions within the major land uses of the region; sugarcane cultivation, beef grazing, horticulture (predominantly bananas), forestry and nature conservation. The monitoring objectives need also to be linked to the bigger picture of Reef Plan. Combined with catchment scale modelling efforts such as SedNet (Brodie et al., 2003; Hateley et al., 2006), this monitoring data will help identify key pollutants of the region and their sources and hence priority land uses for management within the region.



Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 1: Water quality monitoring program framework from the Australian Guidelines for Water Quality Monitoring and Reporting (2000)

The development of this monitoring strategy is based on the *Australian Guidelines for Water Quality Monitoring and Reporting (2000)* through the National Water Quality Management Strategy (ANZECC, 2000). These guidelines provide a framework for developing a water quality monitoring program and emphasise the need for a formal design process that includes:

- Definition of the issue(s);
- Compilation of available information;
- Development of a conceptual model(s) for the system and problem of interest; and
- Setting of clear, measurable objectives.

These guidelines provide a framework for developing a water quality monitoring program as displayed in the flow chart (Figure 1).

There are various reasons for monitoring water quality, some of which are listed below. These categories are not exclusive as a monitoring program may have objectives which encompass several of these objectives.

1.1 Background/baseline monitoring

Monitoring carried out to understand the spatial and temporal range of water quality parameters important to aquatic ecosystem health in water bodies. This sort of monitoring may also be used to assess natural variability of water quality parameters in time and space. This information cab then be used in designing a monitoring program in which the signal (the result we are seeking) can be separated from the noise (the natural variability). Another objective of this type of monitoring can be to gather reference site data to design water quality guidelines or criteria.

1.2 Issues monitoring

Monitoring carried out to identify particular water quality issues, such as:
(a) Is a water body contaminated – that is, can we detect contaminants in the water body at concentrations above those that occur naturally?
(b) Is a water body polluted – that is, can we detect contaminants at concentrations known to cause adverse ecosystem effects?
(c) Does the water body meet water quality guidelines/criteria?
(d) Are there detectable adverse biological effects?

1.3 Identifying contaminant sources

Monitoring carried out to identify (and quantify) the sources, in terms of land uses and activities, of contaminants from the landscape to waterways. In these programs the landscape will be divided into different land uses and potential pollutant sources (e.g. sugarcane cultivation, metallurgical industry, urban, sewage treatment plant) determined and the water quality characteristics of each through monitoring sites downstream of each land use/source.

1.4 Monitoring transport and processing of contaminants in catchments

Monitoring to understand and quantify the transport of contaminants (concentrations and loads) from the generation point (land use, specific activities) to and within the water body of concern. During transport the determination of rates of trapping and removal of contaminants and storage times will be important. Important trapping/removal mechanisms include sedimentation, burial, chemical detoxification, denitrification, biological uptake of nutrients and storage in vegetation and animals, evaporation, dilution, transport completely out of environment of concern. In this type of program, sampling sites spaced out longitudinally from the source to the ecosystem of concern may be used to measure the changes occurring to the key pollutants.

1.5 Trend monitoring

Monitoring carried out to identify trends (commonly temporal trends) in contaminant generation and water body concentration – for example, are contaminant loadings increasing/decreasing? Are contaminant concentrations increasing/decreasing through time? Are biological indications of ecosystem health improving/deteriorating? There are often difficult problems to solve in interpreting the trends as trends may be occurring at a range of temporal scales, such as daily (with light and dark), monthly (with tides), seasonally (summer/winter or wet season/dry season), multi-year (El Nino, sunspots cycle).

1.6 Management effectiveness monitoring

Monitoring carried out to determine whether management intervention to reduce contaminant sources is changing contaminant concentration/loadings. Will normally have a trend or comparison element, such as a comparison data from before the intervention was implemented. In this type of monitoring all the issues associated with comparison between adjacent sites, ‘reference’ sites, before and after comparisons incorporated into the MBACI (multiple before-after control-impact) system, have to be resolved.

1.7 Monitoring to produce a report card

One common use of monitoring programs is to collect data which can be used in an assessment/ranking scheme for the environment, such as a water quality report card or a ‘State of the Environment’ report. The Healthy Waterways Program is a well developed system in south-eastern Queensland in which a score-card system is associated with a comprehensive monitoring program.

1.8 Research monitoring

Some water quality/ecosystem health questions only require a short study at limited locations to reach a conclusive answer and in these cases the boundary between monitoring and research becomes blurred.

It is envisaged that the major monitoring programs needed in the Tully Murray area in the future will consist of four of these types:

a) *Management effectiveness monitoring.* As the WQIP is implemented there will be an absolute requirement to assess the effectiveness of the management regime. This monitoring program will by necessity be of an integrated monitoring modelling type, and focus on event flow conditions. The modelling component is necessary due to long time lags and high inter-annual variability in rainfall runoff, river flows and material dynamics. This program will be closely integrated with Federal and State Government programs addressing the same objectives e.g. State Government GBR Loads Program, GBRMPA Marine Monitoring Program, the Pesticide Reporting and Auditing Scheme;

b) *Reference Site Monitoring Program*. This is necessary to help set regional water quality guidelines. This program should occur at the FNQ scale, and not just in Tully;

c) *A freshwater ecosystem health/water quality monitoring program*. This program will have a focus on ambient water quality in high value freshwater waterbodies; and

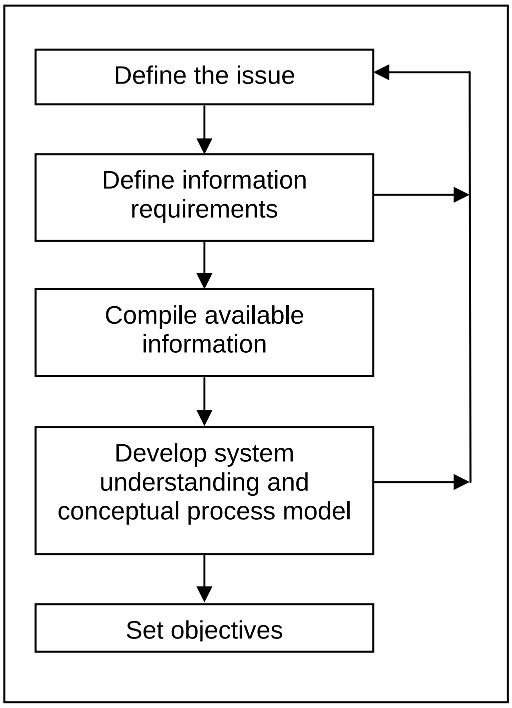
d) *Monitoring to produce a report card.* This program will draw on results from the other three monitoring programs (particularly a and c), as well as State and Federal Government Programs (as above) to report on State of the Environment at the Far north Queensland Scale.

