Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area

Chapters 1 to 4

November 2009

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1. Introduction

1.1 Background

Creek to Coral managed the Townsville Coastal Catchments Initiative (CCI) project and along with its many partners prepared a Water Quality Improvement Plan (WQIP) for the Black and Ross River Basins. One of the first tasks was to delineate the extent of the receiving water bodies to be the subject of the WQIP. The estuarine reaches of major waterways, the catchments, sub-catchments and minor drainage systems adjacent to the receiving water body were also delineated.

This document provides the rationale for the delineation of the receiving waters including the estuarine reaches of the waterways within the Black Ross WQIP study area. The sub-basins, catchments and sub catchments are delineated and the main features of the catchments relevant to the WQIP are described.

1.2 WQIP areas relevant to the GBR

"*The Great Barrier Reef is renowned internationally for its ecological importance and the beauty of its seascapes and landscapes. These natural values also provide important ecosystem services, which underpin Australian $6.9 billion worth of economic activity and incalculable social values. In combination, the social-ecological system centred on the reef is extraordinary in its importance, and in its complexity*" (Johnson and Marshall (eds) 2007, p.2)

The Great Barrier Reef Marine Park (GBRMP) is almost 350,000 square kilometres in area and is located along 2,100 kilometres of the Queensland coastline, spanning 14 degrees of latitude. The Great Barrier Reef (GBR) is a complex maze of about 2,900 separate coral reefs accounting for around 6% of the area of the Great Barrier Reef Marine Park.

"*About 36 percent of the Great Barrier Reef Marine Park is continental slope, where the water is between 150 and 2,000 metres deep. The remaining 64 percent is continental shelf, including the coral reefs, which is anywhere from 1 to 150 metres deep. The other main geographical components of the continental shelf are the inter-reef areas (25% of the Marine Park) and the lagoon (33%). The vast majority of the coral reefs are found relatively far offshore with the inshore lagoon having few reefs*".

"*Within these major geographic divisions of the Great Barrier Reef are many different types of habitat and biological community. The best known of these are the coral reefs, but there are also seagrass beds, algal meadows, sponge and soft coral gardens, sandy and muddy areas, mangrove forests and islands. This array of habitats supports an amazing biodiversity*" (Johnson and Marshall (eds) 2007, p.3).

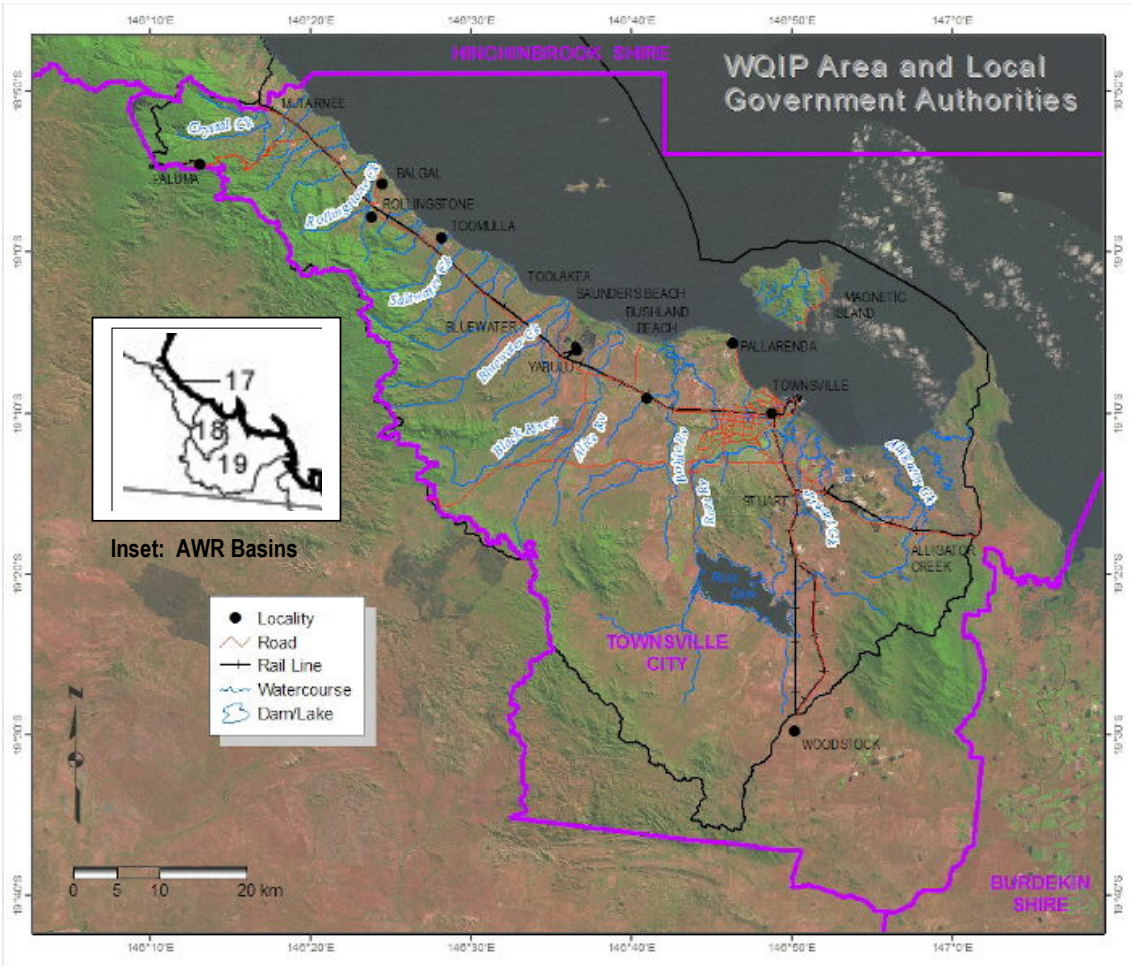
The quality of water in the GBR lagoon is important to the maintenance of the habitats and amazing biodiversity of the GBRMP, and especially of the near shore areas. The water quality of the GBR is impacted by the quality of water entering the GBRMP from the catchments stretching the 14 degrees of latitude from Cape York to the Burnett-Mary catchment. Collectively known as the GBR catchments, the activities that take place on this land mass ultimately have significant impacts on the quality of water of the GBR. The Black River and Ross River Basins are part of the GBR catchment and Townsville is home to the largest urban population in the coastal zone adjacent to the GBR. The Black Ross WQIP area is therefore relevant to the Great Barrier Reef and has some water quality issues which are unique to urban population centres.

2. Black Ross Receiving Waters

2.1 Black and Ross Basins WQIP Area

The Black Ross (Townsville) WQIP area covers most waterways within the Townsville City local government area (LGA) with the exception of the Reid River and Major Creek catchments, which are part of the Haughton River Basin. The WQIP area includes the Black River (No. 17) and Ross River (No. 18) Australian Water Resource Council (AWR) Basins and a small part of the Haughton River Basin (No. 19) where the waterways flow to Cleveland Bay. It also includes Magnetic Island, as well as the coastal and marine waters of Cleveland Bay and Halifax Bay (see Figure 2.1).

