National Action Plan for Salinity and Water Quality

Water Quality State-level Investment Project

Water Quality Information Summary for the Fitzroy Region

Regional Natural Resource Management in Queensland

Peter Negus

Australia
Queensland Government
action Salinity & Water
AUSTRALIA

The National Action Plan for Salinity and Water Quality (NAPSWQ) is a joint Australian and Queensland Government initiative that encourages governments and regional communities to work together to address salinity and water quality issues in priority catchments throughout Queensland. This document has been produced under the NAPSWQ using Australian and Queensland Government financial support.

ISBN 978-1741724585

Project undertaken by:

Peter Negus
Water Quality Assessment and Protection
Natural Resource Sciences
Queensland Department of Natural Resources & Water
80 Meiers Road
INDOOROOPILLY QLD 4068
Phone: 07 3896 9550
Fax: 07 3896 9591
Email: Peter.Negus@nrm.qld.gov.au

Photographs: Main cover photograph courtesy of Robert Packett (DNRW)

For copies of this publication contact:
The National Action Plan for Salinity and Water Quality
Water Quality State-level Investment project
www.regionalnrm.qld.gov.au or www.wqonline.info

Table of Contents

Introduction....................2
Issues impacting river process and function in the Fitzroy Basin 4
Land use, land clearing and riparian land modification....................4
Water Infrastructure and management....................7
Water Chemistry....................10
Increased erosion 16
Introduced and translocated species....................19
Reference conditions....................22
Natural drivers of condition....................22
Reference sites 27
Currently available reference values....................28
Conclusions....................28
References....................33
Appendix....................39

Introduction

A key task for regional bodies under the National Action Plan (NAP) is to set water quality and aquatic ecosystem condition targets as part of the integrated regional Natural Resource Management (NRM) Plan. This process can be supported by assessment of current aquatic ecosystem conditions and trends within the region and analysis of local guidelines or reference condition for indicators related to issues within the region. Negus & Marsh (2006), discuss several methods currently used for conducting condition and trend assessments. The reason for alternate methods is a combination of limitations caused by available resources for data collection and interpretation, and the intended use of the condition and trend assessment. A condition assessment framework developed by Negus & Marsh (2006) is presented diagrammatically in six major steps in figure 1. This framework while focused on a qualitative assessment was also developed to ensure flexibility to cope with potential assessment types being applied.

The framework described is based on a simplified process of ecosystem understanding (figure 2). This process explains natural drivers as the overarching influence on ecological condition and human pressures as a driver of change in ecological condition that can be mitigated through NRM activities. Condition is not directly influenced by these drivers and pressures but through an intermediary mechanism termed here a “vector”. For further information refer to Negus & Marsh, (2006).

Data are collected for purposes specific to individual project objectives with appropriately designed objectives termed in temporal and spatial extents and levels of confidence among other factors. Currently available datasets are applicable to several unrelated and potentially dissimilar objectives and therefore objectives of any assessment not associated with project design will not be addressed due to this limitation. Within this section of the Water Quality State-level Investment Project (WQSIP), the objective is to undertake assessments using currently available datasets and so they have been made with limited understanding of temporal and spatial extents and confidence in the assessments. As such, assessments, information and data discussed in this report should be an initial guide only and used with caution as would further analysis of condition based on the data presented here.

This report is not aimed at analysing condition from any information or existing data but does review and summarise previous reporting of aquatic ecosystem condition and the associated physical, chemical, biological and spatial information from the Department of Natural Resources & Water (NRW) central databases. The synthesis is presented in the context of the simplified pressure; vector and condition conceptual understanding of an aquatic ecosystem presented in Negus & Marsh (2006). More detailed application of the approach presented in Figure 1 has been successful in other regions and is presented in other WQSIP condition reports (Negus et al., 2006; Negus & Farthing, 2007; Schulz & Negus, 2007). In the context of this report, aquatic ecosystems are limited to riverine and do not include estuarine, marine or wetland ecosystems in general.

Initially there is a focus on identifying important natural resource processes in riverine ecosystems (i.e. step 1 in Figure 1). These have been referred to in the Fitzroy Basin in the Central Queensland Strategy for Sustainability: 2004 and beyond (FBA, 2005).

This Natural Resource Management Plan can be accessed at http://www.fba.org.au/ or through the links at http://www.wqonline.info/ . Information from previous studies and NRW data sources is then reviewed in the context of its potential use in steps 2, 3 and 4 – Figure 1.

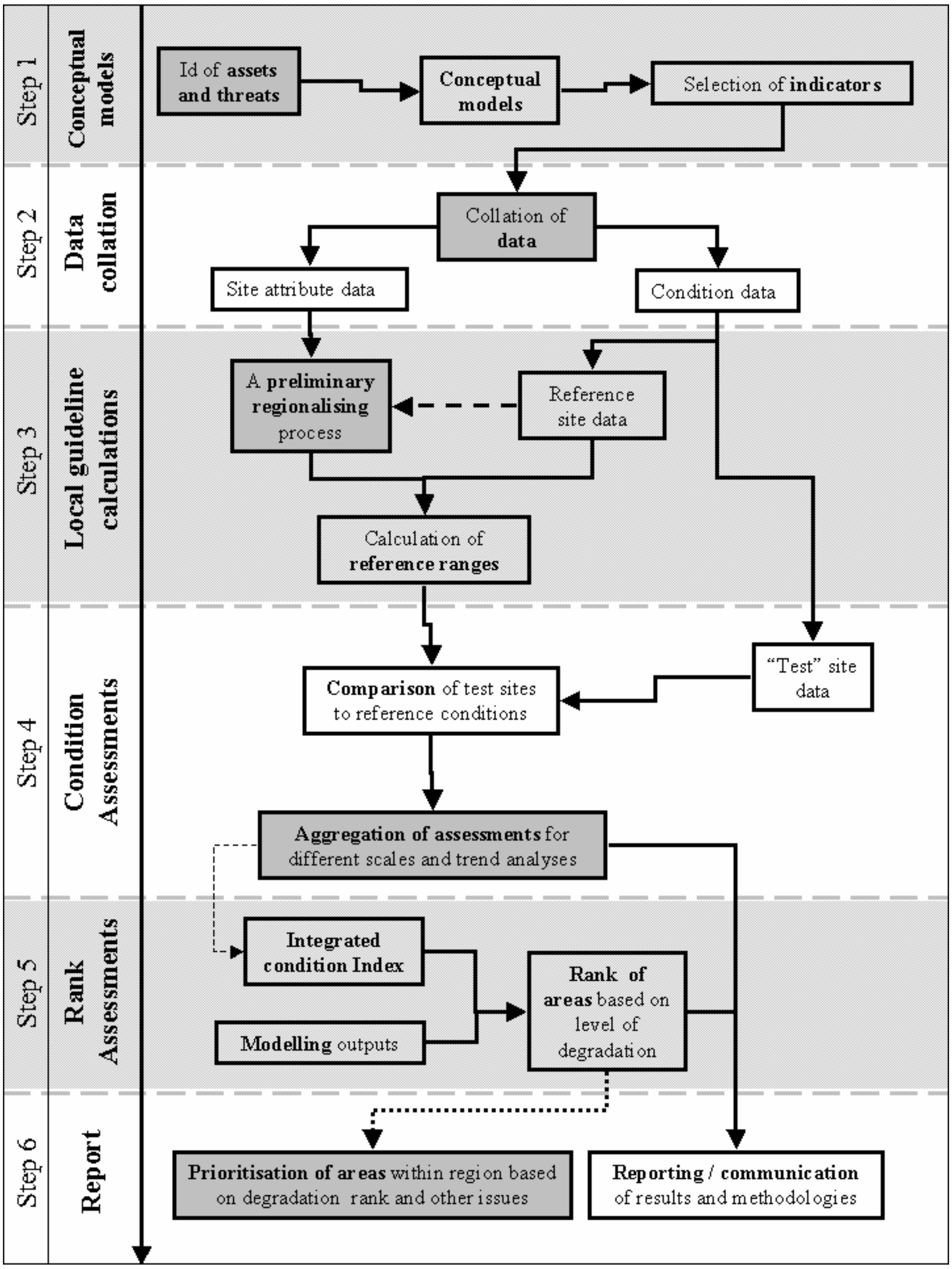


Figure 1. Schematic diagram of the condition assessment framework

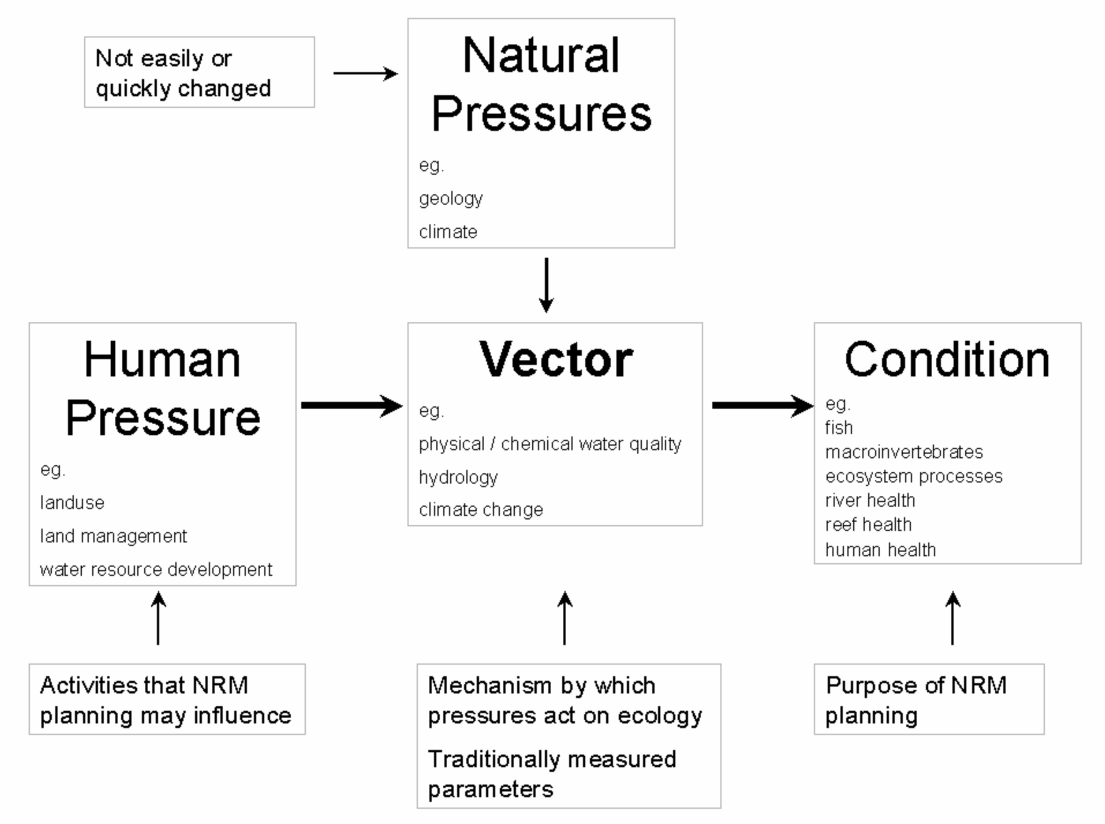


Figure 2. A simplified conceptual understanding of aquatic ecosystem components

Issues impacting river process and function in the Fitzroy Basin

Issues relevant to aquatic ecosystems were selected from the Regional Plan and are discussed below. Each issue is discussed in terms of the conceptual understandings and relevance to previous investigations in the region. Much of this information has been summarised from the State of the Rivers reports (Telfer, 1995; Henderson, 2000; Van Manen, 2005) and also the Central Queensland Information Paper which has previously reviewed the research and data available on aquatic ecosystems in the Fitzroy Basin by the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (CRC CZ, 2003).

Land use, land clearing and riparian land modification

Land use across the basin is dominated by grazing (~80%) with significant areas of forestry and agriculture in the Comet and Nogoa sub-catchments (figure 2; Calvert *et al.*, 2000;7% intensive cropping; dry and irrigated combined for whole Fitzroy). Conservation areas account for approximately 4% of land use across the catchment with most areas situated in the upper Comet and Nogoa sub-catchments. Irrigated cropping and mining land uses while relatively small across the Basin can dominate in localised areas (in particular mining activity on floodplains). For example localised areas of mining are significant in the Mackenzie, Dawson, Isaac – Connors and Nogoa sub-catchments and have associated urban areas (i.e. Gordonstone, Moura, Goonyella and Peak Downs districts; CRC CZ, 2003) and irrigated cropping is intensive around the Emerald Irrigation Area.

The Queensland Land use Mapping Program (QLUMP), a collaborative project between Department of Natural Resources & Water (NRW) and the Bureau of Resource Sciences (BRS) has produced a baseline dataset of land use for the entire state as at 1999. Land use is categorised based on the standard Australian Land use and Mapping Classification and the methods have also been used to detect and map land use change in the Fitzroy River catchment. Further information can be obtained through the QLUMP team in NRW.

State of the Rivers (SoR) surveys are aimed at assessing the aquatic habitats including riparian zones in selected catchments around the state. A number of SoR reports cover the Fitzroy Basin area. These are the Fitzroy River and Isaac Rivers and Capricorn Coastal Tributaries (Van Manen, 2005), The Dawson River and Major Tributaries (Telfer, 1995) and the Comet Nogoa and Mackenzie Rivers (Henderson, 2000). Table 1 shows a summary of the results of the riparian vegetation condition from each report. Riparian condition is poor in general across the Basin and has been attributed to the reduced riparian widths resulting from agricultural and grazing land management (Telfer, 1995).

Table 1. Summary of SoR riparian vegetation condition

Report	% sites rated poor to very poor condition
Fitzroy, Isaac and Capricorn Coast	41%
Dawson and major tributaries	83%
Comet, Nogoa and Mackenzie	50%

A landscape disturbance score for the Fitzroy Basin was developed by the Fitzroy Resource Operations Plan Ecological Monitoring and Assessment Program (FROP; Marshall *et al*., 2004). This score was designed as a secondary gradient within the context of the environmental flow indicators to account for the effects of land use within the study design. While relationships with the flow indicators and ecological condition were few and inconsistent the analyses supported evidence that condition of aquatic biota were related to landscape disturbance within the catchment (Negus *et al*., 2004). The landscape disturbance score was also found to have a significant relationship with turbidity (see increased erosion below).