(Note that the existing sub-catchment land use based monitoring carried out in 2005-07 was of the issue identification and source quantification type; and now having fulfilled those objectives will not be required in the future).

2. Monitoring Objectives

2.1 General monitoring objectives

The process for setting monitoring program objectives for any monitoring program is outlined in the flow chart below (Figure 2). These points are used in the following discussion with respect to the requirements of Reef Plan monitoring and Tully WQIP and the interaction between these two levels of monitoring.



Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 2: A Framework for setting monitoring program objectives

2.2 Reef Plan monitoring objectives

The general objectives of monitoring programs associated with the Reef Plan are:

- Identification and quantification of sources of pollutants to the GBR;
- Assessment of trends in delivery of pollutants (loads) to the GBR;
- Measurement of progress of implementation of pollutant-reducing initiatives on the GBR Catchment;
- Identification of the ‘sink’ areas of land-sourced pollutants in the GBR;

- Measurement of trends (spatial and temporal) in the concentrations of pollutants in compartments of the GBR– water column, sediments, biota;
- Assessment of the effects of pollutants on GBR ecosystems and trends in the status of GBR ecosystems related to terrestrial runoff;
- Assessment of the effects of terrestrial runoff on the GBR in relation to other stresses and impacts.

Overall monitoring programs linked to Reef Plan for should have the following features:

2.2.1. Monitoring management actions and assessing effectiveness

Management action monitoring
- Adoption rates of management actions at a catchment scale
- Stocking rates
- Grass cover and biomass/pasture condition
- Tree cover
- Riparian vegetation and wetland condition

Monitoring management practice surrogates
- Fertiliser and pesticide use
- A spatial analysis program to measure landuse change within catchments. Much of this information is being derived from ongoing mapping of vegetation change (eg NRW SLATS; Queensland Herbarium; EPA Wetlands Inventory; CSIRO vegetation cover surveys), agricultural landuse (NRW, DPI&F, Industry groups, QLUMP), and riparian vegetation condition.

Testing effectiveness of management practices data
- Field studies to quantify the water quality outcomes of particular management practices under a range of scenarios.
- Examples of current paddock-scale monitoring include investigation of the effects of: beef grazing management practices on erosion hotspots (Henderson-Kinsey et al. 2005);ground cover retention on runoff water quality (O'Reagain et al. 2005); reduced fertiliser usage in sugarcane and banana cropping areas on nutrient losses to surface and ground waters (Faithful and Finlayson, 2005); and riparian vegetation and wetlands in trapping sediments, nutrients and pesticides in runoff from sugarcane and banana cropping areas (McKergow et al. 2004a; 2004b).

Monitoring landscape context (eg. climate)

Monitoring actions to achieve specific targets

Monitoring socio-economic context (eg. profitability)

Cost effectiveness of management practices

2.2.2 Water Quality Monitoring

The water quality monitoring program for this strategy is the critical component that requires integration across the catchment to reef interface. The following description of these components is not meant to serve as a detailed design of the program. Detailed design including exact sampling numbers, frequency, parameters, power calculations etc will still need to be undertaken at, for example, a single catchment scale given the resources available for that particular component.

Table 1. Reef Plan water quality monitoring program details.

Scale	Description	Parameters**	Flow Data
Paddock Scale Monitoring/ Research	– Monitoring of water quality at the property scale to measure the impact of particular management practices. – Important for input into catchment scale modelling that is specific to land use/land types in the Regions. – Existing examples of such monitoring include Burdekin Wambiana Grazing Trials (DPI&F) and Virginia Park Station (CSIRO/DPI&F), Sugarcane and banana trials in Tully (ACTFR)	Nutrients (particulate and dissolved) Suspended sediments Pesticides	Management testing so not necessarily gauged sites; design requires flow data
Sub-catchment	– Monitoring of water quality at the sub-catchment scale (particularly in large catchments) to measure the longer term changes in water quality as a result of changes in land management practises and the impact of varying land uses. – Important for input into catchment scale modelling that is specific to land use/land types in the Regions.	Nutrients (particulate and dissolved) Suspended sediments Pesticides	Management testing so not necessarily gauged sites.
Whole of catchment	– Monitoring of water quality at end of catchment sites to enable load calculations. – The NRW I5 GBR Catchments Loads Monitoring Program currently delivers load monitoring at major sub-catchments and end of river sites. – Automated turbidity loggers (AIMS) are installed at end of river sites in priority catchments.	Nutrients (particulate and dissolved) Suspended sediments Pesticides	Load orientated data with all sites located at NR&W watershed gauging stations.
Estuarine and Marine	– Water quality monitoring in inshore waters (i.e. within 20 km of the coast) of the GBR to assess long-term change in the concentrations of key biophysical water quality indicators. – The GBRMPA Marine Monitoring Program delivers transects twice a year (pre- and post-wet season transects). – Passive samplers are located at priority inshore reef sites to measure pesticides; sediment pesticide sampling is also undertaken annually to quantify persistent concentrations.	Nutrients (particulate and dissolved) Suspended sediments Chlorophyll Salinity Temperature Pesticides	N/A
Freshwater plumes	– Water quality monitoring in freshwater plumes to determine the composition of the material being transported in flood events to the inshore GBR. – This sampling program will help to understand the key processes occurring in the plume such as the transport and extent of main pollutants, nutrient/pesticide removal/cycling in the system and the mixing and dispersal of plume waters in the Great Barrier Reef Lagoon. – Highly valuable to compare with the GBRMPA guidelines for ecosystem health and evaluate the potential impacts of herbicides in the marine ecosystem (on mangrove, seagrass and coral communities).	Nutrients (particulate and dissolved) Suspended sediments Pesticides Chlorophyll Salinity	N/A

** Note: As a general rule, priority parameters for the Dry Tropics catchments (eg. Burdekin and Fitzroy) will be suspended sediments and particulate nutrients, whilst Wet Tropics catchments (eg. Tully, Mackay-Whitsunday) will focus on dissolved nutrients, pesticides, and to a lesser extent suspended sediments. These differences are largely driven by the dominant land uses in those areas and the nature of the systems.