Figure 2.1 Black/Ross WQIP Area

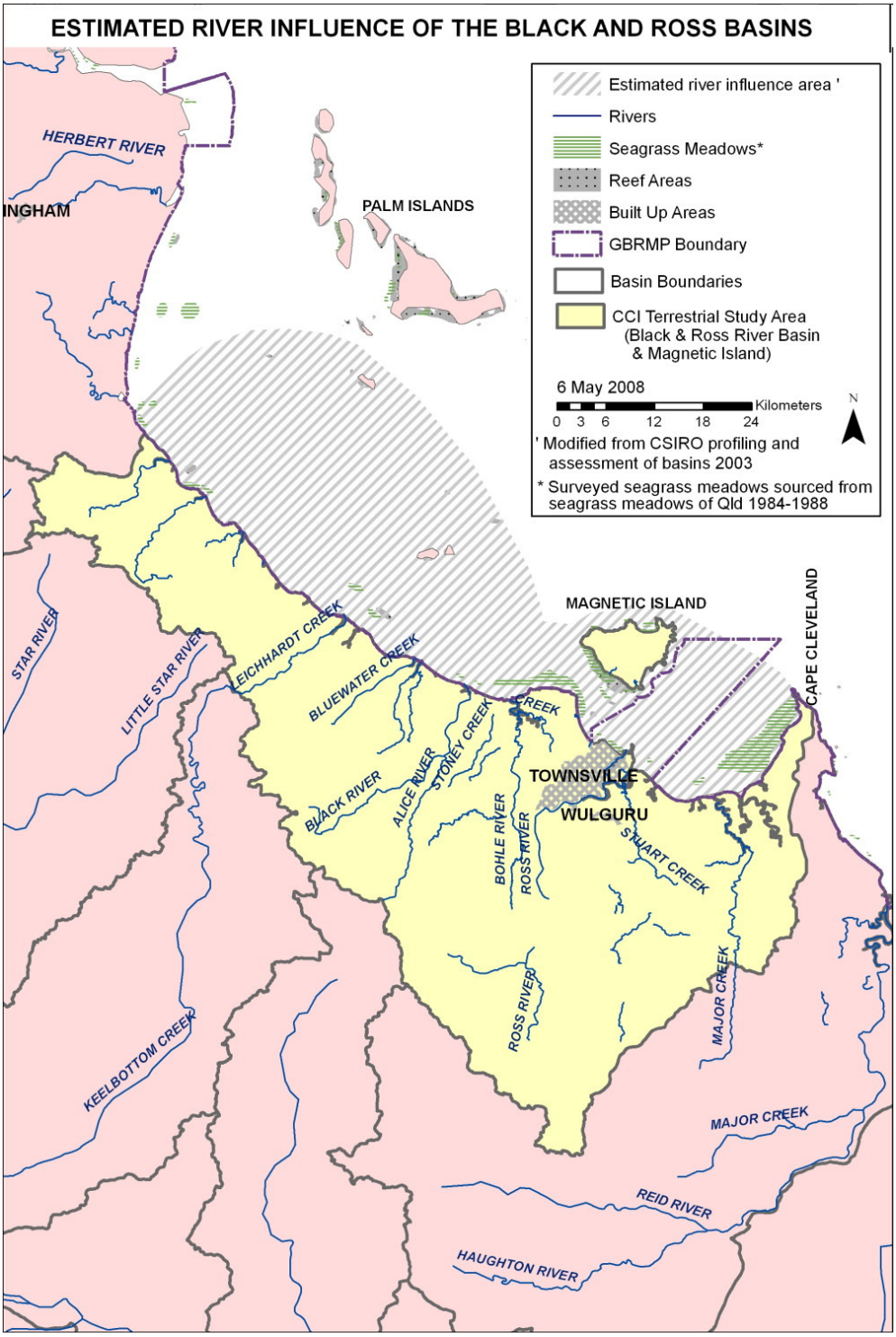


2.2 Black Ross WQIP Receiving Waters

As the initial step in determining the receiving waters of the Black Ross (Townsville) WQIP the estimated marine areas influenced by discharge from the Black River and Ross River Basins, as calculated by Greiner et al (2003), were combined. This accounted for the terrestrial influence from the mainland.

As Magnetic Island is also a part of the Black Ross (Townsville) WQIP area the near coastal zone around the northern extent of Magnetic Island, which could reasonably be expected to be influenced by run-off from the island, was added to the marine waters influenced by mainland terrestrial run-off. The result is the extent of marine receiving waters of the Black Ross (Townsville) WQIP area (see Figure 2.2).

Figure 2.2 Black Ross WQIP Receiving Waters Based on River Influence

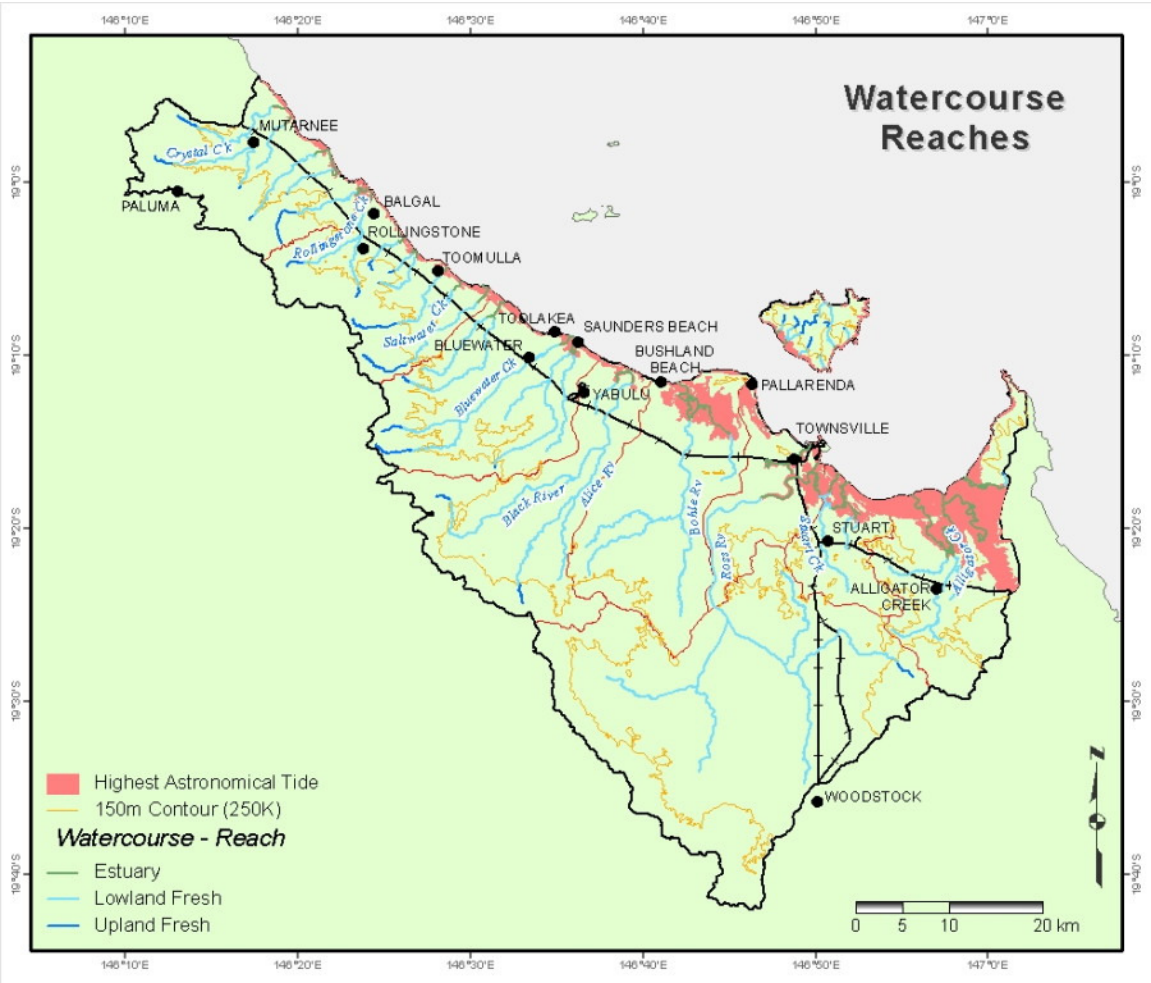


Source: Estimated river/waterway influence prepared by CSIRO based on mapping from a report titled *Profiling and assessment of basins with respect to the sediment, nutrient and other diffuse-source loads they export to the Great Barrier Reef WHA* (Greiner et al 2003).

The extent of estuarine receiving waters was determined primarily from the distribution of 'marine' plants as defined by Queensland's regional ecosystem mapping (Department of Environment and Resource Management). The landward extent of vegetation communities (regional ecosystems) known to be saltwater tolerant was delineated and this was assumed to be the extent of tidal influences and therefore the upstream limit of highest astronomical tides (HAT). Thus the extent of saltwater tolerant vegetation communities was used to define HAT and hence the inland extent of estuarine waters.

The waters upstream of the saltwater tolerant vegetation communities (HAT) line were considered to be freshwater. Lowland and upland freshwaters were also delineated with upland freshwaters being above the 150-metre contour and lowland freshwater between the 150-metre contour and the estuarine line. The delineated water types are shown in Figure 2.3.