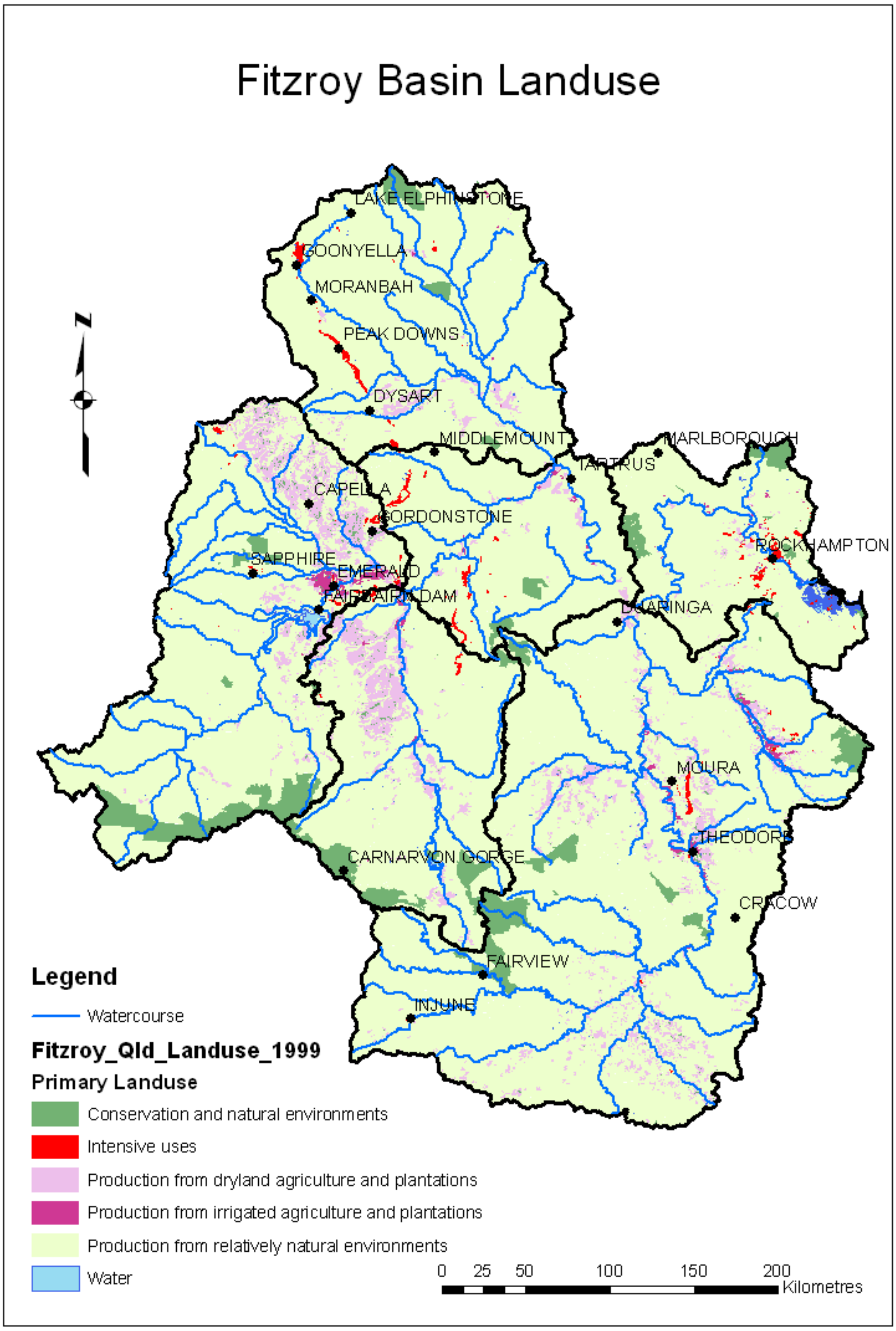


Figure 3. Land use in the Fitzroy Basin
(intensive use listed here is dominated by coal mining; production from relatively natural environments relates to grazing land use)

Water Infrastructure and management

Water resource development occurs across the Fitzroy Basin (figure 3), although major dams and weirs will be concentrated on the main channels where water is more likely to persist. Discharge from the Basin shows marked seasonal variation with strongest flows during the summer and autumn months between November and May which is associated with rainfall in the catchment. Long-term temporal variation has also been recorded for the Basin (Joo & Yu, 2006) and spatial variation in discharge between sub-catchments has been highlighted as a driver of water quality conditions at the end of system (Joo & Yu, 2006). This temporal variation is characteristic of many catchments across Queensland and presents difficulties when it is considered in the context of assessment and monitoring of water resources including water quality and ecosystem condition.

The Fitzroy River Barrage situated at Rockhampton has limited the tidal extent of the estuary from 106 kilometres from the mouth of the river (i.e. the natural tidal extent) to 56 kilometres.

Table 2. Sub-catchment characteristics and hydrological features in the Fitzroy Basin measured at major gauging stations (taken from Joo *et al*., 2005)

Gauging Station	River	Location	AMTD* (km)	Catchment area (km^2)	Area as a % of total	Mean annual discharge between 1974 and 2003 (ML)	Mean annual discharge (%)	Mean annual runoff between 1974 to 2003 (mm)	Maximum discharge recorded between 1974 to 2003 (mm)
130219A	Nogoa	Duck Ponds	625**	27,130	20	613,948	12	23	3,037
130504A	Comet	17.2 km	17	16,422	12	401,743	8	24	1,586
130401A	Isaac	Yatton	43	19,719	15	2,568,913	49	130	23,404
130105A	MacKenzie	Coolmaringa	376**	76,645	56	3,921,860	75	51	15,433
130322A	Dawson	Beckers	71	40,500	30	852,572	16	21	3,127
130005A	Fitzroy	The Gap	142**	135,757	100	5,227,312	100	39	14,550

* - Adopted Middle Thread Distance; ** - on the Fitzroy River;

Hydrology

The Water Allocation and Management Plan (Fitzroy Basin) (WAMP) was approved by the Queensland Government in 1998 after release for public comment and subsequent discussions. The plan aims to "…provide for healthy river systems and aquatic ecosystems through the provision of environmental flow management strategies;" which are implemented through the development of Resource Operations Plans (ROP). The ROP has concentrated on designing management of water based in number of areas, where water resource development and use is most extensive in the Basin.

While the WAMP and ROP have been developed using best available information, collated using expert advice and opinion (DNR, 1998), there are a number of issues requiring further development. The WAMP document (DNR, 1999) lists priority research areas for developing a better understanding of the ecological and physical processes within the river system.

Recent investigations for the Fitzroy ROP monitoring program have highlighted that interaction between the flow regime and ecosystem responses can be complex and distinct relationships difficult to separate from other catchment influences (Negus *et al*., 2004). Recommendations were made for changing the current environmental flows development process to a process which monitors hydraulic habitat requirements of identified flow related biota.

Environmental flows can also be important to estuarine ecosystems. Correlations between age structures of commercial catches of barramundi and rainfall during summer, indicate that the strongest year classes were those when river flows at the mouth were greater than 2.4 million megalitres or high coastal rainfall (Robins *et al*., 2005).

Barriers

Water infrastructure has the potential to influence aquatic ecosystems by limiting fish migration and changes to the flow regime (Gehrke *et al*., 1995). Mitigation of barrier effects has been attempted by the installation of fishways. A number of fishways have been installed within the Fitzroy Basin, including those at the Fitzroy River Barrage, Eden Bann Weir, Baralaba Weir and Moura Weir. However, other barriers to movement will still result from structures such as road culverts, small weirs and dams, private farm dams and causeways (Harris & Mallen-Cooper, 1994), as a comprehensive program of barrier mitigation has not been undertaken (Marshall *et al.*, 2004).

The fishway associated with the Fitzroy River Barrage was initially ineffective (Berghuis & Long, 1999; Stuart, 1997) which has been the case in many Australian fishways due to designs based on northern hemisphere salmonid fisheries (Thorncraft & Harris, 2000; Stuart & Mallen-Cooper, 1999; Stuart, 1997). Since the implementation of several modifications, the Barrage fishway still prevents passage by small individuals and some specific species but generally its effectiveness has increased (Stuart & Mallen-Cooper, 1999; Stuart, 1997).

All the major sub-catchments have major dams or weirs; however there are several contiguous reaches where no barriers exist and which are believed to be significant for maintaining populations of many aquatic species (CRC CZ, 2003). Releases from several weirs are also thought to potentially impact aquatic ecosystems with several reported fish kills (e.g. downstream of Fairbairn Dam) and some unnatural release strategies (e.g. Eden Bann; CRC CZ, 2003).

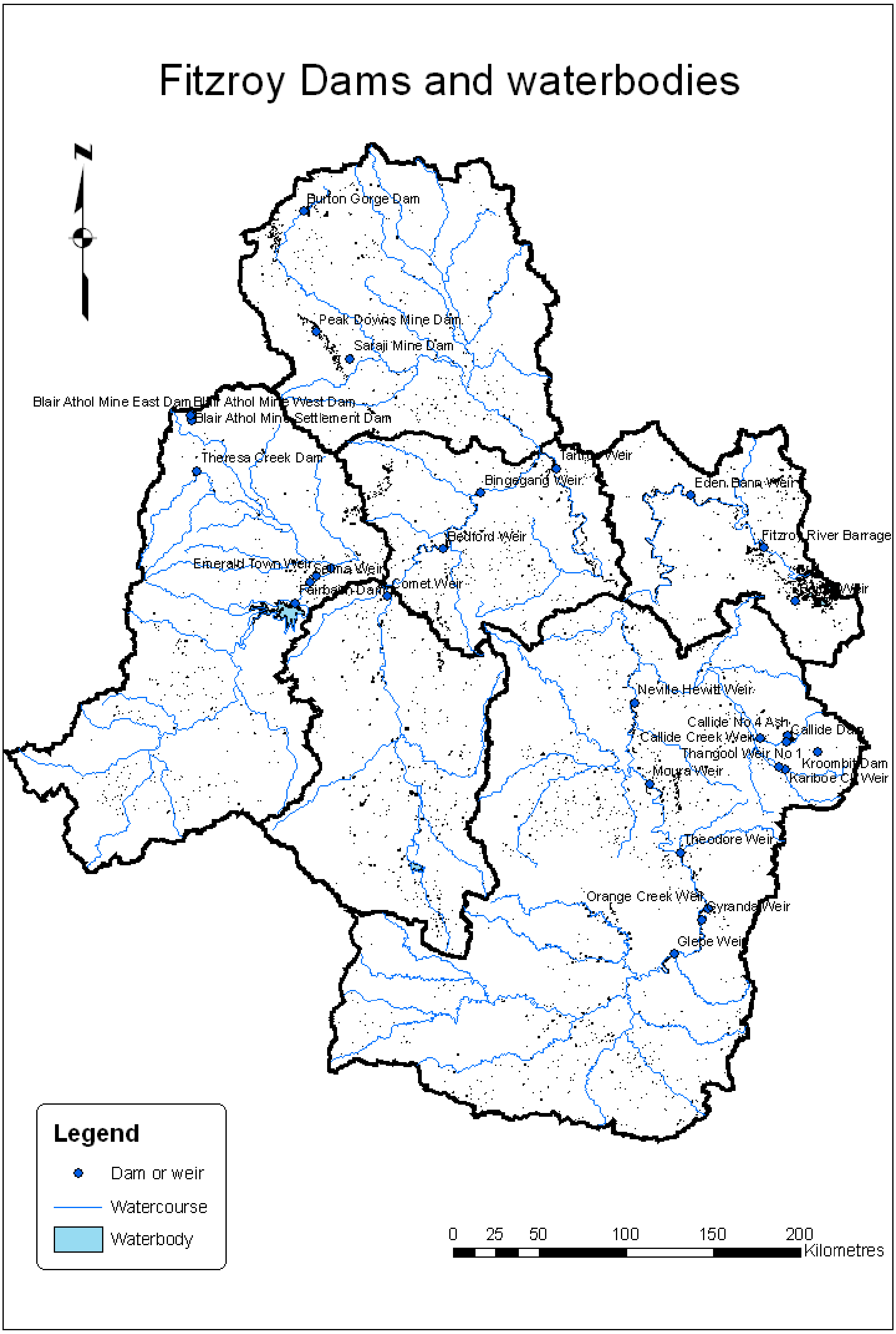


Figure 4. Impoundments and water storages in the Fitzroy basin

Water Chemistry

Nutrients

Nitrogen and phosphorus are essential nutrients for the growth of all plants including aquatic species such as macrophytes and algae. They are also nutrients associated with degraded conditions in aquatic ecosystems (when in higher than natural concentrations). The effect of increased nutrients (eutrophication) on riverine environments is processed mainly through accelerated primary production (or plant growth) which results in proliferation of aquatic macrophytes and algal blooms.

Sources of increased nutrients can be both diffuse and point source. Types of point sources include sewerage treatment plants, aquaculture and industrial waste discharges. Major nutrient inputs to the estuary result from point sources in and around Rockhampton including sewerage treatment plants and meatworks (figure 6; Ford *et al*., 2005). Figure 6 is a map of the major point sources within the Fitzroy catchment listed by the National Pollutant Inventory. This gives an indication of the potential human pressure from point source nutrients on aquatic ecosystems in the context of the pressure – vector – condition conceptual understanding of the system (figure 2). Point source discharges create water quality problems especially during low flow conditions.

Diffuse sources can result naturally from soil, plant and animal matter while human influences increasing diffuse sources are predominantly from agricultural practices (e.g. clearing, fertiliser application and manure) and urban environments (e.g. fertilisers and automotive emissions). The transport of nutrients from diffuse sources requires mechanisms such as runoff and stream flow and so diffuse source problems are associated with rainfall and flow events. In agricultural systems dominated by grazing, nutrients such as Nitrogen and Phosphorus are predominantly transported with sediment, with smaller amounts in dissolved forms (Prosser *et al.*, 2002). In the Fitzroy, upper catchment diffuse sources (where land use is dominated by grazing) have been identified, and combined to a more limited extent with stormwater runoff from Rockhampton, as the main processes delivering nutrients to the Fitzroy estuary (Ford *et al*., 2005; Noble *et al*., 1997).