2.2.3. Monitoring socio-economic indicators

Population and Population Projection

Economic and financial values of the GBR and catchments

Community and visitor perceptions of the GBR

2.2.4. Receiving Waters Ecosystem Health Monitoring

In parallel with water quality monitoring, monitoring of the major marine ecosystems at most risk from land-sourced pollutants is required to ensure that any change in their status is identified. Where possible, biological monitoring sites are located near inshore marine water quality monitoring sites to enable correlation with concurrently collected water quality information.

The key components of the program are:

- *Inshore mangrove monitoring* – mapping and assessment.
- *Inshore seagrass monitoring* – mapping and habitat assessment, sediment herbicide (atrazine, diuron and simazine) and nutrient concentrations, plant reproductive and tissue nutrient status within seagrass beds.
- *Inshore coral reef monitoring* – cover and diversity, demography and recruitment.

Specific detail about the current design employed by the Great Barrier Reef Marine Authority for the Reef Plan Marine Monitoring Program is provided in Haynes et al., (2006).

2.3 Tully WQIP monitoring objectives

2.3.1 Define the Issue for Tully Murray basin

The key pollutant issues for the Tully WQIP region have been defined in a report entitled 'Water Quality Issues in the Tully WQIP region' (Brodie et al., 2007). The primary water quality issue in the region is the degradation of freshwater wetlands and inshore coral reefs through a decline in water quality. This decline in water quality can be attributed to the major land uses of the region. From the initial analysis in this study, reviewing all sources of water quality data for the Tully Murray basin and using modelling studies the list of priority pollutants is: 1. Nitrate and particulate nitrogen. 2. Herbicide residues in the form of atrazine and diuron. 3. Suspended sediment, particulate phosphorus and acid sulphate soil runoff. 4. Dissolved organic nitrogen, dissolved oxygen reducing substances. The principal sources of nitrate, particulate nitrogen, diuron and atrazine are cropping industries, sugarcane for nitrogen and herbicides and bananas for nitrogen.

A second type of issue in the Tully Murray basin is the lack of suitable local water quality guidelines which have been validated for local conditions compared to the National (ANZECC) and Queensland general guidelines. This makes it difficult to credibly compare current water quality to guidelines.

2.3.2 Define information requirements

As the majority of pollutant transport to the receiving water bodies (wetlands and the Great Barrier Reef lagoon) occurs during significant wet season rainfall events, the monitoring strategy needs to have one component to be designed with a focus on event monitoring. An ambient monitoring program is a separate requirement to measure impacts on the receiving waters. The design of the ambient monitoring program will be dealt with separately from the event based program.

General information requirements for the event based monitoring strategy include:

- the identification of pollutant sources, where sources include land use, land types and land management practices;
- information on key pollutant concentrations and loads from these landscapes and land uses and land management practices;
- usage data for chemicals applied to the landscape in more intensive land uses (e.g. fertilisers, pesticides);
- information on vegetation cover (riparian, ground cover) preceding wet season;
- information about the catchment landscape and land use management to help parameterise and validate catchment scale modelling (e.g. water quality, soil analysis and ground cover data);
- river flow data to calculate loads.

2.3.3 Compile available information

The compilation of available information is currently being conducted through the CCI process. In particular, the ‘Water Quality Issues in the Tully WQIP region’ Report (Brodie et al., 2006), ‘Nutrients and suspended sediments in the Tully River: Spatial and temporal trends’ Report (Mitchell et al., 2007), ‘ point sources and their control in the Tully Murray catchment’ (Roberts, 2007), ‘SedNet Modelling of the Tully WQIP Region’ (Armour et al., 2007), ‘Sediment and nutrient modelling in the Far North Queensland NRM region’ (Hateley et al., 2006), the draft ‘Environmental Values and Water Quality Objectives Report’ (Kroon et al., 2007) and the community survey reports (Bohnet et al., 2006; 2007) will bring together available modelling, monitoring and values data in the Tully Murray basin for this purpose.

2.3.4 Develop system understanding and conceptual process model

The development of system understanding and conceptual models of these catchment processes are also being conducted through the CCI process.

2.3.5 Set objectives

Currently the monitoring strategy objectives for the Tully Water Quality Improvement Plan have been defined by the CCI. As further information is provided through the CCI process these objectives may need to be updated. In particular, objectives 2 and 3 are very similar and may need some reanalysis.

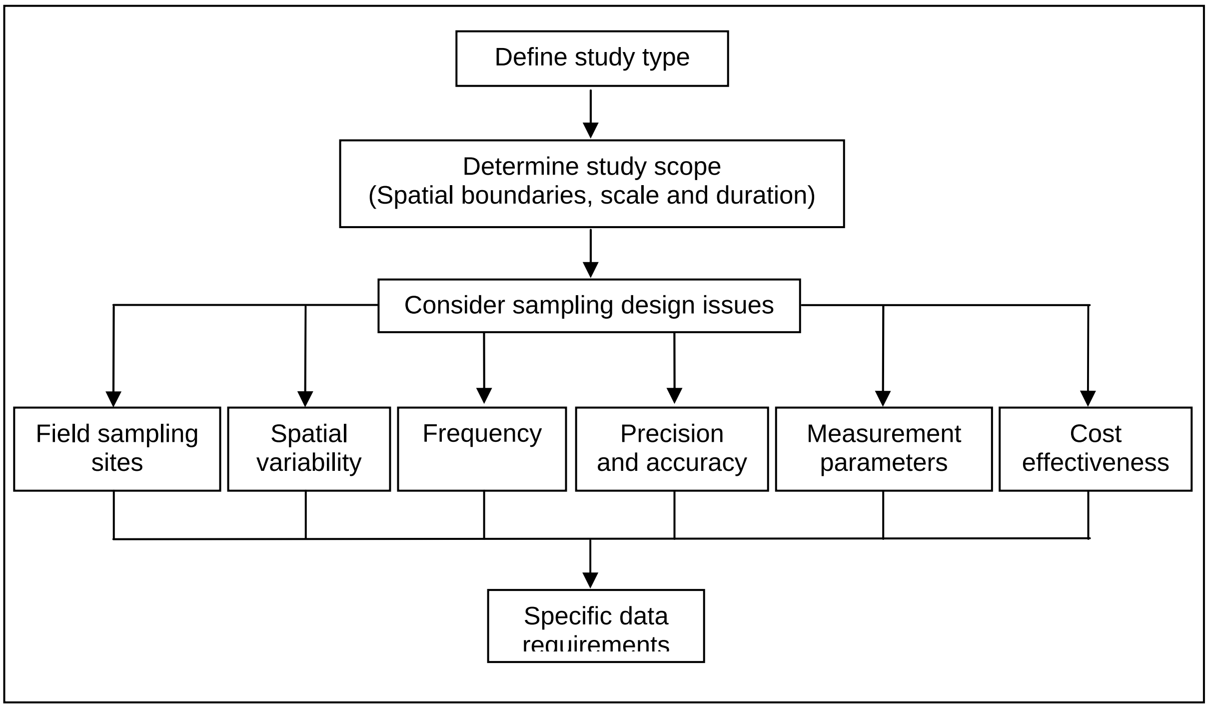
Current objectives to determine:

1. sources of pollutants in the basin;
2. changes in pollutant loads to the receiving water body;
3. changes in key pollutant loads and concentrations in priority water bodies;.
4. effectiveness of management measures and control actions;

Objective 1 is now complete through the sub-catchment monitoring program (Faithful et al., 2007), AIMS long-term monitoring program (Mitchell et al., 2006), flood plain monitoring program (Wallace et al., 2007) and catchment modelling projects (Brodie et al., 2003; Hateley et al., 2006; Armour et al., 2007). Information on sources has been summarised in the issues report (Brodie et al., 2007).

Objectives 2, 3 and 4 are really part of a single objective to assess management effectiveness through measuring water quality change (trend) in priority water bodies (the receiving water bodies). This is the prime objective of catchment monitoring in the Tully Murray Basin from here on as management is implemented under the WQIP.

3. Study Design



Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 3: A Framework for designing a monitoring study

3.1 Study type

Baseline water quality monitoring projects have already been conducted in the Tully Murray basin (Mitchell et al., 2006; Faithful et al., 2007). Both studies answered questions about sources while the Mitchell study also provided information about change due to land use change as it was carried out over many years.

Future monitoring should now concentrate on management effectiveness, setting water quality guidelines and report card type monitoring.

3.2 Study scope

The study scope of this monitoring strategy would include the Tully WQIP region as defined within the CCI. Monitoring will be conducted at varying scales, from the property, small sub-catchment, major sub-catchment and end-of-river scales as outlined in the recommended strategy below. As monitoring will primarily occur during significant rainfall events, sampling duration is limited to one-two major catchment wide rainfall events during the wet season.

3.3 Sampling design issues

Sampling design issues for event monitoring include:

- sample sites will reflect the different sampling scales, with sub-catchment and paddock scale sites selected on the basis of the land management being implemented through the WQIP;
- the frequency of sampling will be determined by the nature of individual rainfall events, with 5-8 grab samples collected over the flow hydrograph. At least one sample must be collected on the rising stage of the hydrograph to ensure the sampling is representative, and can be used for the calculation of loads;
- Measurement parameters will include:
    - Total suspended solids
    - Nutrients (speciation of nitrogen and phosphorus)
    - Pesticides (predominately herbicides)
- consideration to the variability of flow in this wet tropical catchment, and the ability of monitoring to actually detect change in water quality as a result of on-ground management actions in the short term. Hence there is a need for a combined monitoring and modelling approach in this region;
- cost effectiveness can be achieved through the establishment of a regional volunteer network, which also serves practical and logistical purposes over large catchment areas. Such an approach will also allow for the involvement of community in water quality issues in the Tully Murray basin.

3.4 Recommend event monitoring strategy

3.4.1 Research/paddock Scale Monitoring

Monitoring of water quality at the property scale to measure the impact of varying management practices. Water quality data at this scale is important for input into catchment scale modelling that is specific to land use/land types in the Tully Murray basin. Existing examples of such monitoring in the Tully Murray basin include the Catchment to Reef CRC program sites on sugarcane and banana farms (Faithful and Finlayson, 2004, 2005; Faithful et al., 2006).

3.4.2 Sub-catchment monitoring

Focus on prioritised sub-catchments based on land use. Sub-catchments will be monitored to measure longer term changes in water quality as a result of changes in land management practices. Although the number of monitored sub-catchments will be reduced from the baseline monitoring project, there would still be a range of sub-catchments used. Sub-catchment selection would link up with FNQNRM funded projects for improvements in on-ground management such as will be developed through the Tully WQIP.

3.4.3 Major rivers

The monitoring of the major rivers within the Tully Murray basin (Tully and Murray Rivers) should continue. The responsibility for the Tully will be transferred to the State Government GBR GBR Catchments Loads Monitoring Program, which has the responsibility of monitoring GBR catchments under the Reef Plan but the Murray should also be continued.

This monitoring is load orientated with all sites located at NRW watershed gauging stations.

3.4.4 Marine Plume

The Tully Murray marine receiving waters may reach as far north as Cairns during very large to extreme events, although the main influence of the Tully Murray plume in the marine environment is probably as far north as the Franklin Island Group (Devlin et al., 2001). A series of parameters (sediments, nutrients, pesticides, chlorophyll a and plankton composition) have been measured along the salinity gradient throughout the plume. This sampling program will help to understand the key processes occurring in the plume such as the transport and extent of main pollutants, nutrient/pesticide removal/cycling in the system, the mixing and dispersal of plume waters in the Great Barrier Reef Lagoon and the extent of exposure of marine ecosystems to terrestrial pollutants. In particular, these data will be highly valuable to compare with the ANZECC guidelines (and draft GBRMPA guidelines) for ecosystem health and evaluate the potential impacts of herbicides in the marine ecosystem (on mangrove, seagrass and coral communities). It is hoped that this flood plume monitoring will be continued under the GBRMPA Marine Monitoring Program (Haynes, pers. com.).

3.4.5 Links to modelling

The monitoring sites in close proximity to gauging stations will be used to calculate loads from the catchments. These load calculations will help to validate and improve the SedNet, ANNEX and E2 models and also assist to establish a baseline to allow comparisons with future data as well as to evaluate the effectiveness of remedial works.