Figure 2.3 Fresh and Estuarine Water Types

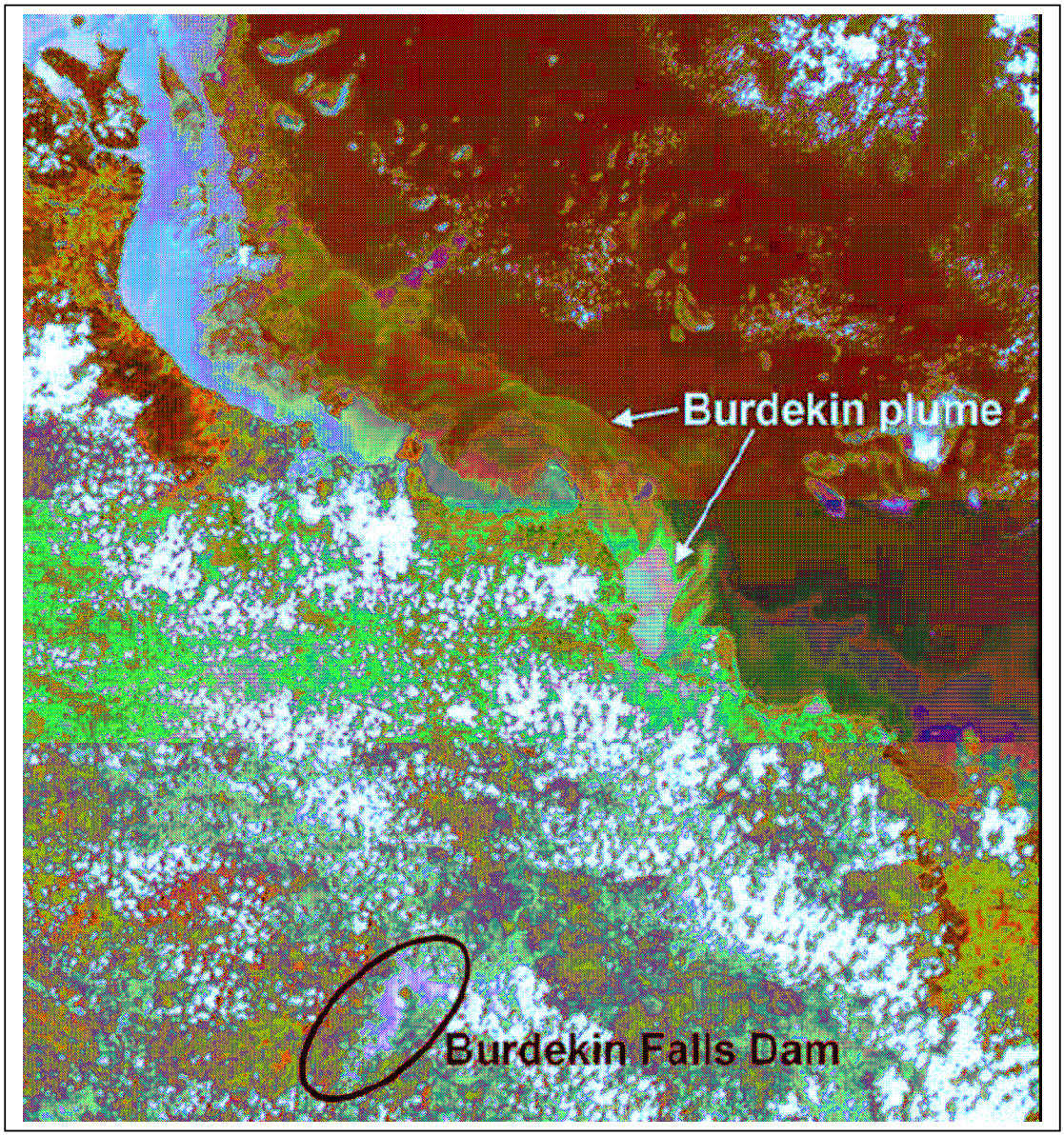


Most of the waterways in the north of the WQIP area have relatively short estuarine reaches and distinct upland freshwater reaches. Waterways in the Ross River Basin generally have short, or no upland freshwater reaches while the estuarine reaches are quite extensive. This is indicative of the topographic differences between the Black River Basin and the Ross River Basin (see section 3.3).

2.2.1 External influences

It is recognised that run-off from the Burdekin and Haughton River Basins (see Figure 2.4) also influences the marine receiving waters of the Black Ross WQIP area, and especially Cleveland Bay.

Figure 2.4 Burdekin River Influence on Black Ross WQIP Area



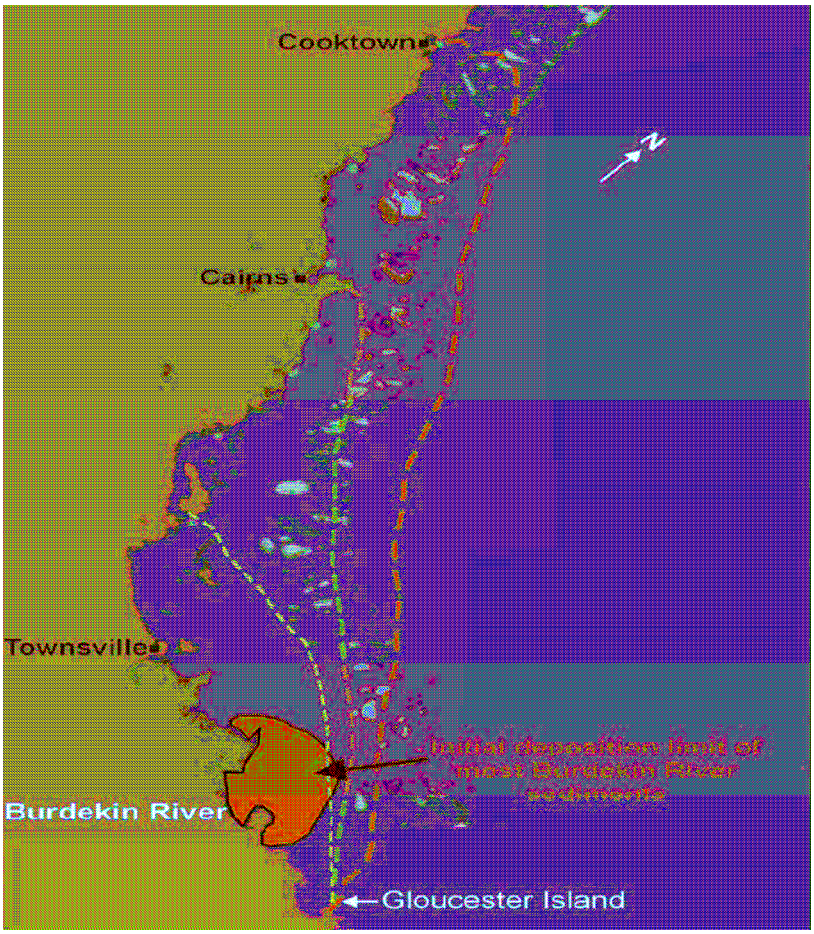
Source: Lewis et al 2006 ACTFR Report No. 06/02 (p.51)

Note: This satellite image of the 2005 Burdekin River shows the plume from the Mackay Whitsunday Rivers joining from the south with the northerly drift. The Burdekin River is characterised by a highly turbid plume near the delta followed by algal outbreaks further away from the river mouth.

"*Most sediments in the Burdekin River plume flocculate and settle out within 10 km from the delta* (see Figure 2.5)*, equivalent to the 0-10‰ salinity zone. These sediments are resuspended and deposited in sheltered north-facing embayments.*

Approximately 80-90% of the fine sediment fraction delivered from the Burdekin River is deposited in Bowling Green Bay while the remaining sediments are trapped within Upstart and Cleveland Bays" (Lewis et al 2006, p.41).

Figure 2.5 Burdekin River Sediment Extent



Source: Lewis et al 2006 ACTFR Report No. 06/02 (p.42)

Notes: Map of the extent of sediments exported from the Burdekin River in the GBR lagoon during very large-extreme events (red dashed line), large events (orange dashed line) and moderate events (yellow dashed line). The limit of the 0-10% salinity zone, where most of the sediment from the Burdekin River is deposited, is shown for the largest Burdekin flood on record (1974) by the red shading.

While the percentage of fine sediment from the Burdekin River discharge reaching Cleveland Bay is relatively small due to the high sediment load discharged from the Burdekin River the amount of fine sediment can be significant (see Table 2.1). Nutrients are also discharged from the Burdekin River and add to the loads discharged from the Black Ross WQIP area direct to Cleveland Bay and Halifax Bay.

Table 2.1 Relative Basin Size and Pollutant Discharge

Parameter	Black	Ross	Haughton	Burdekin
Catchment size (km²)	907	1,296	3,983	130,035
Total land use (%)	57.06	71.94	81.45	95.84
Annual run-off volume (km³)	0.38	0.49	0.74	10.29
Annual sediment export (tonnes)	140,000	180,000	270,000	3,770,000
Average suspended sediment event (mg/L)	N/A	22	110	394
Range of suspended sediment event (mg/L)	N/A	3-69	41-200	74-3,559
TN export (tonnes)	319	411	621	8,633
TP export (tonnes)	63	81	122	1,695

Extracted from Lewis et al 2006, p.1 (Table 1)

2.3 Marine Receiving Waters Condition

Improving the quality of the water entering the Great Barrier Reef lagoon, and in particular Cleveland and Halifax Bays, is the main priority for the Black Ross WQIP. The condition of these marine areas is affected by terrestrial runoff from various land use activities within the WQIP area. Land use is mostly urban and peri-urban in the Ross Basin and predominantly rural in the Black Basin. Flood plumes originating from the Burdekin and Haughton Basins also influence the marine waters of the Black Ross WQIP area, particularly during large flood events.