Nutrients can be measured as a *total*, which is a combination of dissolved components and organic components usually bound to carbon (EPA, 2006). They can also be measured in a number of speciated forms which may be more appropriate to consider in terms of immediate bioavailability, however total measures are still a measure of potential impact as system processes can rapidly transform these nutrient forms. For further information on nutrient species see Furnas (2003).

Total nitrogen (TN) and total phosphorus (TP) are measures of water quality used for condition reporting. State-wide reporting of nutrients is undertaken for State of Environment Queensland (SoE) reporting and reporting for the ambient surface water quality monitoring (SWAN) undertaken by the Department of Natural Resources and Water (NRW). The latest SoE Queensland report was presented in 2003 (EPA, 2003) and the latest SWAN report covers information from the years 2002 to 2005 (Grinter & Clarke, 2006). The CRC CZ Information paper also summarises available data for each major sub-catchment (CRC CZ, 2003).

The SoE report (EPA, 2003) showed that most sites across the basin had poor condition for both total phosphorus (30 sites) and total nitrogen (20 sites) although spatial representativeness may be insufficient to report on the Fitzroy basin in general as data from more sites were available but reliability prevented its use. The SWAN report (Grinter & Clarke, 2006) indicates that uncertain, not sampled, or outside guidelines condition for total nitrogen occurred at approx. 70% of program sites (28 sites total). For total phosphorus these conditions accounted for approx. 80% of sites (28 sites total).CRC CZ (2003) indicated that high TN & TP concentrations occurred at low flows across all sub-catchments with highest levels being associated with the Emerald irrigation area. These high levels were attributed generally to fertiliser use by agriculture and animal excrements associated with feedlots and stock access to in-channel drinking waterholes.

Guidelines used in the assessments may also be inappropriate as alternatives were used in subsequent SWAN reports (Grinter & Hunter, 2005) and comparisons of the results with macroinvertebrate AusRivAS scores for the same area identified inconsistencies (Whitting, Conrick & McNeill, 2003). Further supporting the need for refined guideline levels is that sub-catchments such as the Dawson have naturally high concentrations of nutrients (CRC CZ, 2003).

Brodie & Mitchell (2005) discuss concentrations and load measures of nutrients and sediments in the context of their use as indicators of condition. Concentrations sampled during ambient (low flow) hydrological conditions were presented as important for measuring the ecological health of in-stream ecosystems while load measurements give an indication of catchment conditions in general (Brodie & Mitchell, 2005). The Short-Term Modelling (STM) project initiated for Great Barrier Reef (GBR) catchments focused on developing SedNet models of nutrients and sediment loads for all GBR catchments.

Nutrient outputs for the Fitzroy catchment from the STM project are presented in figures 4 & 5. Nutrient concentrations generally mimic sediment concentrations in many parts of the Fitzroy catchment (Noble *et al*., 1997) and a general comparison of SedNet outputs (figures 4, 5 & 7) also supports this. However while these SedNet outputs are significant in identifying source areas of contaminants they do not discriminate between naturally high source areas and those resulting from human activities. Comparison of these base scenario SedNet outputs to pre-European scenarios will identify those resulting from human activities and therefore where management interventions will have an effect on reducing these loads to the system. It should also be noted that SedNet models loads as a long-term average and results will not reflect monitored results from short term event driven runoff.

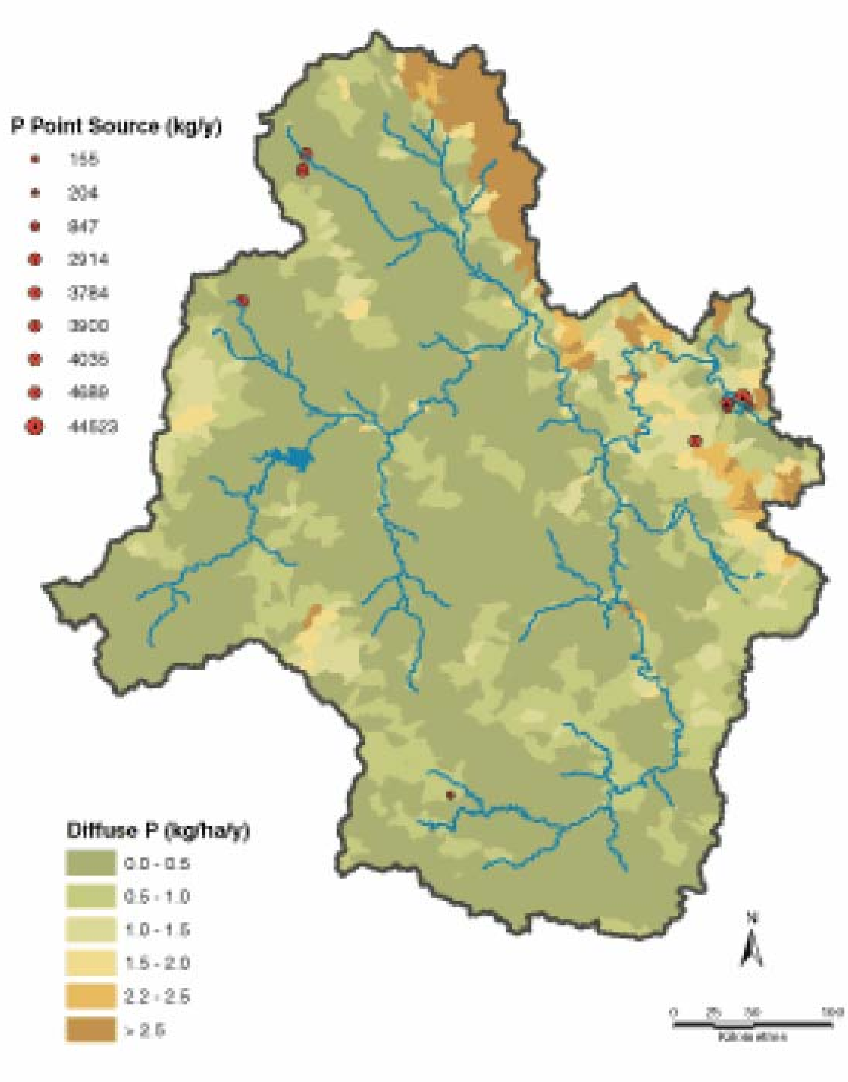


Figure 5. SedNet - Total phosphorus load source strength (base scenario) (taken from Dougall *et al.*, 2006)

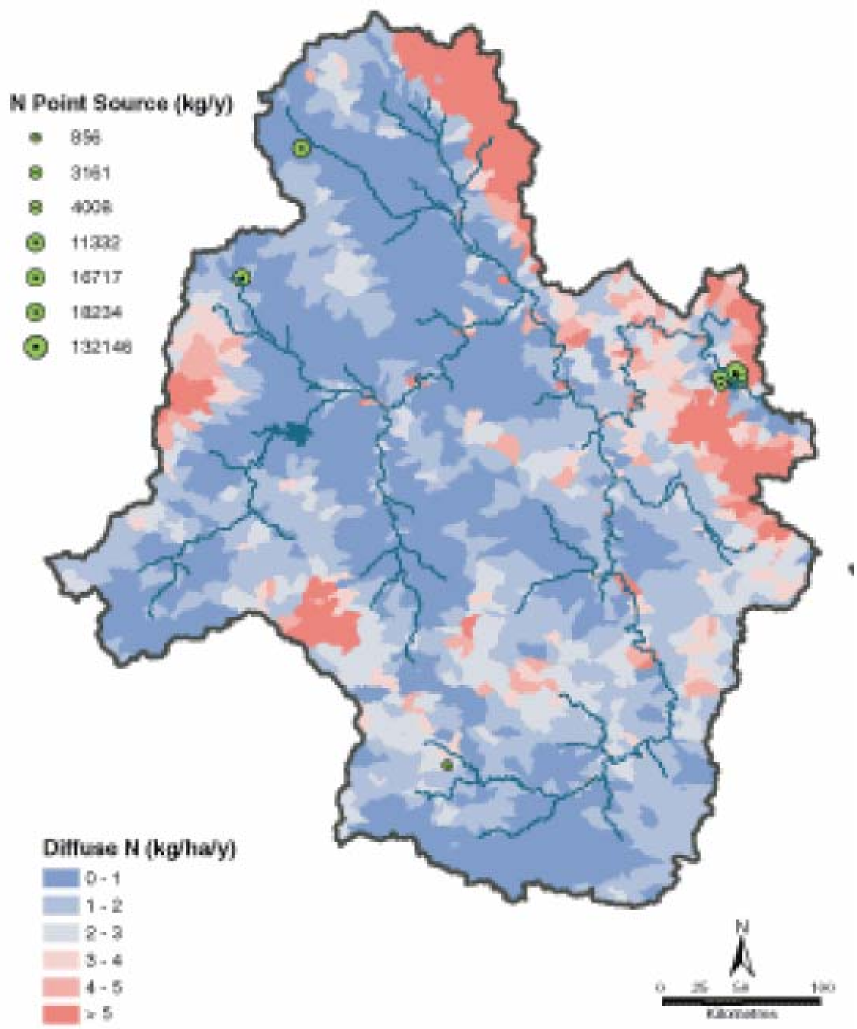


Figure 6. SedNet - Total Nitrogen load source strength (base scenario)
(taken from Dougall *et al.*, 2006)

Pesticides

Pesticide is a term applied to the hundreds of chemicals (e.g. insecticides, herbicides, fungicides, defoliants) used for protecting human resources against damage by biological pests. Environmental concern for pesticide use is the harm it can have on non-target biota, which includes humans. Riverine ecosystems are prone to impacts by pesticides and there are several transport processes by which they enter watercourses including being soluble and leaching through the soil to aquifers and waterways during runoff or rainfall events; and being bound to soil particles which are transported to watercourses by erosional processes (Lovett *et al*., 2003). Some pesticide residuals impact effectively for lengthy time periods, although many pesticides currently in use are broken down to non-toxic substances rapidly and do not persist in the environment. Therefore, the impact of many pesticides will be dependent on application procedures including the quantities used, how it is applied (e.g. sprayed, granules), micro-organisms, and environmental factors (e.g. temperature, humidity, soil pH).

While pesticide occurrence in watercourses is known, detailed understanding of pesticide effects on river condition is relatively limited (Cooper *et al*., 1996). Processes which concentrate and dilute pesticide contamination have been investigated and there is a relatively good understanding (e.g. sedimentation; Finlayson and Silburn, 1996), but the effects on aquatic biota are limited. To complicate this lack of understanding, most studies are limited to the influence a single chemical has on one or few aquatic species, while the synergistic effects of pesticides occurring in real situations or an understanding of the impacts on river health or condition is lacking. Furthermore, low levels of contaminants in general are usually considered a good condition; however low level chronic effects are not completely known.

Currently there is no state-wide program for monitoring and assessment of pesticides in Queensland (Whitting, Conrick & McNeil, 2003) or across the Fitzroy catchment. However an initial pesticide risk assessment project for Great Barrier Reef catchments is currently being undertaken by NRW (planned for stages 1 and 2 to be finalised June 2007) and there are several previous studies in selected catchments including the Fitzroy. While some information from these studies is somewhat dated for assessment of current condition they do present the only available information.

Vicente-Beckett *et al*., (2006) review the limited information on pesticide use and monitoring in the Fitzroy catchment and estuary and further presents pesticides assessment of water and sediment samples from the estuary taken during flood events in 2003/2004 and 2004/2005. Noble *et al*., (1997); Noble, (2000); Packett, Ford & Noble, (2005) and Vincente-Beckett (2006) also report on selected pesticide (and metabolite or residue) monitoring and assessment from various sites and times across the catchment and estuary. In all these studies several pesticides and residues were commonly found in particular Atrazine, Diuron and Tebuthiron were detected at frequencies and concentrations of concern (i.e. above guideline values). In most cases however, levels were below guidelines or guideline levels were unavailable, with the exceptions being endosulfan guidelines for the protection of aquatic ecosystems. These were exceeded at several sites in the Dawson River sub-catchment and some irrigation drains in Emerald irrigation areas of Nogoa River sub-catchment (Vincente-Beckett, 2006).

Packett, Ford & Noble, (2005) also investigated the bioaccumulation of DDE (metabolite of DDT) in crocodile eggs. DDE concentrations in eggs were high compared to other catchments in the study. This was attributed to the extensive use of DDT previously across the catchment and the possible aquatic concentration of aerially deposited DDT.