For the GBR Catchments, a hierarchical set of models at different scales similar to what is already partially occurring (previous sections) is required. The principal purpose of modelling will be to measure water quality changes resulting from land use management in association with monitoring projects.

Conceptual models

Conceptual models are a key component in the development of an integrated monitoring program to assess trends in the ecological status of a system. They assist in identifying the main environmental stressors or threats, appropriate indicators of ecosystem health, and relationships or linkages between the stressors and the indicators. Additionally, conceptual models are an important tool for communicating how complex ecological systems work, the ecological and physico-chemical interactions between the various components, and which components and linkages might be targeted by specific management actions.

In the first instance, the models developed in Haynes et al., (2006a) will be used to build more more detailed products that can be used by the Regions and provide a consistent GBR-wide model.

Plot/paddock scale

Models which allow the prediction of water quality outcomes (e.g. changed loss of nitrate) from changes in management practices at the plot/paddock scale given limited water quality data at this scale are essential. Currently we do not have satisfactory models at this scale for sugarcane or grazing land uses although the model APSIM could possibly be further developed to perform this function in cropping lands.

Catchment scale
A significant problem with the SedNet/ANNEX models is that they only produce a long-term average result and cannot be used to model a single flow event. Material transport in the GBR Catchments occurs predominantly in large flow events and these occur erratically over short time periods. Thus an 'averaged out' modelling framework is not completely suitable to deal with a highly episodic rivers like the Burdekin and Fitzroy. The newer catchment modelling system being developed in Australia - E2 - draws on the former systems used in SedNet/ANNEX and EMSS but allows modelling of single events. Such model results will be far easier to compare to monitoring data, also collected at the single event time scale. It is planned to use E2 in Queensland catchments over the next few years.

The recommended modelling framework for the GBR Catchments at the catchment scale is E2 which will supersede SedNet/ANNEX in the medium term future. However SedNet and ANNEX will remain the current modelling tool for at least the next few years. Monitoring data should continue to be collected to support E2 and eventually to cross-validate between modelling and monitoring.

A range of catchment modelling options are under development which will improve the reliability of water quality targets. This includes the E2 modelling framework currently under development through the eWater CRC. Trial data analysis has been undertaken in the Fitzroy region and the complete product is due for completion in late 2007. However, there is some possibility that early outputs may be available within the WQIP timeframes.

NRW are preparing a proposal to undertake a series of application projects within the eWater CRC across the GBR. These would involve the establishment of E2 models across targeted catchments in GBR regions in 2007.

Floodplain scale
It is well realised that the SedNet/ANNEX modelling systems do not work well in areas of very low slope, where large scale overbank flow occurs (gauged water flow data inaccurate) and where groundwater forms an important component of the water system. Areas such as the canelands of the lower Burdekin have all these characteristics and SedNet/ANNEX outputs are not accurate in these areas. A similar situation exists in the combined lower floodplain of the Tully and Murray Rivers and in this case the model Mike 21 is being trialled for its suitability in water quality modes in this situation (Jim Wallace, pers. com.)

An investigation of the suitability of models such as Mike 21 for use on the floodplain areas of the GBR Catchments is recommended. Mike 21 is a professional engineering software package containing a comprehensive modelling system for 2D free-surface flows. Mike 21 is well suited to the detailed analysis, design and management of flooding behaviour where a description of the 2D flow structure of rivers, lakes and their floodplains is required.

Receiving waters
A material transport modelling framework is needed for the GBR lagoon. This could be built on the King et al. (2001; 2002) framework but needs to also account for particulate material and dissolved material (including biologically active material such as nitrate) transport.

As discussed above, models robustly linking end-of-river contaminant loads to GBR ecosystem health are also essential. Currently only the Wooldridge et al. (2006) model does this for the parameter pair – nitrate/chlorophyll a, and there are no similar models which involve suspended sediments or pesticides.

Substantial work has been undertaken to model estuary behaviour in the Fitzroy through the Coastal CRC; it would be desirable for this capacity to be transferred to other GBR regions where appropriate.

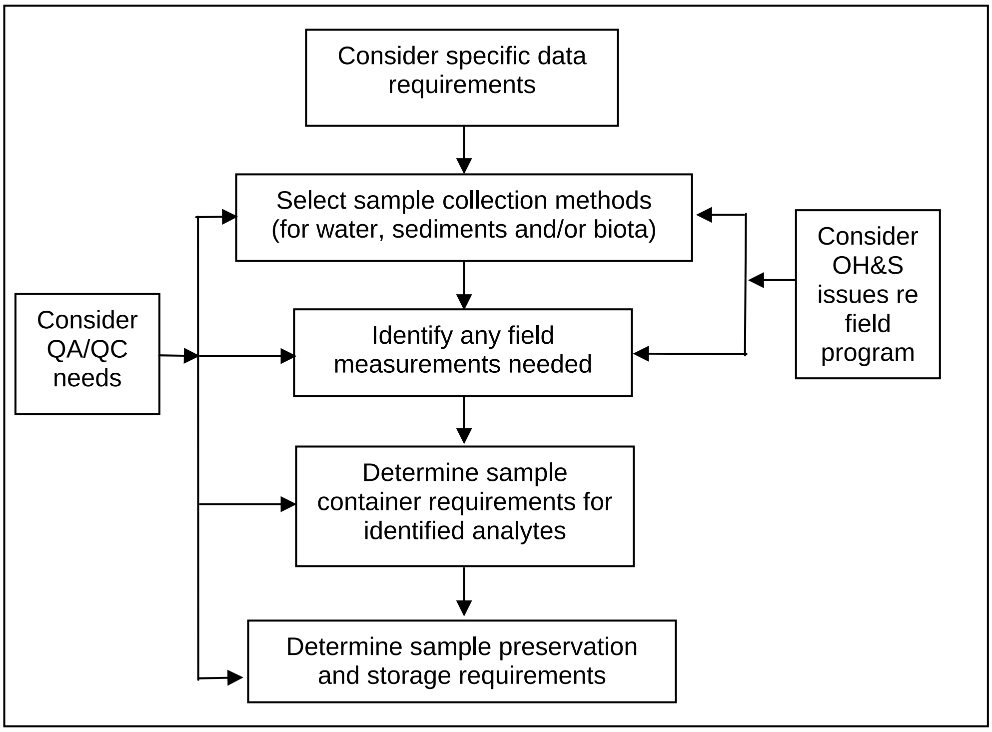
Socio-economic models
Further work on linking socio-economic factors into the biophysical modelling is required. Currently there is still minimal effort in the several of the GBR Catchments in this area (although work in the Tully catchment is progressing).