Recent water monitoring quality data (see Lewis et al 2008) and) and modelling (see BMT WBM 2009 and 2010) and to a lesser extent the Stuart Creek and Alligator Creek sub basins influence the inshore areas of Cleveland Bay. Flood plumes, especially in large events, move up the coast into Halifax Bay where plumes mix with run-off from the Bohle River, Black River and Bluewater Creek and, to a lesser extent from the Rollingstone Creek and Crystal Creek sub basins.

The smaller catchments of Magnetic Island have a limited impact on Cleveland Bay and Halifax Bay with their impact likely to be confined to the bays and near shore areas around the island.

Marine waters are fundamentally different to freshwaters due to higher salt concentrations, variable water depth, tidal influences and the expanse of the waterbody meaning certain water quality parameters are more important for measuring marine water quality condition. In addition, different biological indicators such as sea grass extent and coral condition are used to measure marine ecosystem health.

Marine areas are divided into a number of zones relative to distance from the coastline or continental shelf and the water depth. Near shore and enclosed waters are generally expected to have lower relative water quality than offshore areas due to their proximity to land based runoff and the re-suspension of sediment associated with wind and wave action in shallower water.

A set of draft water quality trigger values for chlorophyll a, suspended solids, particulate nutrients and secchi depth (a proxy measure for turbidity) have been developed (GBRMPA 2009). These values outline the levels that if exceeded may threaten the health of GBR ecosystems.

The GBR Marine Monitoring Program (MMP) has established several sites to measure water quality and ecosystem health, some of which are within or immediately adjacent to the WQIP study area. This program measures chlorophyll a, a full suite of nutrients with a particular focus on particulates, secchi depth and a range of ecosystem health parameters. Site description and sampling frequency is shown in Table 2.2 and results from this program are presented in Table 2.3. Marine sampling sites within and near the Black Ross WQIP area are displayed in Figure 2.6.

Impacts on the inshore reefs of Cleveland and Halifax Bay are most evident during flood events where the maximum values for chlorophyll a, turbidity and secchi depth all exceeded GBRMPA guidelines. Mean values for chlorophyll a also exceeded guideline values 46% of the time indicating that phytoplankton biomass was an issue of concern throughout the year (Schaffelke et al 2008).

In terms of turbidity Geoffrey Bay Reef had the highest mean turbidity in the Burdekin region of ~3 NTU. This was below the suggested 5 NTU limit for coral photo-physiological stress for ~90% of the time (Schaffelke et al 2008).

Table 2.2 Marine Sampling Sites

Site description	Sampling period	Samples
Chlorophyll a		
[1] Inside Cleveland Bay (M1)	26/10/1995 to 10/4/2003	58
[2] Magnetic - Geoffrey Bay (M2)	15/02/2007 to 2/07/2008	11
Nelly Bay Jetty (M3)	23/10/2005 to 9/03/2007	20
Outside Cleveland Bay (M10)	26/10/1995 to 10/04/2003	28
[3] Pandora Reef (M7)	27/10/1995 to 31/10/1996	12
[4] Townsville - Middle Reef (M5)	1/01/2007 to 6/06/2007	14
[5] Townsville Shipping Channel (M9)	3/12/2003 to 17/05/2008	10
MMP sites - nutrients etc		
[1] Cleveland Bay (middle)	21/09/2005	1
[2] Geoffrey Bay	21/09/2005 to 24/03/2008	6
Picnic Bay (M4)	21/09/2005 and 31/01/2006	2
Horseshoe Bay (M6)	21/09/2005	1
Magnetic Island (NE of Orchid rocks) (M8)	21/09/2005	1
[3] Pandora Reef	20/09/2005 to 25/03/2008	6
[4] Middle Reef	20/09/2005 to 15/04/2007	4
[5] Underway (Lodestone Reef - Magnetic Island)	31/01/2006	1

Note: MMP sites are listed in the lower rows and historic chlorophyll a sampling sites are listed in the upper rows. The [numbers] in the site description column indicate chlorophyll a sites that are in similar locations to MMP sites i.e. [1] Inside Cleveland Bay is in a similar position to [1] Cleveland Bay (middle). See Figure 2.6 for site locations.

Figure 2.6 Black Ross WQIP Marine Sampling Points

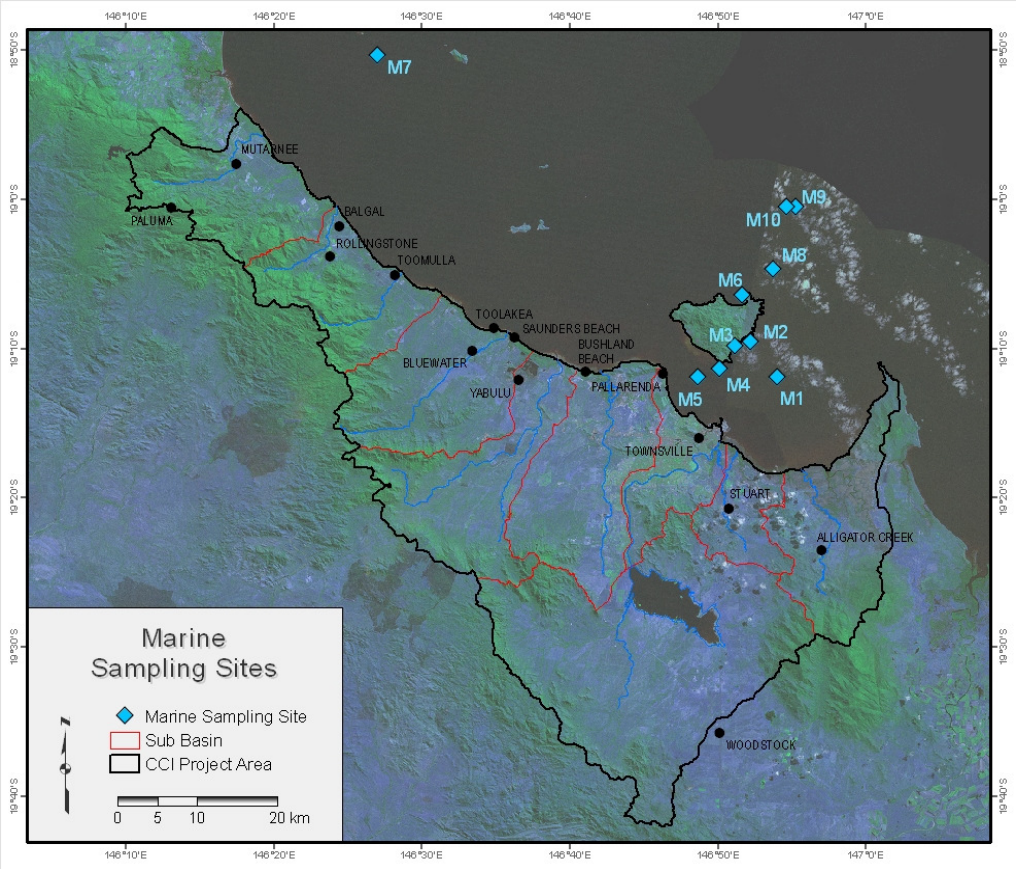


Table 2.3 MMP Sampling Results (Mean)

Site description	SS	Chl a	Secchi	NH4	NO2	NO3	DIN	TDN	DON	PN	TN	PO4	TDP	DOP	PP	TP
	mg/L	µg/L	m	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Cleveland Bay (middle)	2.295	0.32	6.5	0.000	0.000	0.000	0.000	52.061	52.061	13.163	65.224	2.999	17.070	14.071	2.081	19.151
Geoffrey Bay	4.524	0.88	4	1.118	0.417	1.611	3.145	69.113	65.968	20.725	89.838	3.134	8.455	5.321	4.552	13.006
Picnic Bay	2.48	0.96	4.25	1.651	0.000	0.460	2.111	74.358	72.247	22.828	97.187	2.483	15.396	12.912	3.810	19.205
Horseshoe Bay	4.14	0.45		0.000	0.000	0.000	0.000	71.361	71.361	17.896	89.257	2.809	19.314	16.505	3.404	22.717
NE of Orchid Rocks	2.07	0.26	9.5	0.000	0.000	0.000	0.000	57.833	57.833	13.582	71.415	3.133	16.700	13.567	1.748	18.448
Pandora Reef	2.12	0.47	6	0.776	0.010	0.325	1.111	63.946	62.835	12.965	76.910	2.533	7.808	5.327	2.649	10.457
Middle Reef	6.00	0.94	2.13	1.498	0.854	1.136	3.488	83.659	80.171	24.589	108.25	3.757	11.855	8.098	6.072	17.927
Underway	3.14	1.19		4.853	0.000	0.000	4.853	97.902	93.049	40.437	138.34	1.363	9.197	7.834	5.447	14.644
Inside Cleveland Bay		0.61														
Magnetic - Geoffrey Bay		0.53														
Nelly Bay Jetty		2.76														
Outside Cleveland Bay		0.39														
Pandora Reef		0.36														
Tvl - Middle Reef		0.52														
Tvl Shipping Channel		0.93														

Source: Australian Institute of Marine Science (AIMS) and GBRMPA Marine Monitoring Program (MMP) as input to Reef Plan reporting. (ClevelandBay_Data_for GBRMPA_Aug08/excel - Chlorophyll a [Chl_Cleveland bay worksheet]).