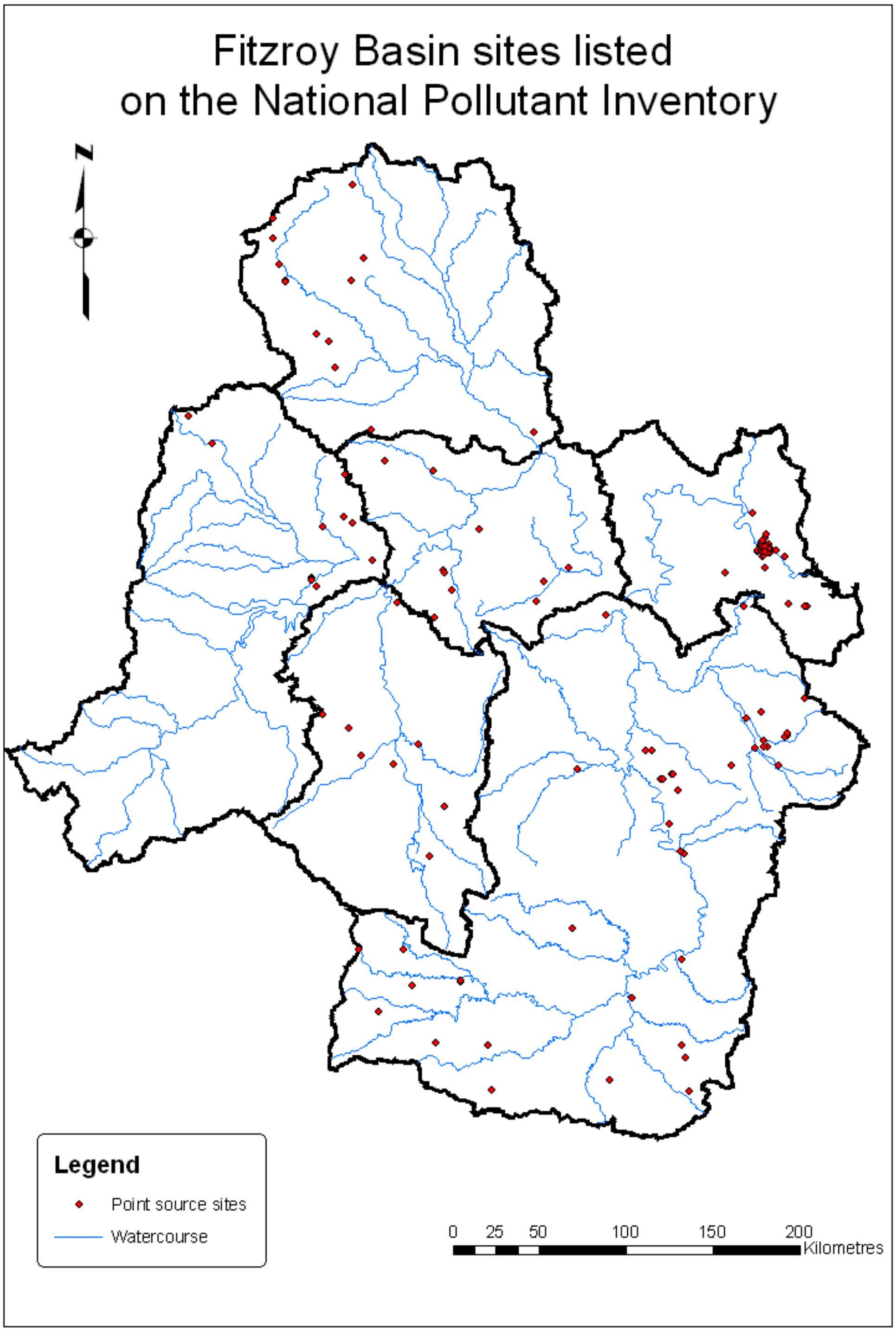


Figure 7. Sites listed on the National Pollutant Inventory
(sites represent potential point sources within the catchment)

Increased erosion

Erosion is a naturally occurring process of sediment movement by the action of wind and water. However, increased erosion can result from human activities and this increase causes degradation of aquatic conditions. Sediment transport and concentration in the water column is identified as a major problem associated with water quality across Australia (NLWRA, 2001) and can be the result of land use, land management and development of water infrastructure. In particular removal of vegetation throughout the catchment and in riparian zones can greatly influence erosion and transport of sediments to and in aquatic environments (Rutherford *et al*., 1999).

In-stream sediment processes that impact on aquatic ecosystems include sedimentation and subsequent change in benthic habitat, direct physical damage to aquatic organisms by fine sediments in suspension (e.g. clogging of gills and feeding apparatus), water clarity issues which change behaviour (e.g. feeding strategies) and survivability of aquatic organisms and photosynthesis of submerged flora. These aquatic ecosystem impacts come on top of the direct impact of the soil loss and soil structure change in terrestrial environments.

Traditional physico-chemical measures of aquatic condition (i.e. in-stream / river health) relating to sediment are concentrations of suspended solids (e.g. silt, clay and fine particles – both inorganic and organic; total suspended solids (TSS) and measures of water clarity such as turbidity and secchi depth. These measures of "health" relate to ambient conditions (e.g. low flow; Brodie & Mitchell, 2005) which are usually characterised by low sediment concentrations. Noble *et al*., (1997) confirms this in the Fitzroy catchment. Sediment loads (using event concentration measurements) are useful for indicating overall catchment condition and receiving water conditions (Brodie & Mitchell, 2005). While concentrations in ambient conditions are directly applicable to aquatic biota due to the longer term interaction, initial high flow events (first flush) can also be important to biota because of the highly elevated concentrations of nutrients and sediments and subsequent reduced availability of oxygen (Brodie & Mitchell, 2005).

Sediment concentrations / water clarity – river health

The Fitzroy Basin Resource Operations Plan Ecological Monitoring and Assessment Program pilot study investigated a range of indicators including turbidity for response to a gradient of flow regime operating measures and developed landscape disturbance scores (based on land use spatial layers; Negus *et al*., 2004). Turbidity was one of the few consistent and significant factors associated with the gradients being examined. The gradient of landscape disturbance was correlated with turbidity during both autumn and spring season sampling occasions ($r = 0.74$ & 0.666, $p < 0.05$) and using generalised linear modelling 74% of turbidity variation were explained by landscape disturbance and flow gradient variables.

The SWAN report (Grinter & Clarke, 2006) indicates that uncertain, not sampled, or outside guidelines condition for turbidity occurred at approximately 65% of program sites (28 sites total). High total suspended solid (TSS) levels were described for most sub-catchments during high flows and this has been attributed to bare agricultural soils during rainfall events and streambank erosion caused by poor riparian management, stock access and in some sub-catchments (i.e. Isaac / Connors) mining activities (CRC CZ, 2003). Some smaller tributary sites in the Dawson River sub-catchment have also reported comparably low TSS levels of which the causes are unknown (CRC CZ, 2003). Investigation of land management on TSS loads in the Nogoa sub-catchment have shown some techniques can reduce the sediment loads from the area (CRC CZ, 2003).

Sediment loads
Recent investigations of aquatic sediments in the Fitzroy catchment have focused on investigation of annual load estimations which has largely resulted from the Reef Water Quality Protection Plan initiative (The State of Queensland and Commonwealth of Australia, 2003) aimed at managing water quality entering the Great Barrier Reef Lagoon. End of system load estimations have been undertaken using rating curves or discharge relationships (Neil & Yu, 1996; Kelly & Wong, 1996; Horn *et al*., 1998; Joo *et al.*, 2005; Joo and Yu, 2006) and modelling approaches such as SedNet (Moss *et al*., 1992; Dougall *et al.*, 2005; Brooke *et al.*, 2006; Dougall *et al*., 2006) and others have resulted in widely varying sediment loads (Joo *et al*., 2005; Dougall *et al*., 2006 See both reports for comprehensive list of results). However, recent investigations have used refined techniques and models giving more confidence in the results. Fenti *et al*., (2005) compared estimated loads using SedNet with loads calculated using rating curves for six sites within the Fitzroy catchment. The results are comparable with SedNet estimates being higher at 4 of the 6 sites. Differences were attributed to uncertainties in both methods such as rating curve approaches underestimating mean annual loads and spatial input data values for SedNet. It should also be noted that the information behind this research is beneficial to the understanding of sediment transport. It will identify gaps in the understanding and guide management on sediment sources within the catchment (Dougall *et al*., 2006).

The short term modelling project described in Dougall *et al*., (2006) has used the SedNet catchment model to identify source areas of sediment loads to the river system (figure 7). Hillslope erosion (71%) is shown to be the most spatially diverse and dominant source of sediments across the catchment, with bank erosion dominating along the catchment’s main channels (15%) and gully erosion (14%) restricted to areas in the Upper Nogoa catchment. While this is a good source of information on sources of sediment, in the context of understanding condition and implementation of management actions to address increased riverine sediment it would be prudent to compare these outputs with similar pre-European scenario outputs. That is, areas indicating high source loads may be naturally high and a comparison with more “natural” loads will identify areas which have high sediment loads due to human activities.

Further to this, management has been encouraged to produce end of system targets for contaminants which in large catchments may be difficult given the complex rainfall-runoff-transport mechanisms involved and the spatial variability of rainfall across large areas, which in turn can produce unpredictable loads if monitoring is focused at the end of system (Joo & Yu, 2006). The results in Webster *et al*. (2005) support this by explaining that the annual load of fine sediment is shown to be highly variable and reflects changes in river discharge. This unpredictability would hinder any efforts for solely monitoring management effects at end of system and more detailed sub catchment monitoring, assessment and targets may be required (Joo & Yu, 2006).

The WQSIP website (http://www.wqonline.info) has a number of products relating to loads estimation and event monitoring information and the Coastal CRC website (http://www.coastal.crc.org.au/) also has several reports relevant to the Fitzroy catchment.

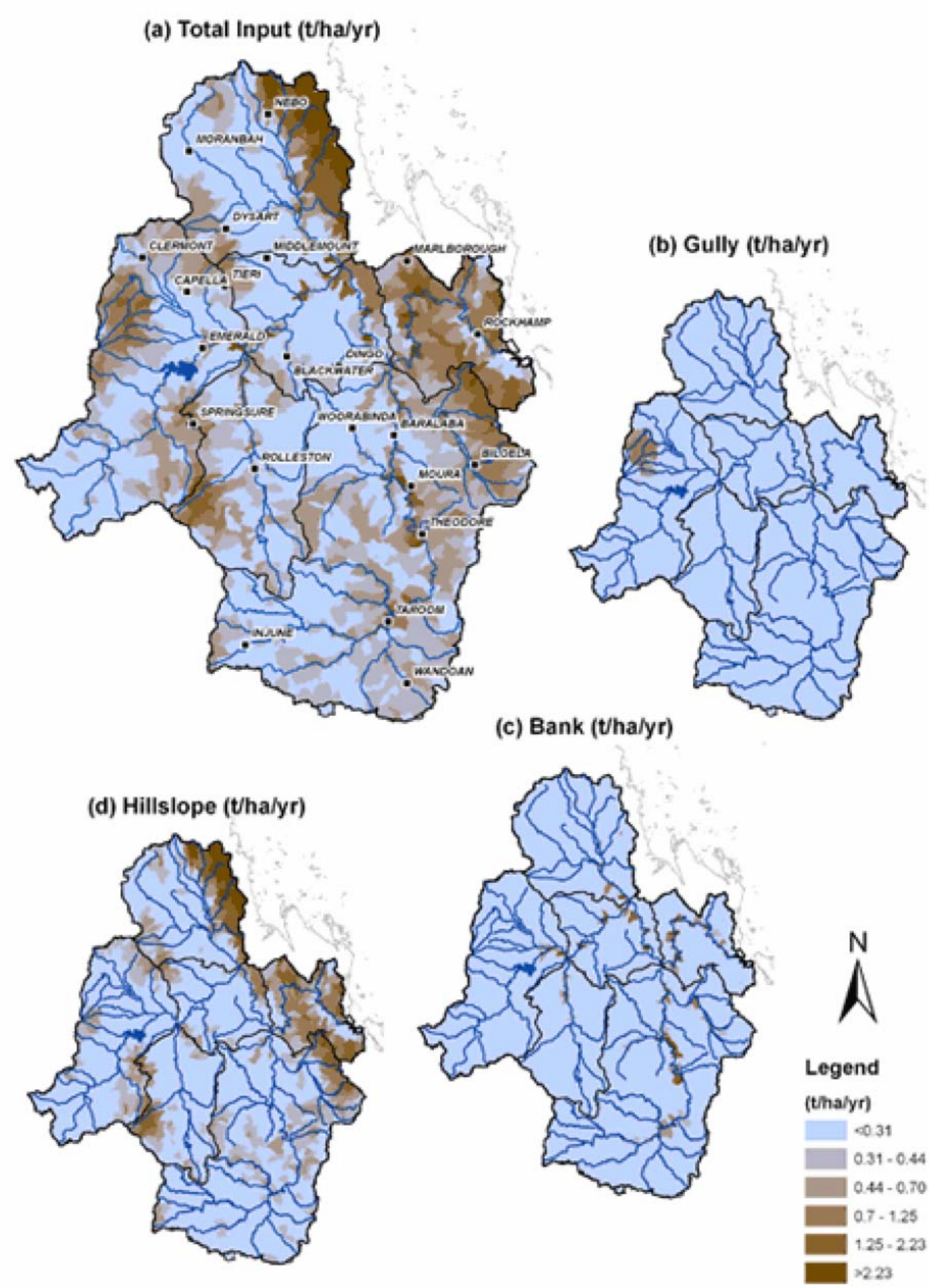


Figure 8. SedNet Predicted Suspended Sediment input to stream (T/Ha/yr), (a) Total Input, (b) Gully, (c) Bank and (d) Hillslope (taken from Dougall *et al.*, 2006)

Introduced and translocated species

Riparian weeds

Riparian vegetation being an "ecotone" can have a number of functions in aquatic ecosystems as well as terrestrial ecosystems. Functions relating to aquatic ecosystems include for example protection of water quality in adjacent waterways by filtering overland flows and providing microclimate conditions (e.g. shade, temperature), provision of food and habitat to in-stream organisms, and support of stream banks against erosion (figure 7.; Lynch & Catteral, 1999; Askey-Doran *et al*., 1999). Therefore disturbance to riparian zones can affect these functions and ultimately reduce in-stream condition. Introduction of exotic plant species can cause impacts on riparian vegetation with many effectively competing against native species (especially seedlings) for light, nutrients, space and water. Competition by weeds influences the structure of riparian vegetation and also the types of allochthonous inputs that adjacent waterway receives. While general issues relevant to riparian weeds are understood, localised areas need investigation as in some cases weeds do little harm and can actually be a benefit (e.g. aid in the establishment of native species).

CRC CZ (2003) indicates that in the Fitzroy sub-catchment several significant weeds (based on PestInfo information) have a presence in riparian zones. These include Hymenachne, Rubber Vine, *Luecaena leucocephala* and Paragrass. The other sub-catchments have less riparian weed impacts but still Hymenachne and *Luecaena leucocephala* have been reported in the Mackenzie. The State of the Rivers reports (Henderson, 2000; Van Manen, 2005; Telfer, 1995) have assessed riparian vegetation and recorded exotic riparian species throughout the Fitzroy catchment (see Table 3). They confirm the PestInfo information and describe that riparian ratings across the Fitzroy Basin sub-catchments are diverse with results from very poor to very good. The very poor ratings were largely the result of a high percentage of exotics and narrow buffer widths of natural vegetation.