Linking Models
Ultimately, a suite of integrated catchment, estuarine and marine models will deliver the capacity to predict water quality influences on the receiving waters of the GBR resulting from change in land management practices, (i.e. models that link management actions and catchment pollutant loads to environmental effects and outcomes in the freshwater, estuarine and marine ecosystems). A integrative mechanism is required to link these models, or adoption of an approach that can incorporate model parameters from the catchment to the reef.

Bayesian modelling
The possibility of using Bayesian Belief Network modelling in the GBR Catchments should be further pursued. This framework has the advantage of being better able to incorporate expert knowledge into the modelling and also treating all model scale in one overall model. A model of this type is being built for the Herbert catchment and coastal waters (Thomas et al., 2005) and CSIRO also have interests in this area in the Burdekin and other Regions.. A number of these models are currently under development (Wooldridge *et al*., 2006; Wolanski and De'ath, 2005).

4. Field Sampling Program

As an event monitoring project has been conducted by ACTFR for the FNQNRM in the Tully Murray basin over the past two wet seasons and the AIMS program covered a 12 year period the basis for a field sampling program is already well established, and will feed into the development of this monitoring strategy. In addition, ACTFR has been involved in a joint collaborative between CSIRO/JCU, WQSIP and the Reef Partnership to improve field, laboratory and load methods for event monitoring in GBR catchments. During the latest workshop water quality scientists outlined a preferred sampling method flow chart for field sampling which will be incorporated into this monitoring strategy, including all components in Figure 4.

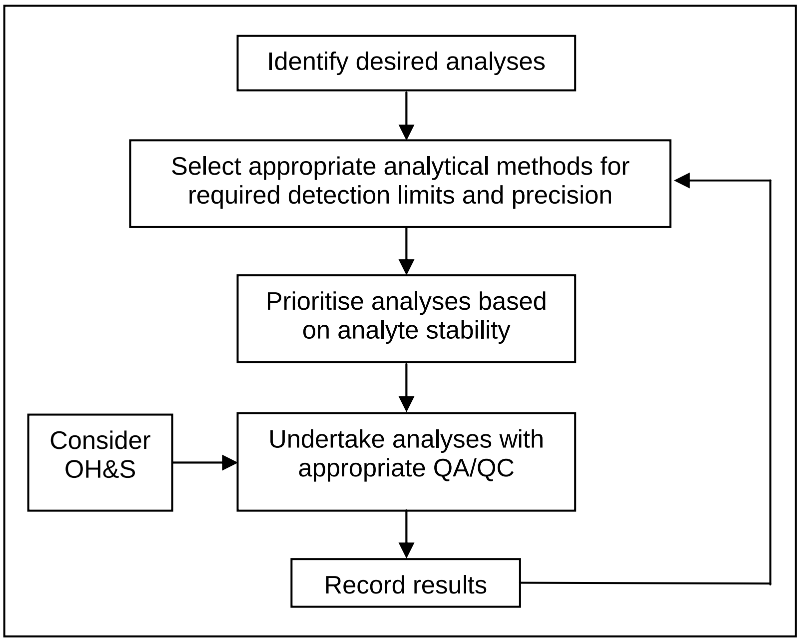


Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 4: A Framework for designing sampling programs

5. Laboratory Analyses

As for the field sampling program, improvements in the conduct of analytical programs are being continued through a Queensland Government/Reef Partnership lead *Event Monitoring Protocols* project. These protocols will guide future monitoring conducted in the FNQNRM region in addition to the framework provided in Figure 5.



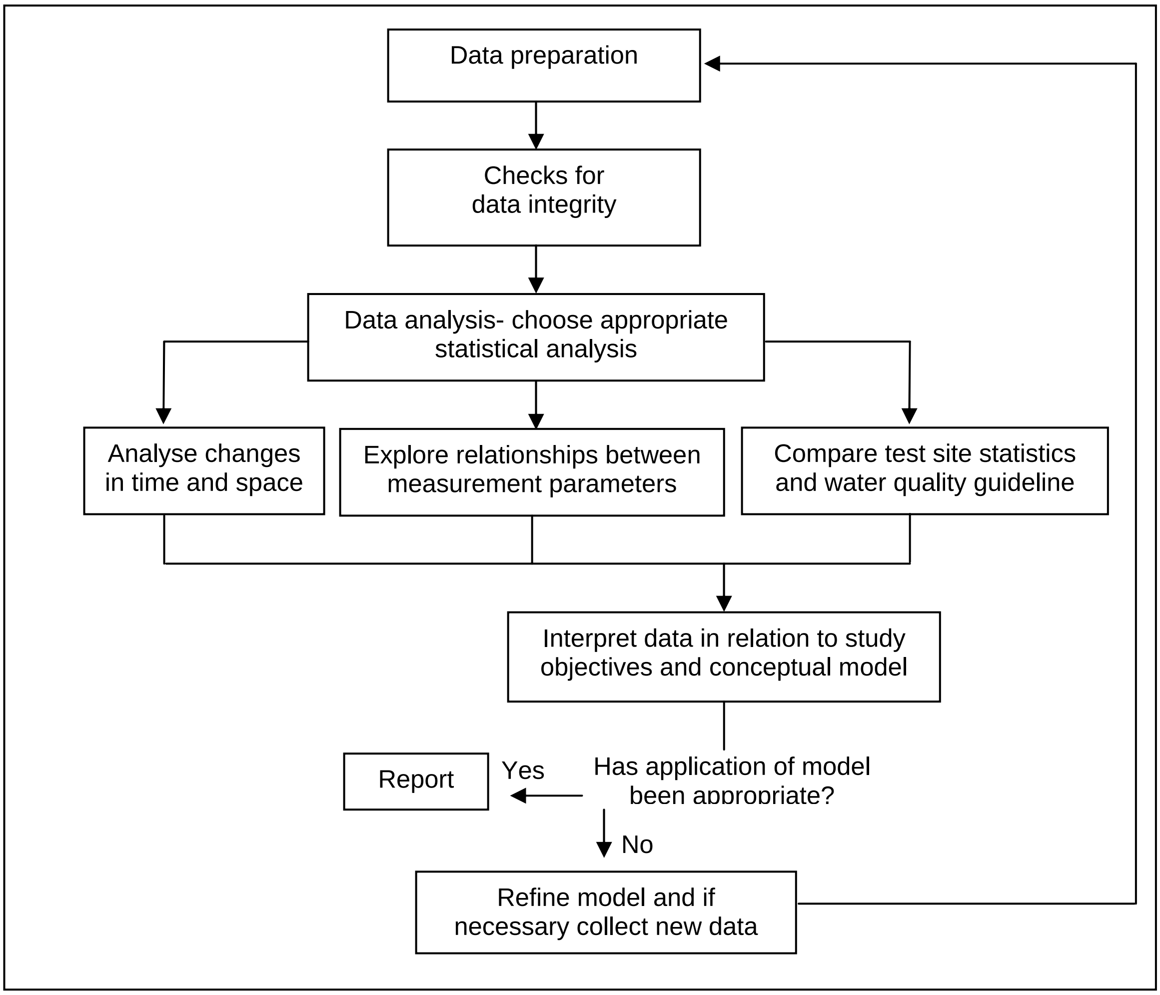
Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 5: A framework for designing an analysis program