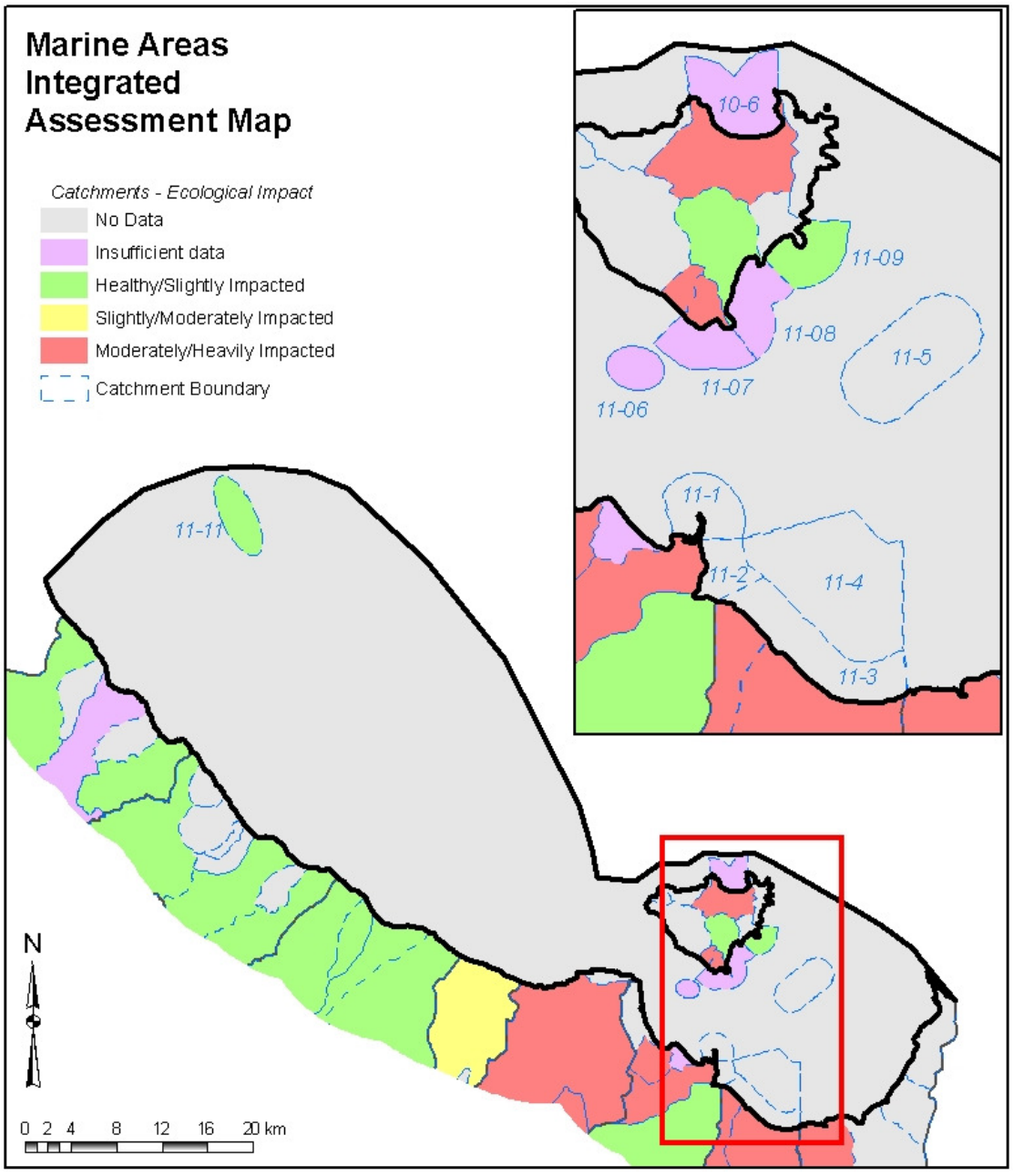
Studies suggest that generally the Burdekin average for hard coral cover is lower while macroalgae cover is higher when compared with other GBR regions. This may be attributed to the frequency and severity of disturbances to reefs in this region in recent times. Of the reefs monitored in the WQIP region hard coral cover was generally above the overall GBR wide mean but settlement of recruits was lower meaning fewer juvenile colonies and therefore negligible potential for increases in hard coral cover over time.

The exception in our WQIP region is Middle Reef, which continues to exhibit higher than the GBRMP average for hard coral cover and consequently lower than average macroalgae cover for data collected up until 2007/08 (Schaffelke et al 2008). However recent and unpublished data indicates that Middle Reef and other reefs around Magnetic Island have exhibited a significant loss in hard coral cover which is most likely the result of temperature and salinity (freshwater input) stresses, combined with an outbreak in coral disease in 2009 (pers. comm. Groves, P.). Given the lower than average coral recruitment to reefs in this region it is unlikely that these reefs will recover significantly in the short term.

A water quality condition analysis (Connell Wagner 2008) indicated that generally there is insufficient data to adequately assess the water quality for the marine areas of Cleveland Bay, Halifax Bay and the waters around Magnetic Island (see Figure 2.7). From the data available, of the twelve areas, three were assessed as slightly impacted, one was moderately impacted and one was heavily impacted. Of the remaining areas six have insufficient data and one has no data.

Recently recorded data for these areas were generally within the guideline values however the number of monitoring events and the parameters sampled make it difficult to determine the level of impact on these areas.