Table 3. General riparian ratings and dominant exotic species recorded in State of the Rivers reports
(from: Telfer, 1995; Henderson, 2000; Van Manen, 2005)

Sub-catchment	**Range of riparian Condition Ratings**	**Presence of exotic species**									
		Lantana	**Rubber Vine**	**Parthenium**	**Mexican Poppy**	**Castor Oil**	**Parkinsonia**	**Buffel Grass**	**Noogoora Burr**	**Prickly Acacia**	**Green Panic**
Fitzroy	Very poor – poor (lower main channel moderate – very good)	✓	✓	✓	✓						
Isaac	Good – very good in main Isaac R and Connors; very poor – poor in western uplands, northern and central uplands					✓	✓		✓		
Dawson	Very poor – poor			✓					✓	✓	
Mackenzie	Very poor – moderate (lower main channel moderate to good)		✓	✓			✓	✓	✓		✓
Comet	Very poor – very good			✓			✓	✓	✓		✓
Nogoa	Good – very good			✓			✓	✓	✓		✓

In-stream weeds

Introduced aquatic plants can result from unintentional spread by movement of boats or through growing and harvesting for commercial purposes (e.g. the aquarium trade; irrigated pastures). Introduced and native plants can become prolific with the introduction of increased nutrients and light. Nuisance aquatic plants can cause impacts on the aquatic environment by changing flow patterns, reducing water quality (e.g. reduction in dissolved oxygen caused by decomposition), competition for space, nutrients and light and change in habitats for aquatic fauna. A number of human resource problems can also occur such as clogging of irrigation and watering equipment, water-based recreation activities, and the problems with water use with the presence of toxins created from algal blooms.

The Fitzroy catchment has a naturally high level of turbidity which can be indicative of low abundance and species richness of submerged aquatic plants. High turbidity levels are also commonly associated with increases in nuisance algae and weed species (Sainty & Jacobs, 1994). Duivenvoorden (1995) showed that few species of submerged aquatic plants were found and this was at only 3 of 11 sampled sites and overall few aquatic species were identified in the Fitzroy catchment. This lack of richness and abundance was attributed to climatic conditions, high turbidity and grazing pressures (Duivenvoorden, 1995). Fabbro & Duivenvoorden (1995) and Noble *et al*., (1996) showed that algae sampled at the same sites had generally low species richness and abundance, with 3 sites (Eden Bann and 2 MacKenzie River sites) showing high seasonal specific algae cell densities. However blue-green algal blooms are listed as a regular occurrence and issue of concern for the region (Greening Australia, 2003; CSIRO, 2000) and there is recent research activity investigating management of weirs for reducing these blooms (CSIRO, 2000). SunWater also has current assessments of blue-green algae levels for their water storages within the catchment (See SunWater website: http://www.sunwater.com.au/#).

CRC CZ (2003) reported that several aquatic weed species have been recorded in the catchment and the State of the River reports also confirm this. Most significantly it has been noted that abundance of macrophytes in most areas was low, which was potentially a natural feature due to the ephemeral nature of the system (Van Manen, 2005). The State of the River report on the Eastern Fitzroy tributaries recorded the emergent exotics Hymenachne, Umbrella Sedge and Paragrass, which have the potential to become significant problems in aquatic ecosystems (Van Manen, 2005). While Telfer (1995) recorded only Paragrass as an exotic aquatic macrophyte in the Dawson sub-catchment, Henderson (2000) recorded very few sites with macrophytes due to the high level of turbidity, but Paragrass was recorded in the Comet sub-catchment.

Reference conditions

Natural drivers of condition

Aquatic ecosystem condition is influenced by a multitude of factors. These factors include human pressures which are those investigated in an assessment such as this and also natural drivers which can confound the conclusions of any assessments undertaken. Natural variability can cause specific indicator assessment values to be 'noisy' and unsuitable for use, therefore an approach to assessments that account for this variability will contribute to certainty in correctly identifying impacts by human pressures.

Ideally a referential approach to condition assessments will collect data from sites having no or minimal interference from human pressures, to test conditions from sites in question. In this way data from these "reference sites" are used to account for some natural variability. Natural variability can change across several scales and this can reduce the applicability of available reference data for specific reporting purposes. Partitioning reporting regions into areas of similar character (i.e. smaller scale information) is beneficial to reduce the influence natural variability can have on assessments. However, partitioning has to be "realistic" as separated areas being too small, will also be impractical due to the resource constraints in trying to gather adequate information. Classifying riverine landscapes (regionalisation) is an essential component of many monitoring and assessment programs and is used for not only partitioning natural variability, but also for identifying areas expected to exhibit a similar indicator response to anthropogenic disturbances (Karr & Chu, 1999).

A landscape regionalisation process is recommended and used in many assessment programs. For example, ANZECC & ARMCANZ (2000) describe a regionalisation process that groups reference sites by geology, soil type, topography, bioregion and climate as the "first step' in developing water quality guidelines for Australia.
Also, the Sustainable Rivers Audit used major process zones to scope changes in variability across the Murray darling region and the Design and Implementation of Baseline Monitoring (DIBM) project applied this process to develop the Ecosystem Health Monitoring Program (EHMP) used in riverine assessments for south-east Queensland (Smith & Storey, 2001).

No formal statistical analysis of the landscape data available has been undertaken for this summary report. The NRM plan lists a number of Fitzroy sub-catchments for reporting purposes (shown in each of figures 8, 9, 10 & 11) and these have been used and discussed in terms of the landscape data summarised below. For further detailed regionalisation methodologies refer to Negus & Farthing (2007).

Inclusion of natural drivers that are easily influenced by humans or inclusion of human pressures as a natural driver will bias a regionalisation towards factors of human influence and therefore affect guideline development. In many cases information on natural drivers is available in the form of GIS layers which can be used in the development of a landscape regionalisation. For example information on soils, geology, geomorphology, climate and topography (Figures 8 -11; metadata supplied in Appendices) are readily accessible for this process (Negus & Farthing, 2007).

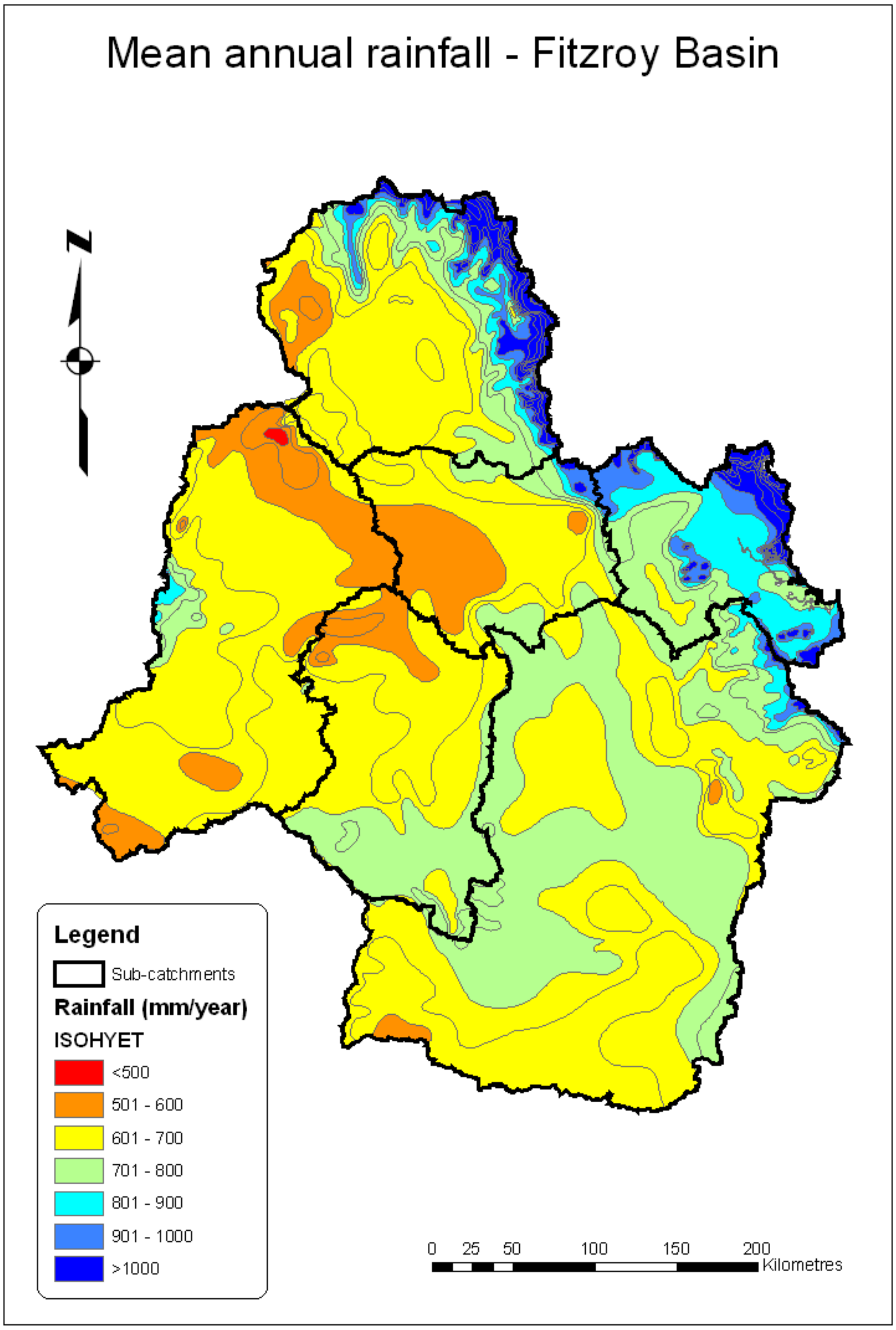


Figure 9. Rainfall in the Fitzroy region

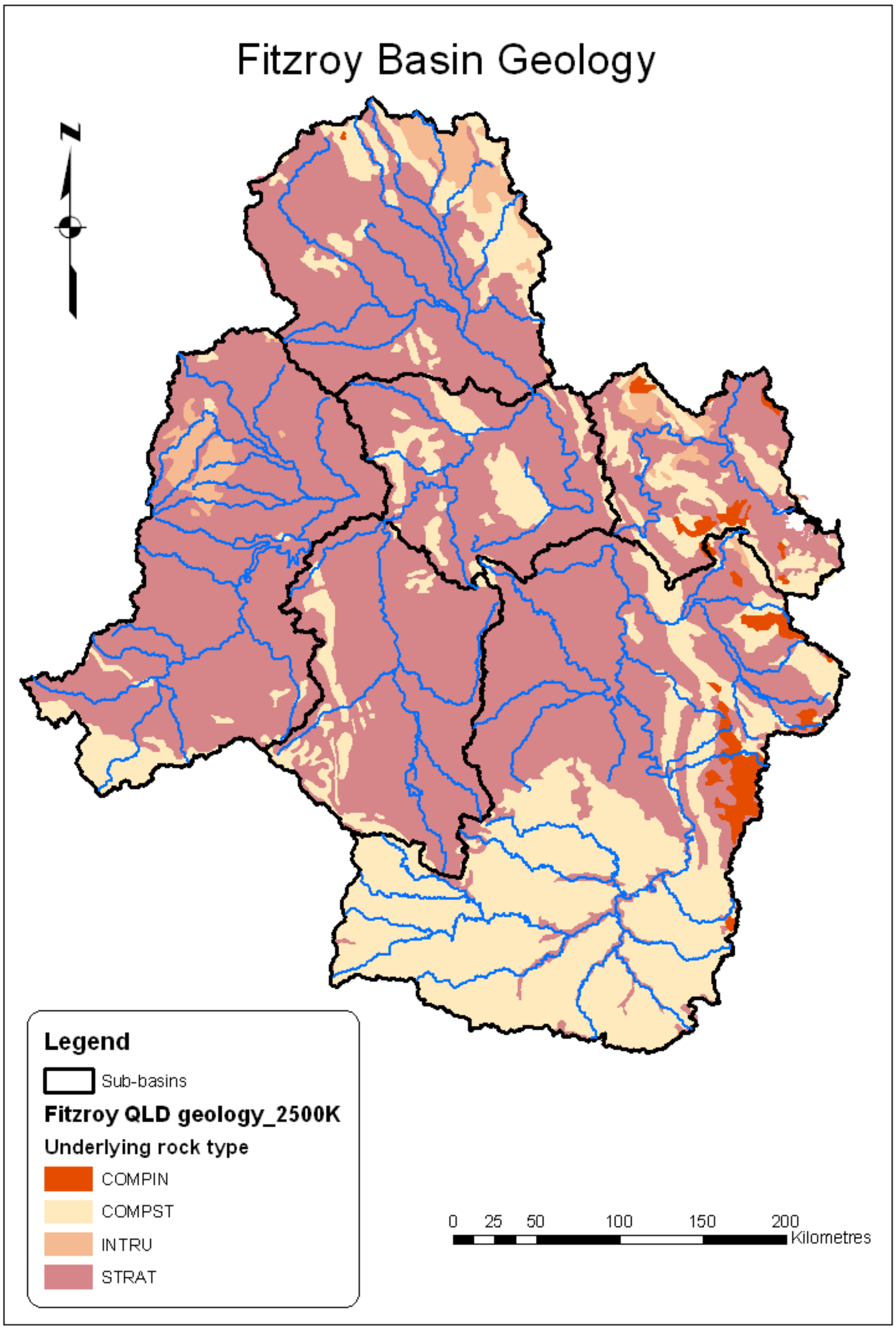


Figure 10. Geology in Fitzroy region

(STRAT- Stratigraphic unit, including sedimentary, volcanic and metamorphic rock units. INTRU- Intrusive rock units; COMPST- Compound unit where the polygon includes two or more rock units, either stratigraphic, intrusive or both; COMPST- Compound unit, as above where the dominant or topmost unit is of the STRAT type; COMPIN- Compound unit, as above, where the dominant unit is of the INTRU type)