6. Data Analysis and Interpretation

The analysis and interpretation of water quality data collected through this monitoring strategy will be conducted through scientific reporting, similar to that produced through the current monitoring project.

Local water quality guidelines need to be developed for the FNQ Region as the current Queensland Water Quality Guidelines (2006) are specific only to the central region of Queensland. Both upland and lowland freshwater parameter guidelines are currently based on the generic Australia-wide guidelines for upland and lowland freshwater systems (ANZECC 2000). A monitoring program of reference sites to do this in FNQ should be established cf Mackay Whitsunday.

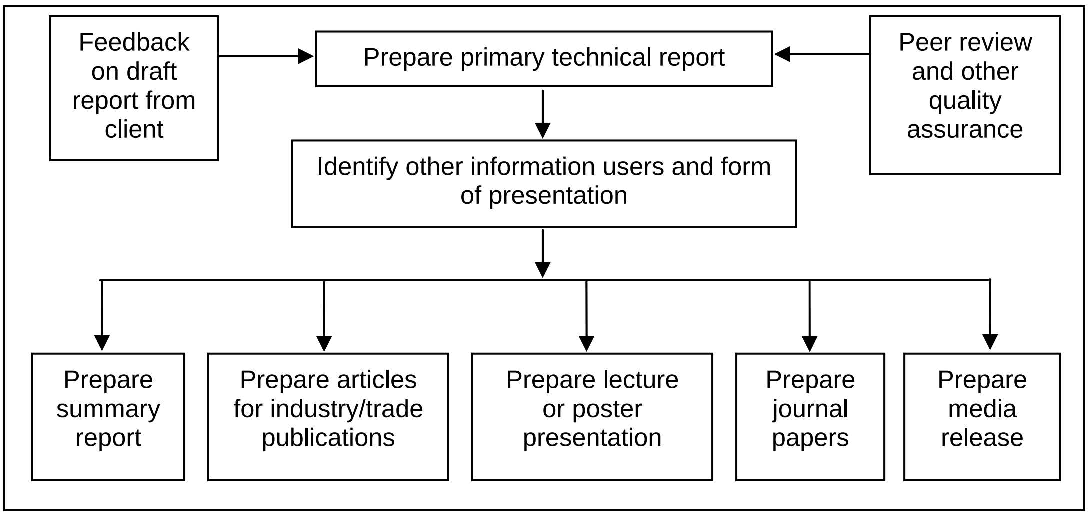


Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 6: Framework for data analysis and interpretation

7. Reporting and Information Dissemination

A successful reporting and information dissemination approach was utilised in the sub-catchment (pollutant identification) monitoring program by CSIRO and ACTFR through the Cardwell Shire Floodplain Renewal Program. This approach has a strong community information dissemination component, and should be used as a basis for future monitoring programs. The State Government and Reef Partnership are currently designing a reporting system for GBR catchments. A report card system for the FNQ region should also be designed such as that in the MWNRM region.



Source: Australian Guidelines for Water Quality Monitoring and Reporting (2000)

Figure 7: A framework for designing a reporting system

8. Design of the ambient monitoring program

The design of the ambient monitoring program also follows the above steps but in a simplified scheme the following steps are required.

8.1 Map waterbodies

Identify the waterbodies – river reaches, wetlands, reservoirs, estuaries, coastal water bodies, lakes, artificial lakes – of interest in the region. Map these into GIS. Type these using a standard typing system to the degree possible with available data (e.g EPA wetland types).

8.2 Document values

Identify and document values of these waterbodies – ecological, aesthetic, cultural, economic, recreational, heritage, fisheries, flood control, pollution control, local, national (Registers), international (e.g. Ramsar, World Heritage). Largely finished as part of WQIP (Bohnet et al., 2007).

8.3 Identify priority waterbodies

Using the values matrix identify a sub-set of the waterbodies in the region which are of highest value with a practical limit set on the number.

8.4 Water quality issues

Assess the water quality issues facing this priority waterbody set, particularly those issues which impinge on the values for which the waterbody was chosen to be in the sub-set.

8.5 Monitoring program

Design monitoring program to address these issues with parameters measured in alignment with the issue. Thus all waterbodies will not necessarily have the same parameter set.

8.7 Management effectiveness

If management actions are taken to address water quality issues for the waterbody then the monitoring program morphs from a baseline/source of issue program into an 'effectiveness of management' program as management progresses.

9. Conclusions

Water quality monitoring programs recommended for the Tully Murray area and the FNQ region generally are:

a) *Management effectiveness monitoring.* As the WQIP is implemented there will be an absolute requirement to assess the effectiveness of the management regime. This monitoring program will by necessity be of an integrated monitoring modelling type, and focus on event flow conditions. The modelling component is necessary due to long time lags and high inter-annual variability in rainfall runoff, river flows and material dynamics. This program will be closely integrated with Federal and State Government programs addressing the same objectives e.g. State Government GBR Loads Program, GBRMPA Marine Monitoring Program, the Pesticide Reporting and Auditing Scheme;

b) *Reference Site Monitoring Program*. This is necessary to help set regional water quality guidelines. This program should occur at the FNQ scale, and not just in Tully;

c) *A freshwater ecosystem health/water quality monitoring program*. This program will have a focus on ambient water quality in high value freshwater waterbodies; and

d) *Monitoring to produce a report card.* This program will draw on results from the other three monitoring programs (particularly a and c), as well as State and Federal Government Programs (as above) to report on State of the Environment at the Far north Queensland Scale.