Figure 2.7 Marine Areas Ecological Impact



Source: Connell Wagner 2008

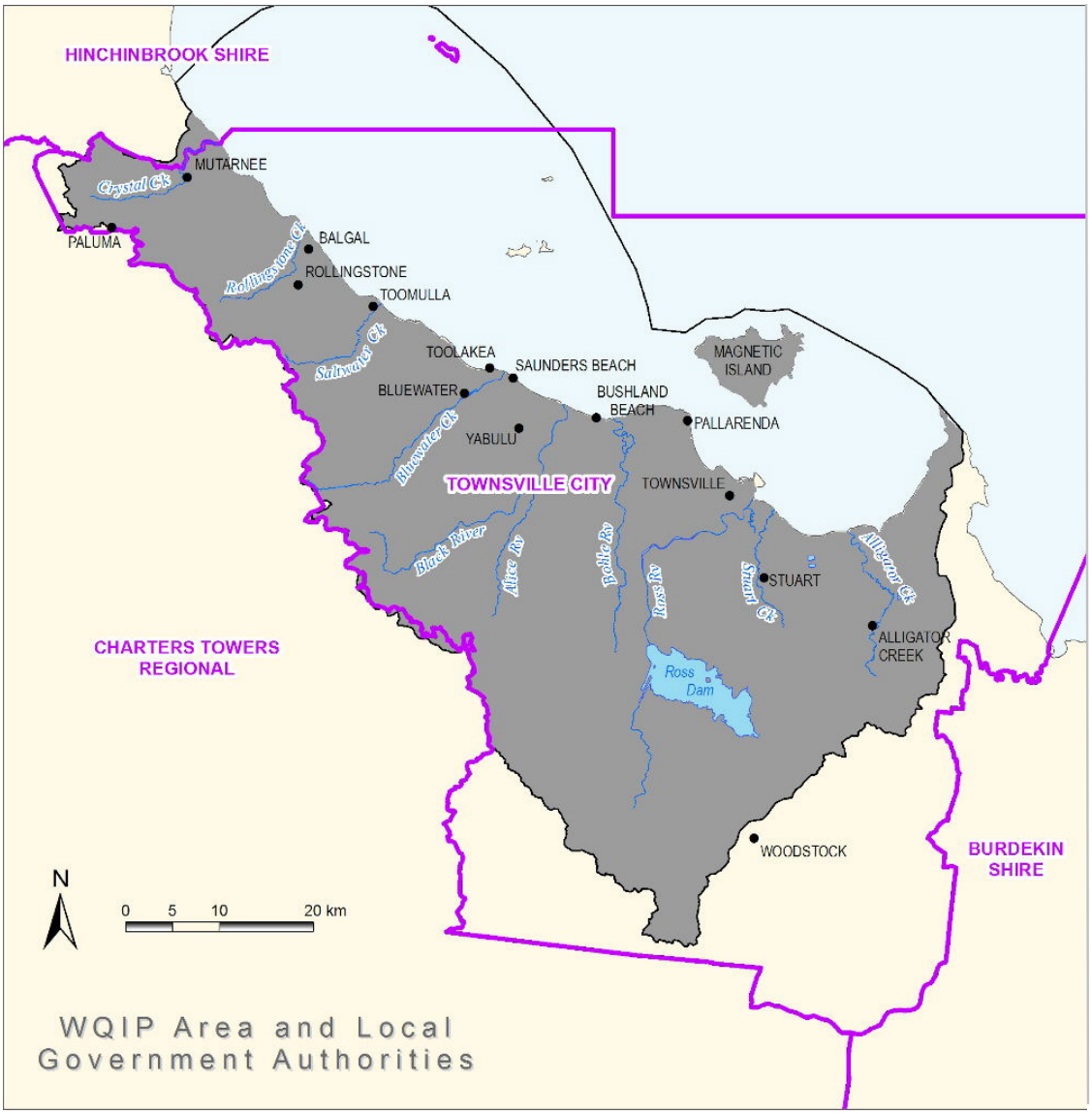
3. WQIP Area Overview

3.1 Introduction

Statistical and descriptive information is not readily available for the overall Black Ross WQIP area so a number of aggregations and disaggregations were required to provide a relevant overview (see *Black Ross Water Quality Improvement Plan – Socio-Demographic Profile* (Cardiff 2009) Townsville City Council). The overview is based primarily on the Townsville City local government area, which consists of the now combined Townsville and Thuringowa local government statistical divisions (Australian Bureau of Statistics), with some modifications to fit the WQIP area.

The Black Ross WQIP area is shown in relation to the Townsville City local government area in Figure 3.1.

Figure 3.1 Black Ross WQIP Area and Townsville LGA

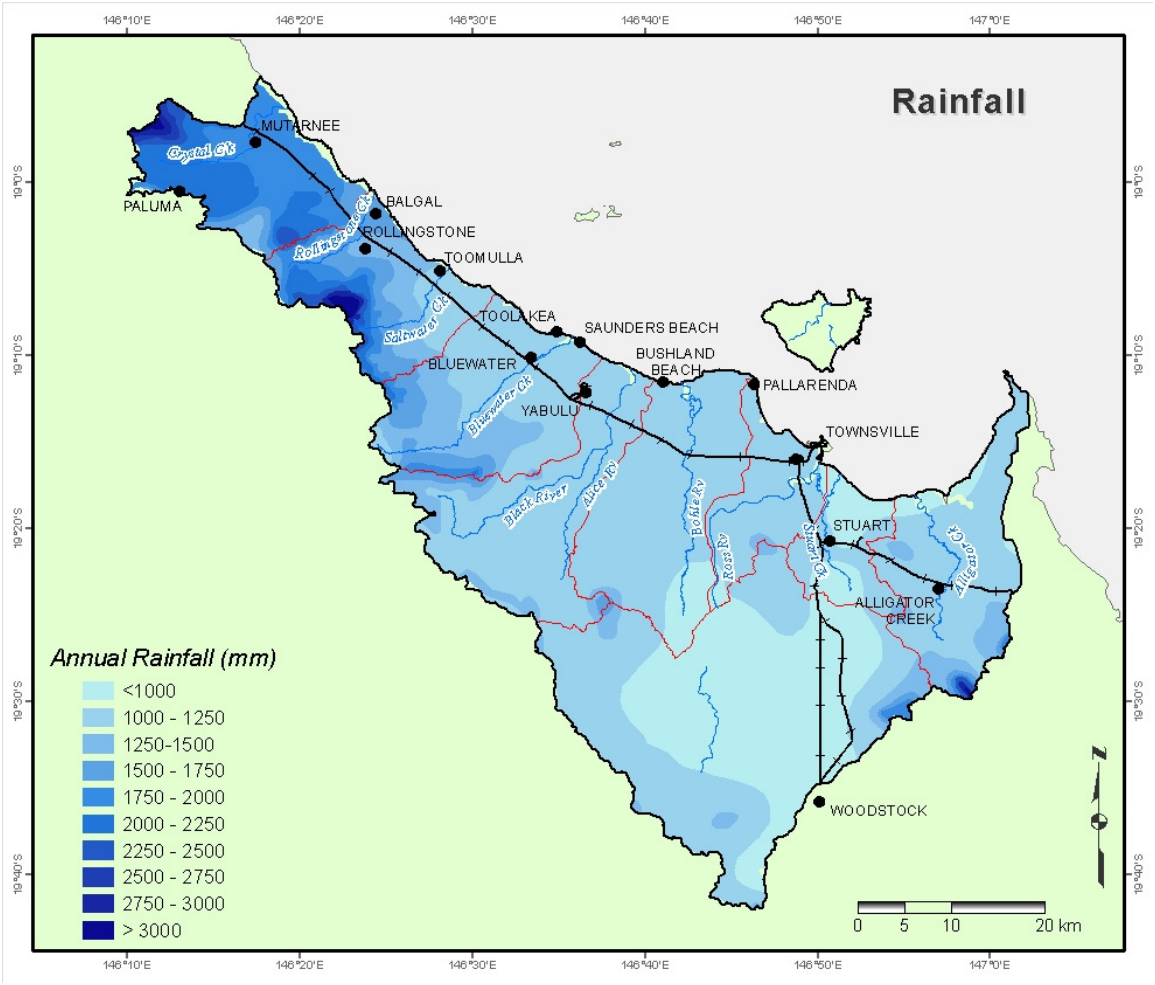


3.2 Climate

The region typically experiences a dry tropical climate, characterised by distinct wet and dry seasons. The typical yearly weather pattern features a short wet summer (December to March) with considerable rainfall, warmer temperatures and higher relative humidity, followed by a period of relatively cooler temperatures, lower humidity and minimal rainfall for the remainder of the year.

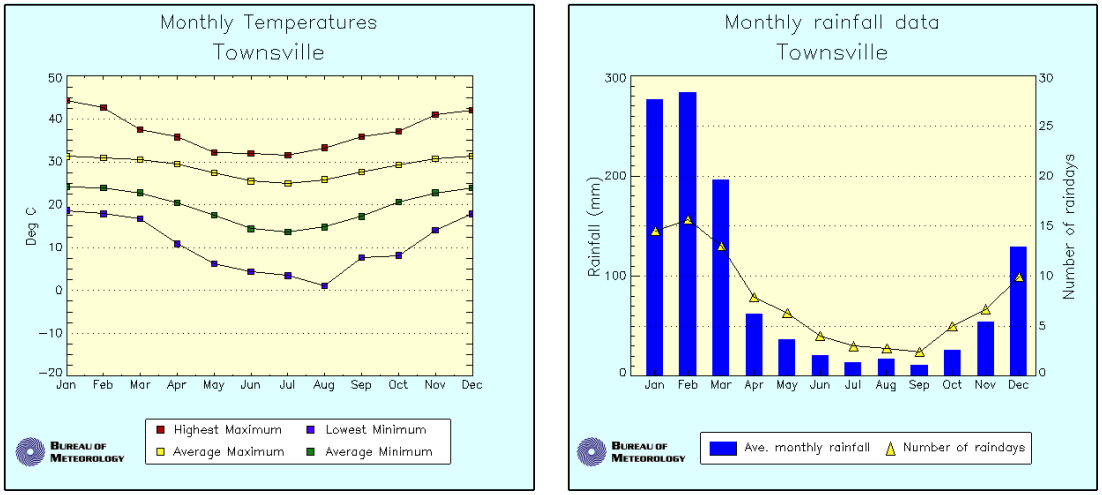
The average annual rainfall for Townsville is approximately 1,100 millimetres with substantial variation across the region from a high of 2,571 millimetres at Paluma (northern ranges) to a low of 853 millimetres at Woodstock on the western boundary of the WQIP area (see Figure 3.2). In comparison evaporation for Townsville is approximately 2,400mm per annum (BOM records 1969-1999).

Figure 3.2 Rainfall



High intensity tropical storms and cyclones are also a feature of the region's weather patterns.