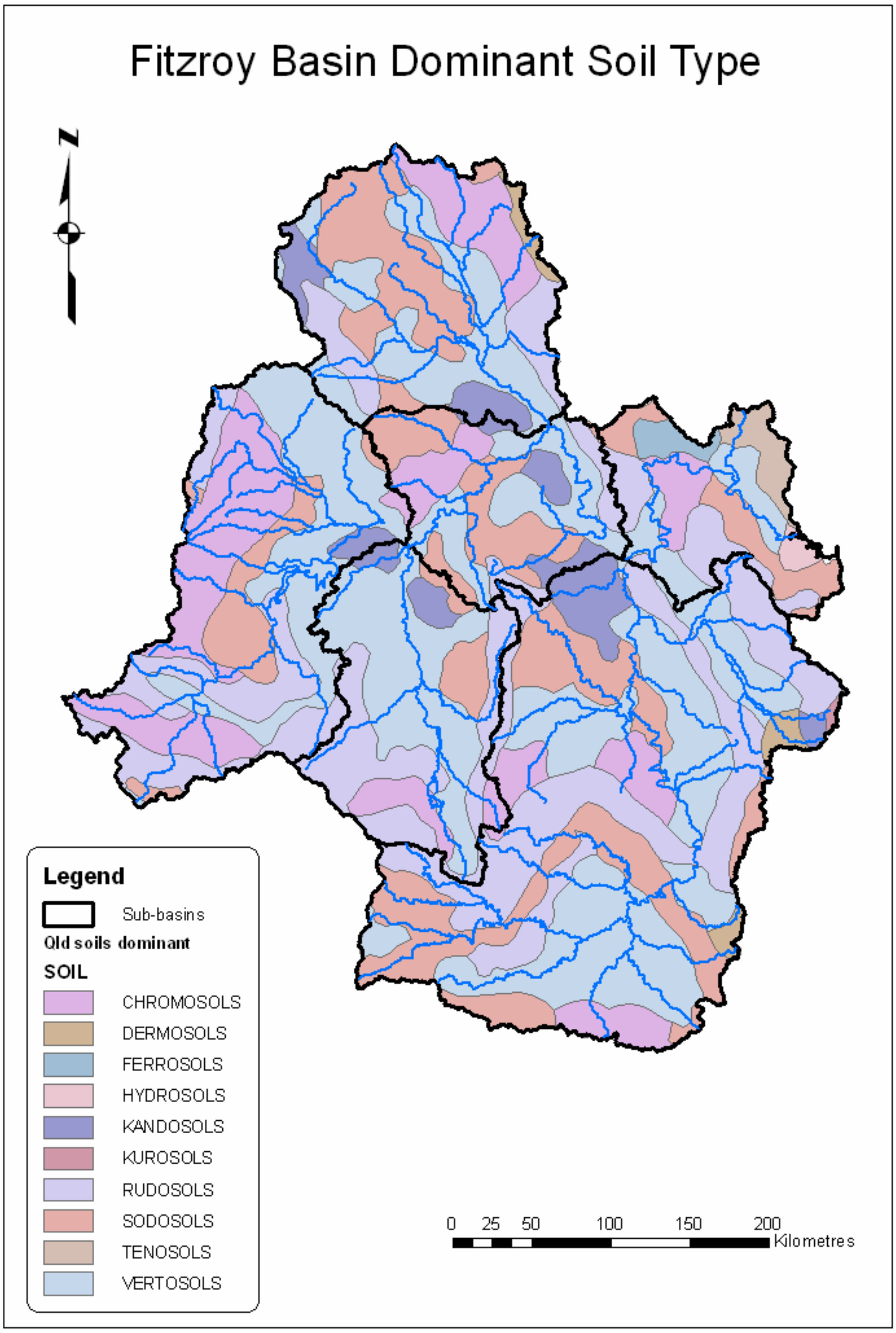


Figure 11. Soil types in the Fitzroy region

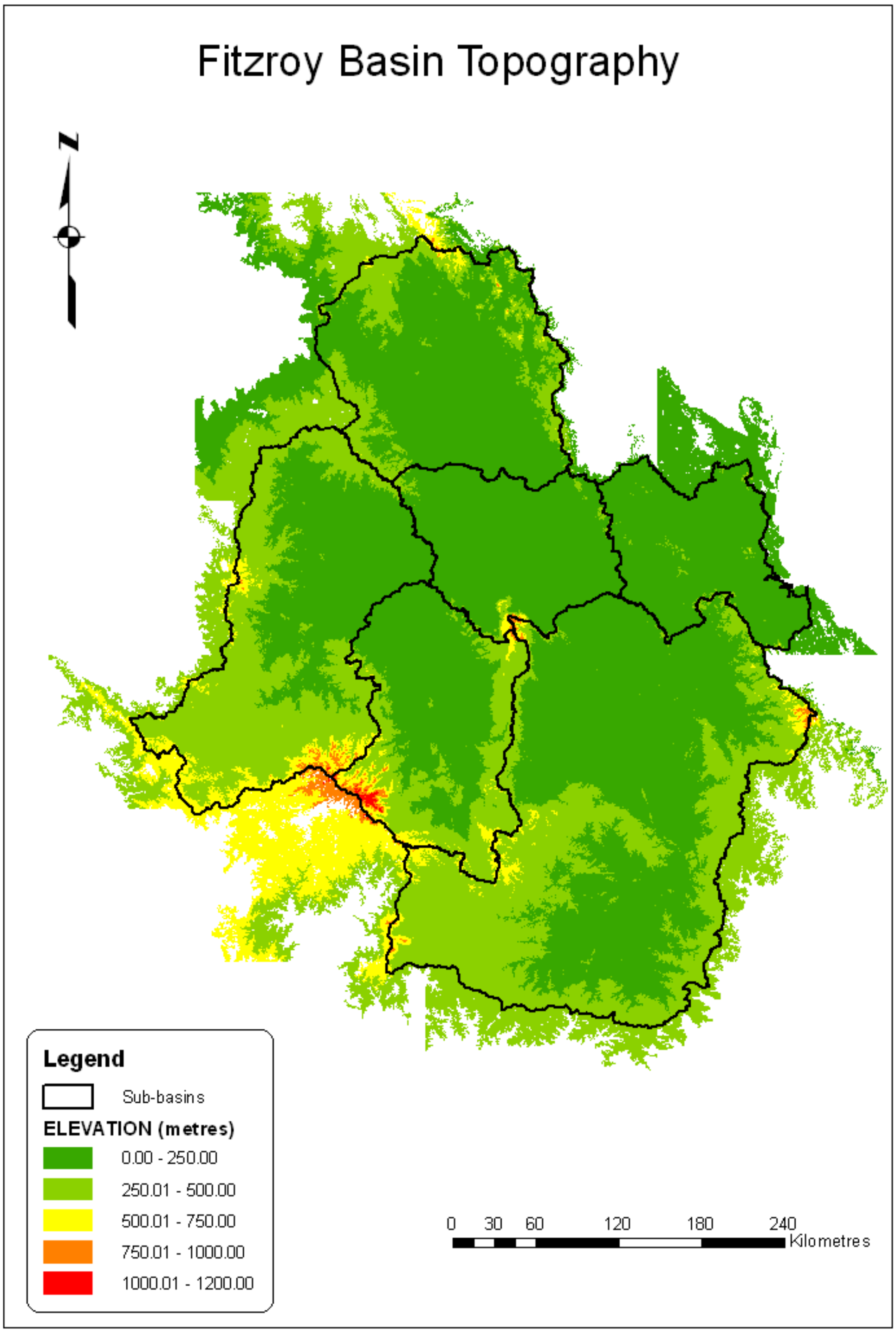


Figure 12. Elevation (metres) in the Fitzroy region

Reference sites

Both the ANZECC & ARMCANZ (2000) and the EPA (2006) recommend the use of locally derived guidelines for use in reference type assessments. This approach is applicable to assessments at any scale. Negus & Marsh (2006) explain that determining areas where sites are applicable to a specific reference or guideline condition and areas for reporting are determined using different processes. Reporting areas are specific to the objectives of the monitoring and assessment program and should be developed by managers of natural resources. The scale of an area applicable to developing a reference or guideline condition is determined using the regionalisation processes mentioned above (i.e. ecologically relevant information). While this scale does not have to be limited or equivalent to the scale of the reporting area in question it should be determined using a pragmatic approach whereby there is a trade-off between the errors in calculating reference condition and the setting of a realistic spatial scale that can be accommodated in the resource constraints of the program. Without this trade-off, scales could be set at ridiculously small sizes which further produce issues of replication and serial correlation.

Selection of reference sites is therefore also an essential step in any assessment process. A challenge to the referential approach in many areas is the lack of available sites in "pristine condition" (Karr & Chu, 1999; Whittington, 2000; Bailey et al., 2004; Negus & Marsh, 2006). A practical approach to this problem is to use reference sites identified and considered to be in "best available" condition. Best available sites selected using criteria assessments undertaken for NRW's ambient monitoring programs (Conrick & Cockayne, 2002) have been identified in the Fitzroy catchment (Table 3).

Conditions recorded at one representative site are regularly used for assessment comparisons, but will not account for natural variability within the region being represented. Information and data from a number of reference sites (spread across the region) are needed to account for the natural spatial variability (Karr & Chu, 1999). Ideally, data from these sites should be temporally applicable for assessment purposes. However, rarely are there resources to adequately cover the quantity of reference data needed to be both spatially and temporally relevant to all site assessments and 6 sites for the entire Fitzroy catchment supports this lack of information. Recommendations listed in the Queensland Water Quality Guidelines (EPA, 2006) are appropriate for interim guideline development however will most likely not cover the variability for each sub-region.

Further to this resource limitation is the problem described above, that adequate numbers of reference sites are difficult to locate and sample (Chessman, 2006). Negus & Farthing (2007) and Schulz & Negus (2007) describe several methodologies using currently available datasets to initially identify areas for future ground-truthing of reference sites (i.e. using criteria assessments from Table 4). Ideally any future program based on a referential approach should consider incorporating a complementary reference site sampling process with selection of sites similar to selection of assessment ("test" sites). The number of sites selected and spatial location of sites for each part of a future program should consider the appropriate power analyses and sampling design (probability based is recommended) relevant to the assessment objectives.

These assessments use 10 potential pressures or stressors evident at the site (Table 4). The QWQG (EPA, 2006) list a subset of 5 of these 10 criteria (bolded criteria in Table 4) for use in the development of interim guidelines. Each site is scored 1 to 5 for each of the 10 criteria resulting in a total score of 50. Sites selected for calculating reference condition (Table 3) had to meet the "best available" conditions by scoring at least 4 out of 5 for each criterion. In this way, a reference site was not necessarily in pristine condition but had limited human influence.

Currently available reference values

As mentioned above, the current default QWQG (EPA, 2006) and ANZECC & ARMCANZ (2000) recommend the use of locally developed guidelines and where the data is not available for this then use of default guidelines can be used. A detailed approach for calculating guidelines is not described in these documents; however the WQSIP projects include the development of a target setting tool which is useful for setting any target or reference condition based on collated data from reference sites and can also be used to compare "test" data against any guideline value. Table 5 lists a collation of currently derived local and default guidelines for water physico-chemical measures in the Fitzroy catchment.

Conclusions

The Fitzroy region is the largest by area catchment in Queensland and incorporates a diverse array of aquatic and riparian habitats. These habitats are influenced by a multitude of human pressures and natural drivers of which this report has summarised information for. Specific assessments showing exceedance of guidelines in many areas across the catchment, changes in aquatic ecosystem dynamics and observations of degraded riparian conditions, are consistent with the identified human pressures within the region. These pressures include land use, riparian management, water infrastructure and point sources of pollution. However, in many cases information on reference conditions on which guidelines and targets are based, is lacking and requiring further investigation.

Model outputs represent the processes of sediment and nutrient generation, and are useful in providing spatial representation of key ecosystem processes in the region. High levels of sediment generation in areas of the catchment are consistent with observed guideline exceedences recorded in other studies. However, it should be noted, in the context of aquatic condition, that areas of high modelled sediment generation do not necessarily deviate from natural conditions. In particular the Fitzroy catchment has been known to have naturally high levels of suspended solids and turbidity and determining areas of degraded water quality requires the comparison of current and pre-European scenarios to elucidate areas showing the impacts of human activities.

This summary of currently available assessment information is a valuable reference for further investigation on the influence that human pressures and natural drivers can have on ecosystem conditions. The evaluation of aquatic ecosystem condition or "health" that is provided is consistent with observed human pressures. However, it is limited from reporting formally on the extent of deviation from natural ranges across the Fitzroy Basin. This limitation is driven largely by the lack of coordinated spatial and temporal designs of each previous program result. It is recommended that future monitoring programs consider specific reporting objectives and appropriate spatial and temporal design strategies for improving assessments of ecosystem condition, including the collation and collection of adequate data for development of reference conditions of each selected indicator.