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Appendix 1:

Draft framework for GBR Catchment monitoring and modelling.

Attachment 1: Draft framework for GBR Catchment monitoring and modelling.

Targets	Monitoring objective	Examples of indicators	Associated modelling needs	Existing modelling capacity	Summary Status
Reef Plan	Measure success of Reef Plan implementation.		A suite of integrated catchment, estuarine and marine models to predict water quality influences on the receiving waters of the GBR resulting from change in land management practices at a GBR wide scale.	Limited capacity to meet this need. A number of programs in development for catchment scale.	Integrative mechanism required to link models to allow upscaling across regions, or adoption of an approach that can incorporate model parameters from the catchment to the reef. Eg, Bayesian Belief Network modelling
RW health[1]	Identify change in the status of major marine ecosystems at most risk from land-sourced pollutants. Scale: GBR wide	• Inshore mangrove monitoring – mapping and assessment. • Inshore seagrass monitoring – mapping and habitat assessment, sediment herbicide (atrazine, diuron and simazine) and nutrient concentrations, plant reproductive and tissue nutrient status within seagrass beds. • Inshore coral reef monitoring – cover and diversity, demography and recruitment.	• Receiving water models that link land management activities to GBR ecosystem health. • Socio economic models that link socio-economic factors into the biophysical modelling. • Assess the effectiveness of improved land management activities using linking models.	• Chlorophyll-nitrate receiving water model (King & Wooldridge) - Burdekin & Tully. • Catchment and Estuarine/near shore modelling underway in Fitzroy (CSIRO with FBA). • Various MTSRF funded projects related to reefal connectivity, sediment tracing and climatic modeling – AIMS, CSIRO, JCU, UQ. • DEW review of management needs, current knowledge, knowledge gaps, and opportunities for GBR receiving water modelling activities.	• Methods under development. • Monitoring program in place. • Modelling to link to water quality limited.
RW quality[1]	*Event*: Understand the key processes occurring in freshwater plumes such as the transport and extent of main pollutants, nutrient/pesticide removal/cycling in the system and the mixing and dispersal of plume waters in the GBR. Ambient: Assess long-term change in the concentrations of key biophysical water	• Water quality monitoring in inshore waters (i.e. within 20 km of the coast) of the GBR. • Cross shelf transects twice a year (pre- and post-wet season transects). • Passive samplers at priority inshore reef sites.	As above.	• Reef Risk Exposure model update (Regional bodies & ACTFR). • 2-D Hydrodynamic receiving water model (Wolanski, AIMS) - whole of GBR. • Particle distribution models (Mason & Bode, JCU) • Various MTSRF funded projects related to reefal connectivity, sediment tracing and climatic modeling – AIMS,	• Methods under development. • Modelling to link to water quality limited. • Monitoring program in place.

Targets	Monitoring objective	Examples of indicators	Associated modelling needs	Existing modelling capacity	Summary Status
	quality indicators. Scale: GBR wide Input and validation of receiving water models.			CSIRO, JCU, UQ.	
FW health[2]	Integration of monitoring and assessment activities in freshwater and estuarine ecosystems to improve understanding of pressures, vectors and responses within the ecosystem.	Still in development: Will range from land use pressures (riparian extend, cropping etc) to traditional vectors (turbidity, species presence, toxicants) to responses (population structure, health indices, channel conditions)	Still under consideration		• Methods under development. • Some monitoring in place. • Modelling capacity limited.
FW quality[2]	Measure longer term changes in water quality as a result of changes in land management practises and the impact of varying land uses. Important for verification of catchment scale modelling specific to land use/land types in the Regions. Scale: Sub-catchment and catchment	Nutrients Suspended Solids Toxicants Particle Size Adaptable to receiving water needs.	Catchment scale models are required to allow event based prediction of material transport. In addition, flood plain scale models are necessary to incorporate areas of low slope and overbank flow.	• eWater is major catchment modelling development arena. • Review of catchment modelling undertaken to support Reef Plan I5 monitoring program (Grayson). • QScape PRogram • Short-term Modelling Project provided SedNet and ANNEX scenarios for high-priority catchments (with CSIRO). • Pilot projects trialling E2 in some GBR catchments proposed by NRW. • Hydro-ecological floodplain modelling (Wallace – CSIRO).	• Monitoring program in place. • Interpretation under development. • Further development of modelling capacity required. • Project-based modelling support.
Groundcover[3]	Measure groundcover extent and spatial distribution in areas identified as high risk for sediment runoff.	• Bare ground index. • Remotely sensed vegetation cover and mosaics.	Catchment models to predict material transport based on altered groundcover extent and distribution.	• Various activities conducted under APSIM & AGSIP. • QSCAPE.	• Methods under development. • Monitoring program in place.
Management practices[4]	Monitor water quality and social and economic indicators at the property scale to measure the impact		Plot/paddock scale models that allow the prediction of water quality outcomes (e.g. changed loss of nitrate) from changes in	• Various activities conducted under APSIM & AGSIP. QSCAPE.	• No monitoring program in place.

Targets	Monitoring objective	Examples of indicators	Associated modelling needs	Existing modelling capacity	Summary Status
	and effectiveness of varying management practices. Scale: Plot/paddock, subcatchment. Input into catchment scale modelling specific to land use/land types in the region.		management practices at the plot/paddock scale.		
Rehabilitation[5]	?		?	• Hydro-ecological floodplain modelling (Wallace – CSIRO).	Methods need development. No monitoring program in place.

[1] RW= receiving waters (estuaries, inshore areas, reefs, seagrass beds, GBR lagoon)
[2] FW = fresh waters (rivers, wetlands, groundwater)
[3] Groundcover = ground cover targets in dry tropic grazing lands
[4] Management practices = identified management practices for water quality outcomes in intensive industries
[5] Rehabilitation refers to rehabilitation of wetlands, riparian zones and floodplain