Figure 3.3 Climatic graphs

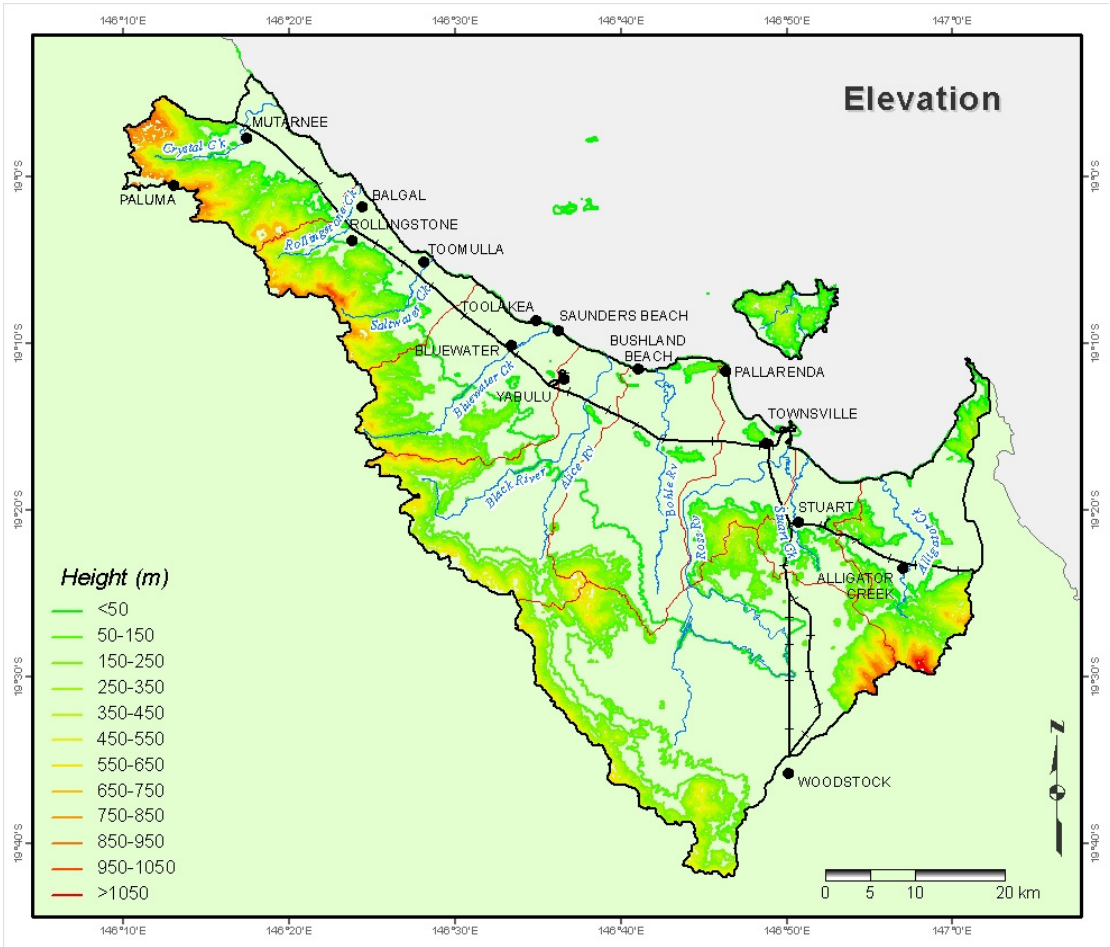


Source: Bureau of Meteorology (BOM)

3.3 Environment

"*The landscape of Townsville is an abrupt contrast between flat coastal lowlands, isolated mountain masses (Castle Hill, Mount Stuart and Mount Elliot) and the ramparts of the Hervey Range escarpment on the western horizon*" (Trezise and Stephenson 1990) (see Figure 3.4).

Figure 3.4 Elevation/Relief Map



A brief explanation of how the region has been shaped is provided in the section on geology (3.3.2).

The region can be roughly divided into four distinctive geographic sub-regions (see Figure 3.5):

- 1 Crystal Creek to Bluewater Creek sub basins – relatively short coastal streams draining the Paluma Range;
- 2 Black River, Bohle River and Ross River sub basins – larger drainage systems dissecting the sediments of the Townsville coastal plain, and bounded on the west by the Hervey Range;
- 3 Stuart Creek and Alligator Creek sub basins – relatively short coastal streams draining from the Mt Stuart and Mt Elliot isolated coastal mountain masses, and Cape Cleveland; and
- 4 Magnetic Island.

With the exception of some wet tropics vegetation on the Paluma Range and Mt Elliot (geographic sub-regions 1 and 3), the Black Ross (Townsville) WQIP area primarily consists of savanna landscapes generally described as the Dry Tropics. The Townsville dry tropics environment is primarily a function of the climatic regime, the underlying geology and the topographic features of the region. Sections of the ranges in geographic sub-region 1 are part of the Wet Tropics World Heritage Area (WHA).

Figure 3.5 Black Ross WQIP Geographic Sub-regions

Source: http://wiki.bdtnrm.org.au/index.php/Townsville_Catchments

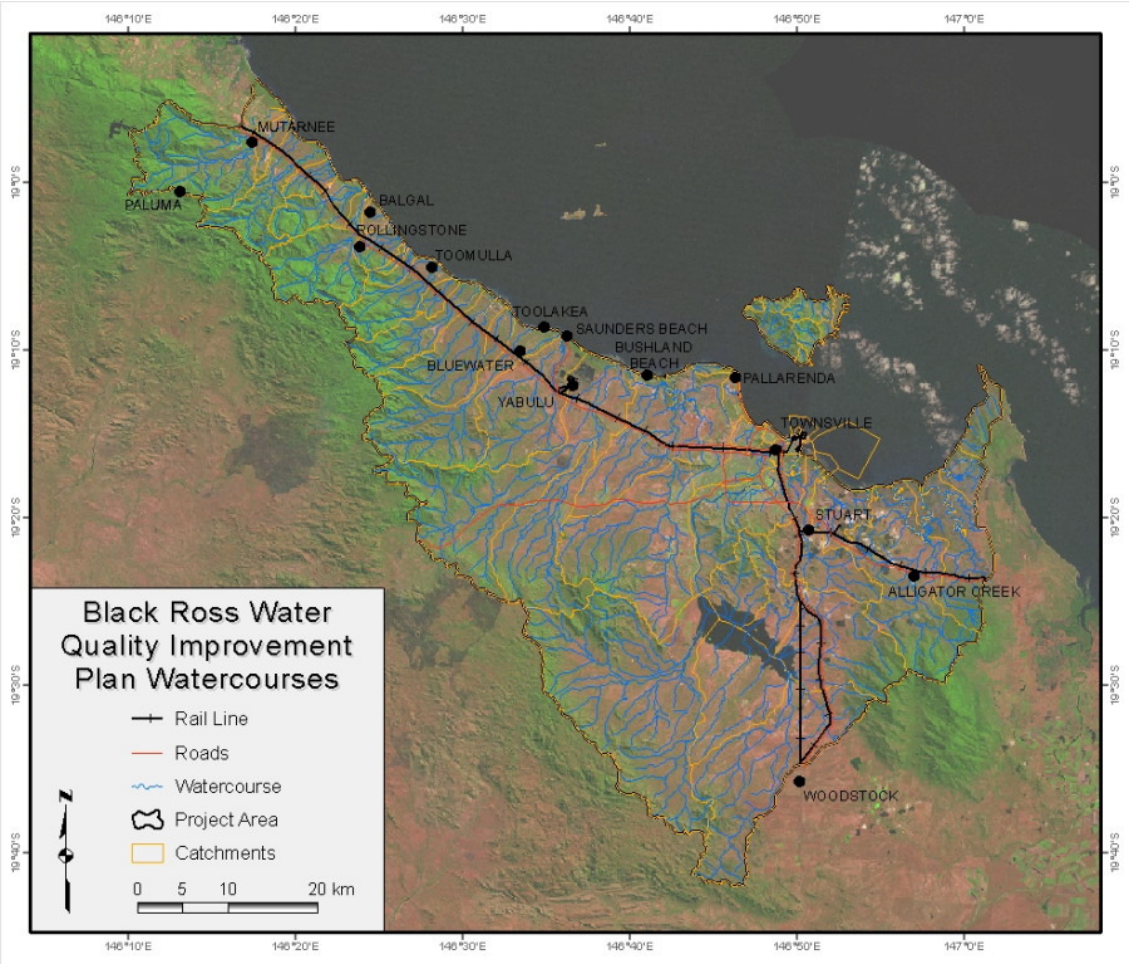
The main environmental features of the region are described briefly in the following sections.