Table 4. Pressure Criteria scores for reference sites within the Fitzroy Basin
(shaded sites indicate those meeting reference site threshold for use as reference sites using all 10 criteria; other sites meet reference site threshold for 5 EPA recommended criteria)

Site No.	Site Name	Agriculture	Extraction	Urban	Point source	Dam/weir	Flow regime	Veg Alteration	Riparian erosion	Geomorphic change	In-stream habitat	TOTAL
1302055	Nogoa River at Spyglass Peak	5	5	5	5	5	5	5	5	5	5	50
1303140	Zamia Creek at Dawson Highway	5	5	5	5	5	4	4	5	4	4	46
1303211	Dawson River at Baroondah	4	5	5	5	5	5	3	4	4	4	44
1305020	Carnarvon Creek at Ingelara	5	5	5	5	5	5	3	4	4	5	46
130306B	Don River at Rannes	5	5	5	5	5	5	3	4	4	4	45
130406A	Funnel Creek at Main Road	5	5	5	5	4	5	5	4	5	4	47

Table 5. Table 1. List of pressure criteria used to identify reference sites

Possible Pressures	5 (No Impact)	4 (Minor Impact)	3 (Moderate Impact)	2 (Major Impact)	1 (Extreme Impact)
1. **Agriculture and forestry***	No impact	Present but level of impact is barely discernible	Evident, however, not severe and/or widespread	Obvious impact to stream, moderate and/or widespread	Severe and widespread, impact obvious
2. **Sand/gravel extraction***	No evidence or prior knowledge of extraction	Small scale historical extraction	No current extraction; large historical extraction	Current small scale/localised extraction	Current and widespread extraction
3. **Upstream urban areas***	No impacts from urbanisation	Possible impacts caused from urbanisation	Definite impacts caused from urbanisation	High impacts caused from urbanisation	Extreme impacts caused from urbanisation
4. **Point source pollution***	Nil point source pollution	Low volumes of point source pollution discharged	Low to moderate volumes of point source pollution discharged	Moderate to high volumes of point source pollution discharged	High to extreme volumes of point source pollution discharged
5. Dam/weir*	No artificial barriers in basin which will affect the site	Few small upstream barriers; not within impoundment	Many small barriers; site not within impoundment	Multiple small barriers; Large barriers upstream; within small impoundment	Large barriers upstream; within large impoundment
6. **Flow regime alteration***	Seasonal flow regime natural	Seasonal flow regime not obviously altered	Flow regime altered	Flow regime obviously altered	Flow regime highly modified
7. Streamside veg. alteration@	Streamside vegetation unaltered	Vegetation slightly modified	Obvious modification	Highly modified vegetation	Severe modification
8. Riparian zone/ streambank erosion	No evidence of erosion beyond natural	Slightly more than natural levels of erosion	Moderate levels of unnatural erosion	High levels of erosion	Extreme erosion
9. Geomorphic change@	No evidence	Slight geomorphic change	Moderate change	High changes	Extreme alteration
10. In-stream habitat alteration@	In-stream habitats of natural appearance and diversity	Barely discernible impacts	Moderate modifications to in-stream habitats	Highly modified modifications to in-stream habitats	Severe modification of in-stream habitats

* Note: Pressures in bold are discussed in the text

Table 6. Guideline values relevant to the Fitzroy region

Indicator	Guideline values	Applicable area	Source	Comments
Total N	**500 µg/L**	Lowland	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	250 µg/L	Upland	EPA(2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	540 µg/L	Lowland	Grinter (2005)	Based on 34 samples
	520 µg/L	Upland	Grinter (2005)	Based on 22 samples
Total P	**50 µg/L**	Lowland	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	30 µg/L	Upland	QWQG (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	75 µg/L	Lowland	Grinter (2005)	Based on 50 samples
	30 µg/L	Upland	Grinter (2005)	Based on 22 samples
Turbidity	**50 NTU**	Lowland	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	25 NTU	Upland	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	20 NTU	Lowland	Grinter (2005)	Based on 60 samples
	10 NTU	Upland	Grinter (2005)	Based on 32 samples
Conductivity	**720 µS/cm**	Fitzroy North	EPA (2006)	Based on 75th percentile of all EC samples in area
	340 µS/cm	Fitzroy Central	EPA (2006)	Based on 75th percentile of all EC samples in area
	1250 µS/cm	Lowland	Grinter (2005)	Based on 71 samples
	500 µS/cm	Upland	Grinter (2005)	Based on 46 samples
pH	**8.0**	Lowland streams	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed
	7.5	Upland streams	EPA (2006); ANZECC & ARMCANZ (2000)	Default guideline – recommend local guidelines developed

References

ANZECC &ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy No. 4, Environment Australia.

Askey-Doran M. & Pettit N. (1999) Some impacts of human activity on riparian land. Chapter 10 in (eds: Lovett, S. and Price, P.) Riparian *Land Management Technical guidelines, Volume One: Principles of Sound Management*, Land and Water Resources Research and Development Corporation, Canberra.

Bailey R.C., Norris R.H. & Reynoldson T.B. (2004) *Bioassessment of Freshwater Ecosystems: Using a Reference Condition Approach.* Kluwer Academic Publishers, USA.

Berghuis A.P. & Long P.E. (1999). Freshwater fishes of the Fitzroy Catchment, central Queensland. *Proceedings of the Royal Society of Queensland*, 108: 13-25.

Brodie J.E. & Mitchell A.W. (2005) Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments. *Marine and Freshwater Research*. 56: 279-302.

Brooke B., Bostock H., Smith J. and Ryan D. (2006) *Geomorphology and sediments of the Fitzroy River coastal sedimentary system – summary and overview*. Cooperative Research Centre for Coastal Zone, Estuaruy and Waterway Management. Technical Report 47. QNRM06296.

Calvert M., Simpson J. & Adsett, K. (2000). *Land Use Mapping of the Fitzroy Catchment.* Fitzroy Catchment Implementation Project Final Report July 2000

Chessman B.C. (2006) Prediction of riverine fish assemblages through the concept of environmental filters. *Marine & Freshwater Research*, 57: 601-609.

Conrick D. & Cockayne B. (eds) (2002) *Australia-Wide Assessment of River Health: Queensland AusRivAS Sampling and Processing Manual.* Queensland Department of Natural Resources and Mines, Monitoring River Health Initiative Technical Report Number 12, Environment Australia.

Cooper B., Jones G., Birch M. & Davis R. (1996) Chapter 5, Agricultural Chemicals and Algal Toxins - Emerging Water Quality Issues. In *Managing Australia's Inland Waters: Roles for Science and Technology.* A paper prepared by an independent working group for consideration by the Prime Minister's Science and Engineering Council at its fourteenth meeting

CRC CZ (2003) *Central Queensland Information Paper to support regional natural resource management planning*. Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management. QNRM03151.

CSIRO (2000) Algal Mysteries Revealed. In: *CSIRO Land & Water News*, Issue No. 8, December 2000. http://www.clw.csiro.au/publications/clw-link/clwlink-8.pdf

DNR. (1998) Technical Report 4, Environmental Flow Requirements. *In*: Department of Natural Resources (ed). *Fitzroy Basin Water Allocation and Management Planning Technical Reports*. Department of Natural Resources, Brisbane.

DNR. (1999) *Water Allocation and Management Plan (Fitzroy Basin) 1999 (WAMP)*. DNRQ990170, Department of Natural Resources, The State of Queensland.

Dougall, C., Packett, R. and Carroll, C. (2005). Application of the SedNet model in partnership with the Fitzroy Basin community. In Zerger, A. and Argent, R. M. (eds) *MODSIM 2005 International Congress on Modelling and Simulation.* Modelling and Simulation Society of Australia and New Zealand, December 2005.

Dougall C., Packett R., Carroll C., Sherman B.S., Read A., Chen Y. & Brodie J. (2006) Sediment and nutrient modelling in the Fitzroy NRM region. Volume 5. *In:* Cogle A.L., Carroll C. & Sherman B.S. *The use of SedNet and ANNEX models to guide GBR catchment sediment and nutrient target setting*. Department of Natural Resource, Mines and Water. QNRM06138.

Duivenvoorden L.J. (1995). *Biological and Ecological Data (excluding fisheries) on the Dawson River System with Particular Reference to the Proposed Nathan Dam: August 1995.* Report by River and Wetland Ecology Group, Centre for Land and Water Resource Development, Central Queensland University, Rockhampton, Queensland.

EPA (2003) *State of the Environment Queensland 2003*. The State of Queensland.

EPA, Environmental Protection Agency (2006) *Queensland Water Quality Guidelines* 2006, Version 2. The State of Queensland.

Fabbro, L. D. & Duivenvoorden, L. J. (1995) Abstract: Biological assessment of the Fitzroy River system: Phytoplankton, *Downstream Effects of Land Use National Conference*, 26 -28 April, 1995, Central Queensland University, Rockhampton, Queeensland, p. 69.

FBA (2005) *Central Queensland Strategy for Sustainability, 2004 and beyond*. Developed by the people of Central Queensland through the Fitzroy Basin Association.

Fentie B., Joo M., Yu B., Hunter H., Marsh N., Carroll C. and Dougall C. (2005) Comparison of mean annual suspended loads estimated by the Sednet Model and rating curves in The Fitzroy Catchment, Australia. In: Zerger A. and Argent R.M. (eds) *MODSIM 2005*. International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand. December 2005.

Finlayson B. & Silburn M. (1996) Soil, nutrient and pesticide movements from different land use practices, and subsequent transport by rivers and streams. pp 129-

140 In: Hunter H.M., Eyles A.G. & Rayment G.E. (eds), *Downstream Effects of Land Use*, Department of Natural Resources, Brisbane, Australia.

Ford P.W., Webster I.T., Tillman P., Robson B., Revill A., Noble B. and Packett B. (2005) Nutrient and carbon cycling in subtropical estuaries (Fitzroy): Overview of the biogeochemistry of the Fitzroy Estuary. *In*: Noble B., Bell A., Verwey P. and Tilden J. *Fitzroy in focus: Coastal science for the Fitzroy region*. Cooperative research Centre for Coastal Zone, Estuary and Waterway Management.

Furnas, M. (2003) *Catchment and Corals*. Australian Institute of Marine Science, Townsville, 334 pp.

Gehrke P.C., Brown P., Schiller C.B., Moffatt D.B. and Bruce A. (1995) River regulation and fish communities in the Murray-Darling river system, Australia. *Regulated Rivers: Research and Management*, 11: 363-375.

Greening Australia (2003) *Bushcare Support 2003: Native Vegetation Management A needs analysis of regional service delivery in Queensland – Central.* http://www.deh.gov.au/land/publications/nvm-qld/pubs/qld-central.pdf

Grinter S. (2005) *Ambient surface water quality in Queensland. 2003-04. Technical Report*. Department of Natural Resources and Mines. State of Queensland. QNRM05222.

Grinter S. & Hunter H. (2005) *Ambient surface water quality in Queensland 2003-04, Summary report*. Department of Natural Resources & Mines. The State of Queensland. QNRM05221

Grinter A. & Clarke R. (2006) *Ambient surface water quality in Queensland: 2002-05: Summary Report.* QNRM05463, Queensland Department of Natural Resources, Mines & Water, Queensland Government.

Harris J.H. & Mallen-Cooper M. (1994). Fish-passage development in the rehabilitation of fisheries in mainland south-eastern Australia. In Cowx I.G. (ed.) *Rehabilitation of freshwater fisheries*. Fishing News Books, Oxford.

Henderson C. (2000). *State of the Rivers. Comet, Nogoa and Mackenzie Rivers. An Ecological and Physical Assessment of the Condition of Streams in the Comet, Nogoa and Mackenzie River Catchments.* Department of Natural Resources, Natural Sciences Precinct.

Horn A., Joo M. & Poplawski W. (1998) *Queensland riverine sediment transport rates. A progress report.* Water quality group report No. 2/98. Department of Natural Resources, Coorparoo, Queensland.

Joo M., Yu B., Fentie B. and Carroll (2005) Estimation of long-term sediment loads in the Fitzroy Catchment, Queensland, Australia. In: Zerger A. and Argent R.M. (eds) *MODSIM 2005*. International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand. December 2005.

Joo M. & Yu B. (2006) *Sediment Yield and Sediment Sources of the Fitzroy River, Queensland, Australia.* Draft Technical Report. Department of Natural Resources & Water. The State of Queensland.

Karr J.R. & Chu E.W. (1999) *Restoring Life in Running Waters: Better Biological Monitoring.* Island Press, USA.
Kelly & Wong (1996)

Lynch R.J. and Catterall C.P. (1999). Riparian wildlife and habitats, Chapter 9 in (eds: Lovett, S. and Price, P.) *Riparian Land Management Technical guidelines, Volume One: Principles of Sound Management,* Land and Water Resources Research and Development Corporation, Canberra.

Lovett, S., Price, P. & Lovett, J. (2003) *Managing Riparian Lands in the Cotton Industry*, Cotton Research and Development Corporation.

Marshall C., Negus P., Winning M., Johnson D. & Harch B. (2004) April 2004 Draft, *Fitzroy Basin Resource Operation Plan: Ecological Monitoring and Assessment Program: Part 2 Research Project Methods: Using a gradient of impact approach to identify indicators for inclusion in the design of an on-going monitoring program.* Freshwater Biological Monitoring Report, Department of Natural Resources and Mines, Queensland Government.

Moss A.J., Rayment G.E., Reilly N. & Best E.K. (1992) *A preliminary assessment of sediment and nutrient exports from Queensland Coastal Catchments*. Queensland Department of Environment and Heritage Technical Report No. 5, Queensland Government, Brisbane, Australia.

Negus P., Marshall C., Winning M., Cheshire K. and Harch B. (2004) April 2004 Draft, *Fitzroy Basin Resource Operations Plan: Ecological Monitoring and Assessment Program: Part 3 – Results: Using a gradient of impact approach to identify indicators for inclusion in the design of an on-going monitoring program*. Freshwater Biological Monitoring Report, Department of Natural Resources and Mines, Queensland Government.

Negus P. & Marsh N. (2006) *Water Quality Condition Assessment Framework.WQ02 Technical Report.* National Action Plan for Salinity and Water Quality, Water Quality State-level Investment Project. The State of Queensland.

Negus P. & Farthing B. (2007) *Summary of Information for Spatial data and Aquatic Ecosystem Condition in the Condamine Balonne Catchment.* WQ02 Technical Report. National Action Plan for Salinity and Water Quality, Water Quality State-level Investment Project. The State of Queensland.

Neil, D. & Yu, B. (1996) Fluvial sediment yield to the great Barrier Reef Lagoon: Spatial patterns and the effects of land use. In: Hunter H.M., Eyles A.G. & Rayment G.E. (eds), *Downstream Effects of Land Use*. pp281-286, Department of Natural Resources, Brisbane, Queensland, Australia.

Noble R.M., Rummenie S.K., Long P.E. & Fabbro L.D. (1996). The Fitzroy River Catchment: An Assessment of the Condition of the Riverine System. *Proceedings of the 8th Australian Agronomy Conference 1996.* http://www.regional.org.au/au/asa/1996/contributed/446noble.htm

Noble, R.M., Duivenvoorden, L.J., Rummenie, S.K., Long, P.E., Fabbro, L.D. (1997) *Downstream effects of land use in the Fitzroy catchment.* Queensland Department of Natural Resources, Brisbane, 97pp

Noble, R.M. (Ed.) 2000. River Health in the Fitzroy Catchment – Community Ownership. Summary Report, Department of Natural Resources, Queensland.ISBN 0 7345 1689 4.

NLWRA (2001) *Australian Water Resources Assessment 2000. Surface water and groundwater availability and quality*, National Land and Water Resources Audit.

Packett, B. Ford, P.W. and Noble, R. (2005). Overview of the delivery of pesticides to the Fitzroy Estuary and persistent organic pollutants in the food chain. *In*: Noble, R.; Bell, A.,Verwey, P. and Tilden J. (Eds.). *Fitzroy in Focus: coastal science for the Fitzroy region.* pp.73–74. Cooperative Research Centre for Estuary and Waterway Management, Brisbane.

Prosser I., Moran C., Lu H., Scott A., Rustomji P., Stevenson J., Priestley G., Roth C. & Post D. (2002) *Regional Patterns of Erosion and Sediment Transport in the Burdekin River Catchment.* CSIRO Land and Water Technical Report 5/02 http://www.clw.csiro.au/publications/technical2002/tr5-02.pdf

Robins J., Halliday I., Staunton-Smith J., Sellin M., Roy D., Mayer D., Platten J. and Vance D. (2005) Environmental flows for estuarine fisheries production. *In*: Noble B., Bell A., Verwey P. and Tilden J. *Fitzroy in focus: Coastal science for the Fitzroy region*. Cooperative research Centre for Coastal Zone, Estuary and Waterway Management.

Rutherford I., Abernathy B. & Prosser I. (1999) Stream erosion. Chapter 6 in (eds: Lovett, S. and Price, P.) *Riparian Land Management Technical guidelines, Volume One: Principles of Sound Management*, Land and Water Resources Research and Development Corporation, Canberra.

Sainty G.R. & Jacobs S.W.L. (1994) *Waterplants in Australia*. Sainty & Associates - Publishers, Darlinghurst, NSW, Australia.

Schulz C. & Negus P. (2007) *Burdekin regional water quality summary. To support the development of the Water Quality Improvement Plan.* WQ02 Technical Report. National Action Plan for Salinity and Water Quality, Water Quality State-level Investment Project. The State of Queensland.

Smith M.J. & Storey A.W. (2001) *Design and Implementation of Baseline Monitoring (DIBM3): Developing an Ecosystem Health Monitoring Program for Rivers and Streams in Southeast Queensland.* Report to the South East Queensland Regional Water Quality Management Strategy, Brisbane.

Stuart I.G. (1997). *Assessment of a modified vertical-slot fishway, Fitzroy River, Queensland.* Department of Primary Industries Queensland, Report QO97023.

Stuart I.G. and Mallen-Cooper M., (1999). An assessment of the effectiveness of a vertical-slot fishway for non-salmonid fish at a tidal barrier on a large tropical / subtropical river. *Regulated Rivers: Research and Management*, 15: 575-590

Telfer D. (1995). *State of the Rivers. Dawson River and Major Tributaries. An Ecological and Physical Assessment of the Condition of Streams in the Dawson River Catchment*. Department of Primary Industries, Resource Management, Brisbane.

Thorncraft G. & Harris J.H. (2000). *Fish Passage and Fishways in New South Wales: A Status Report.* Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

The State of Queensland and Commonwealth of Australia (2003) *Reef Water Quality Protection Plan; for catchments adjacent to the Great Barrier Reef World Heritage Area*, Queensland Department of Premier and Cabinet, Brisbane.

Van Manen N. (2005) *State of the Rivers. Fitzroy and Isaac Rivers and Capricorn Coastal Tributaries. An Ecological and Physical Assessment of the Condition of Streams in the Fitzroy River, Isaac Rivers and Capricorn Coastal Catchments*. Department of Natural Resources & Mines, The Queensland Government.

Vincente-Beckett V., Noble R., Packett R., Verwey P., Ruddle L., Munksgaard N. and Morrison H. (2006) *Pesticide, polycyclic aromatic hydrocarbon and metal contamination in the Fitzroy Estuary, Queensland, Australia*. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Technical Report 37, QNRM06327.

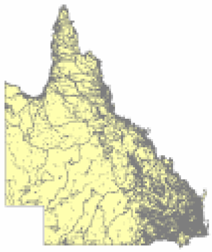
Webster I.T., Ford P.W., Margvelashvili N., Sakov P., Herzfeld M., Andrewartha J. and Parslow J. (2005) Modelling of the hydrodynamics, sediment transport and biogeochemistry in the Fitzroy Estuary. *In*: Noble B., Bell A., Verwey P. and Tilden J. *Fitzroy in focus: Coastal science for the Fitzroy region*. Cooperative research Centre for Coastal Zone, Estuary and Waterway Management.

Whitting N., Conrick D. & McNeil V. (2003) *Background information for surface water quality and groundwater quality*. State of the Environment Queensland 2003. Department of Natural Resources, Mines & Energy, The State of Queensland.

Whittington, J. (2000). *Development of Relationships between flow regime and river health: outcomes of a joint CRCFE and QLD DNR workshop*. Technical Report No:6/2000, Cooperative Research Centre for Freshwater Ecology.

Appendix

Queensland Land use - QLD_LAND USE_1999 SDE Feature Class



Description

Abstract

This dataset is a digital land use map of the state of Queensland. As nearly as possible it shows land use in 1999. The dataset is a product of the Queensland Land Use Mapping Program (QLUMP) and was produced by QDNRM. It is part of a national catchment scale land use mapping project coordinated by the Commonwealth Bureau of Rural Sciences (BRS) and being undertaken by QDNRM as well as government agencies in other states and territories. The dataset is a baseline (1999) land use map for the entire state and comprises one digital map in vector format at nominal scales of 1:50,000 and 1:100,000, dependent on intensity of land use in individual catchments. The map consists of a mosaic of 79 catchment-based land use datasets. Coordinates are geographic referred to the Geocentric Datum of Australia 1994 (GDA94) on the Geodetic Reference System 1980 (GRS80) ellipsoid. The map is a polygon coverage with each polygon having attributes describing land use. Land use is classified according to the Australian Land Use and Management Classification (ALUMC) Version 5, February 2002.

Purpose

This dataset has been prepared and is intended for use at catchment scale. It depicts the primary use or management objective of land in 1999.

Supplementary Information

Mapping has been undertaken on a catchment basis progressively over several years. Refer to links to graphics describing the data (below) for metadata files relating to individual catchments.

Status of the data

Complete

Time period for which the data is relevant

Date and time: 1999

Description:
publication date

Publication Information

Who created the data: Queensland Department of Natural Resources & Mines

Date and time: 26 May 2003

Data storage and access information

File name: SIRQRY.QLD_LAND USE_1999

Type of data: vector digital data

Location of the data:

- Server=indsirqry; Service=sirqry; User=sirqry; Version=SDE.DEFAULT

Data processing environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 9.1.0.722

Accessing the data

Data format: ARCE

Constraints on accessing and using the data

Access constraints: Dataset is available for viewing and/or use outside the Department of Natural Resources and Mines under the following conditions. Dataset freely available for viewing. Authorisation required for download.

Use constraints:
None

Details about this document

Contents last updated: 20070123 at time 09042300

Who completed this document

O'Donnell Tim
Department of Natural Resources and Mines
mailing and physical address:
Block C Level 2
80 meiers Road
Indooroopilly, Queensland 4068
Australia
(07) 3896 9820 (voice)
(07) 3896 9858 (fax)
Timothy.Odonnell@nrm.qld.gov.au

Queensland National Pollutant Inventory - QLD_NATPOLLUTANTINV
SDE Feature Class

Description

Abstract

Pollutant release to air, waterand land of National Pollutant Inventory listed substances from facilities large enough to trigger reporting requirements under the Environmental Protection Act 1994.

Purpose

Location of facilities large enough to trigger reporting requirements under the Environmental Protection Act 1994.

Status of the data

In work

Data update frequency: Annually

Time period for which the data is relevant

Beginning date and time: 1998/1999 financial year

Ending date and time: 2002/2003 financial year

Description:
publication date

Publication Information

Who created the data: Environmental Protection Agency

Date and time: March 2006

Data storage and access information

File name: SIRQRY.QLD_NATPOLLUTANTINV

Type of data: vector digital data

Location of the data:

- Server=indsirqry; Service=sirqry; User=sirqry; Version=SDE.DEFAULT

Data processing environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 9.1.0.722

Constraints on accessing and using the data

Access constraints: Restricted to within the Department of Natural Resources and Mines. View access permitted. Dataset is available for viewing to registered users via web delivery tools, for example, through an access controlled internet site like NAP RIS Portal. External enquiries should be directed to the Queensland Environmental Protection Authority.The use of the dataset is subject to the conditions of use detailed in the data usage agreement, signed between the Custodian and the Recipient. No third party usage is permitted other than indicated in the agreement. Data which is downloaded from the NAP RIS Portal, can only be used for the purpose of project-related work for the client / regional body who downloaded the data. The data is not to be supplied to a third party and also is not to be used for commercial purposes.

Use constraints:
None indicated.

Details about this document

Contents last updated: 20060327 at time 14591400

Who completed this document

Finney Gary

Department of Natural Resources and Mines

mailing and physical address:

Level 3, Block C,
80 Meiers Road, Indooroopilly
Brisbane, Queensland 4068

Australia

(07) 3896 9393 (voice)

(07) 3896 9782 (fax)

Gary.Finney@nrm.qld.gov.au

SIRQRY.QLD_ISOHYET_250K

SDE Feature Dataset

Data storage and access information

File name: SIRQRY.QLD_ISOHYET_250K

Type of data: vector digital data

Location of the data:

- Server=indsde; Service=sirqry; Database=sirqry; User=sirqry;

Version=SDE.DEFAULT

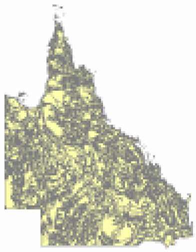
Data processing environment: Microsoft Windows 2000 Version 5.0 (Build 2195) Service Pack 4; ESRI ArcCatalog 9.1.0.722

Details about this document

Contents last updated: 20051213 at time 10063600

Queensland Geology Surface Units - QLD_GEO_2500K_A

SDE Feature Class



Description

Abstract

The polygons in this dataset are a digital representation of the distribution or extent of geological units within the area. Polygons have a range of attributes including unit name, age, lithological description and an abbreviated symbol for use in labelling the polygons. These have been extracted from the Rock Units Table held in the Department of Natural Resources, Mines and Energy Merlin Database.

This theme depicts the distribution of geological units at the surface for Queensland.

Purpose

To display the geology polygons which define the extent of rock units at the surface.

Supplementary Information

Compiled 1975 by the Regional mapping Section GSQ chiefly by WG Whitaker and KG Grimes, simplified from existing, mostly 1:250000-scale geological maps produced 1950-74 by joint BMR-GSQ field parties

Capture scale 1:2 500 000

Status of the data

Complete

Data update frequency: As needed

Time period for which the data is relevant

Date and time: January 2005

Publication Information

Who created the data: Natural Resources and Mines, Natural Resource Sciences, Geological Survey of Queensland
Date and time: January 1975
Publisher and place: Department of Natural Resources and Mines, Brisbane, Australia

Data storage and access information

File name: SIRQRY.QLD_GEO_2500K_A
Type of data: vector digital data
Location of the data:

- Server=indsde; Service=sirqry; User=sirqry; Version=SDE.DEFAULT

Data processing environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 9.0.0.535

Accessing the data

Network location:

- lasun107

Access instructions: Online connection within NR&M available through ArcGIS
Available media: CD-ROM, DVD

Constraints on accessing and using the data

Access constraints: Restricted to within Natural Resources and Mines. Dataset is not available for viewing outside the Department of Natural Resources and Mines. The Department licenses all digital data and products, whether there is a fee charged or not. The information sheet on the Department's website provides an overview of the different licences available. http://www.nrm.qld.gov.au/products/access_pricing/licence.html The Department only enters into sharer agreements where there is mutual benefit and these must be approved by the Deputy Director General, Natural Resource Services. This data is provided under a User Licence- refer to website as above, and follow the links to User Licence. To request provision of the data under any other licenses described on this website, a written request must be made to the Department.
Use constraints:
The data are supplied under a User Licence for non-commercial purposes for internal use only, and must not be sold or distributed to any third party. Refer to web address: http://www.nrm.qld.gov.au/products/access_pricing/licences/user_info.html A sample User Licence is available in http://www.nrm.qld.gov.au/products/access_pricing/pdfs/sample_user_licence_v1_2.pdf With reference to the "Methods of Acknowledging Agreement"; in 4.1- you must register at www.nrm.qld.gov.au/products so you can be advised of updates to the data.

Details about this document

Contents last updated: 20060215 at time 11353800

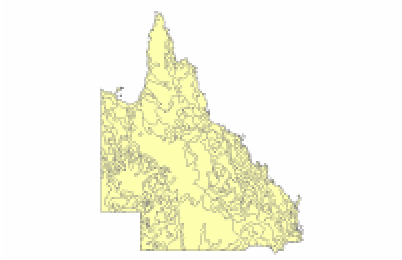
Who completed this document

Chris MacWhirter
Department of Natural Resources and Mines, Graphic Services Unit
physical address:
Block C, 80 Meiers Rd, Indooroopilly
Brisbane, Queensland 4068
Australia

3896 9837 (voice)
chris.mcwhirter@nrm.qld.gov.au

Hours of service: 8:00 am to 4: 30 pm AEST Monday to Friday

Queensland Dominant Soils - QLD_SOILS_DOMINANT SDE Feature Class



Description

Abstract

A dataset dividing Queensland into 12 dominant soil orders as depicted in the publication ' Reef, Range and Red Dust'.

Purpose

Generalized soil boundaries in Queensland.
Intended scale use 1 : 7 500 000

Status of the data

Complete

Publication Information

Publisher and place: Queensland Government, Queensland

Data storage and access information

File name: SIRQRY.QLD_SOILS_DOMINANT

Type of data: vector digital data

Location of the data:

- Server=indsde; Service=sirqry; User=sirqry; Version=SDE.DEFAULT

Data processing environment: Microsoft Windows 2000 Version 5.0 (Build 2195) Service Pack 3; ESRI ArcCatalog 8.3.0.800

Constraints on accessing and using the data

Access constraints: Restricted to within the Department of Natural Resources and Mines. View access permitted. Dataset is available for viewing to registered users via web delivery tools, for example, through an access controlled internet site like NAP RIS Portal.

Use constraints:
No Restrictions.

Details about this document

Contents last updated: 20051206 at time 17044100

Who completed this document

Gary Finney

Department of Natural Resources and Mines

mailing and physical address:

Level 3 , Block C
80 Meiers Road, Indooroopilly
Brisbane, Queensland 4068

Australia

(07) 3896 9393 (voice)

(07) 3896 9782 (fax)

Gary.Finney@nrm.qld.gov.au