3.3.1 Drainage

The study area is comprised of two major AWR drainage basins, the Black River and Ross River Basins. There are four rivers and numerous creeks and waterways, which drain the catchments from the escarpments of Mount Elliot, Herveys Range and the Paluma Range in the west to the coast. The drainage system generally trends from southwest/south, at the headwaters, to northeast/north at the coast.

The drainage of Magnetic Island is a radial system with waterways flowing from the high points in the centre of the island to the various bays around the island. The main drainage features, including minor tributaries, of the study area are illustrated in Figure 3.6 with more detailed drainage patterns for each sub basin in Chapters 5 to 14.

Figure 3.6 Drainage patterns of the Black/Ross WQIP area



3.3.2 Geology

The principle geological features of the Townsville region consist of remnants of Permian and Carboniferous volcanics and plutonics, protruding above the sedimentary deposits of the coastal plain. "*The regional geological setting for Townsville is complex; ancient rocks about 600 million years old form a basement of foundation which is largely concealed by rocks of younger igneous activity – volcanic eruptions and emplacement of molten granite magmas*" (Trezise and Stephenson 1990).

The oldest rocks in the Townsville region (formed 600 to 460 millions years ago) consist of remnants of a once extensive sedimentary and volcanic sequence, which now occurs around Charters Towers. This ancient basement rock was crumpled and metamorphosed around 480 to 460 million years ago with isolated outcrops occurring on the lower slopes of the Hervey Range and Frederick Peak plateau. Elsewhere they have been eroded away or buried by later volcanic activity.

The ensuing period (500 to 250 million years) was dominated by activities associated with the Tasman Orogenic Zone. This included periods of upheaval and mountain building associated with the movement of tectonic plates, formation and submergence of basins and subsequent erosion of mountains and formation of marine sediments. The evidence of this activity can be seen in the limestone deposits at Calcium, to the west of the Black/Ross WQIP area. While difficult to imagine it is conjectured that the mountains formed in the Tasman Orogenic Zone might have been as significant as the present European Alps.

Following this period of mountain building and erosion there was a period (320 to 286 million years ago) of large-scale eruptions of volcanic material i.e. rhyolite, dacite and andesite. This series of explosive events created large sheets of welded and compacted, very hard volcanic rock. Towards the end of this volcanic episode (296 to 283 million years ago) molten magma rose up through the denser surrounding basement rock to push into and push aside the base of the volcanic pile. The magma slowly cooled to form granites. The granites were eventually exposed after erosion of the older rocks above.

Another period of volcanic activity occurred during the early Permian period (286 to 258 million years ago) believed to be associated with tectonic plate movement. The Julago Volcanics are the remnants of this event with considerable volumes of the material having been eroded. Remnants include parts of Mount Stuart and the hills to the southeast as well as Mount Saint John, Mount Bohle and the Many Peaks Range. As with the earlier volcanic event after the Julago Volcanics ceased erupting a period of magmatic intrusion took place. The Magnetic Island Granite, Muntalunga Range Granite and Mount Storth Granite were formed from this process, along with a number of unnamed intrusions northwest of Townsville and Cape Cleveland.

There was a long period of stability (150 million years) marked mainly by erosion, which removed much of the volcanic sequences to expose the underlying granitic rocks. There was a further period of granitic intrusion during the Cretaceous (144 to 100 million years ago) however most of the activity was off shore from Townsville with the only landward evidence of the activity being near Mount Margaret.

Over the next 45 million years (100 to 55 million years ago) an extensive erosion surface was formed with parts of this surface being older. The Hervey Range and Frederick Peak plateau are sections of this surface. Around 65 million years ago there was a significant event, which resulted in the sinking of part of the Australian landmass including the formation of the Townsville Trough and Halifax Basin. This formed a new escarpment, which gradually eroded westwards eating into the higher Cretaceous erosion surface to eventually reach its current position along the Hervey Range. More resistant rocks were left behind as remnant mountains and hills such as Mount Stuart and Mount Elliot.

Sediments resulting from this Tertiary erosion were deposited on the newly formed coastal plain and offshore. Fluctuating sea levels of recent times (last 2 million years) has seen periodic exposure and erosion of the continental shelf with subsequent sea level rise then resulting in erosion of coastal features and a change in marine sediment deposition.

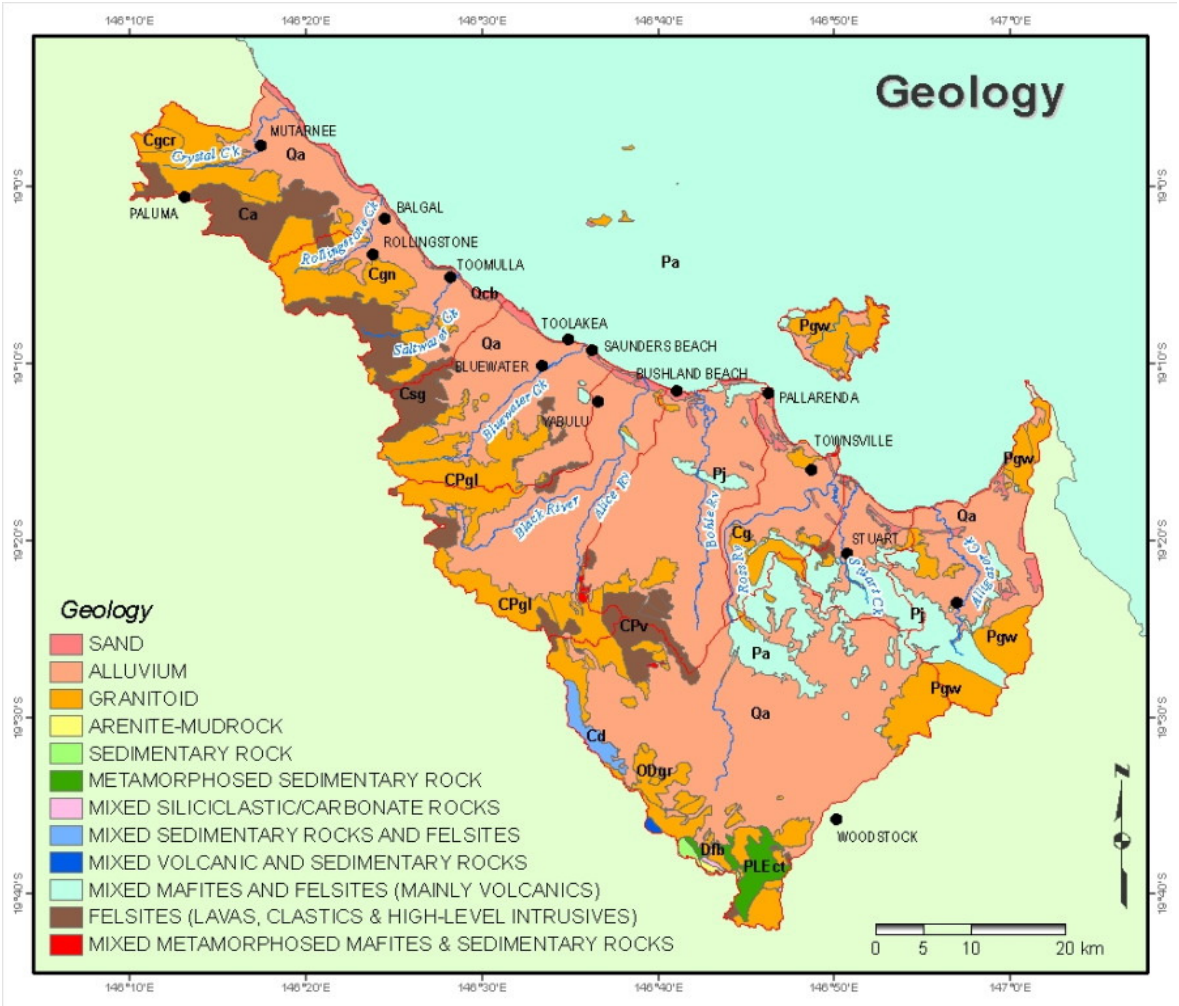
The coastal plain as we see it now is composed of relatively coarse recently weathered and eroded material at the base of the Hervey Range grading into the older (Pleistocene) alluvial plains towards the coast. The material of the alluvial plains was deposited mainly by braided stream systems with a sequence of abandoned and infilled channels visible as slightly raised areas in the Ross, Bohle, Alice and Black River catchments.

Most of the present drainage pattern across the Townsville coastal plain has emerged over the last 6,000 years with the larger rivers and streams cutting narrow channels into the older alluvial plain.
(Source: Trezise and Stephenson 1990).

The major bedrock type for the Black and Ross Basins is igneous material (>95%) compared to the average for the GBR catchments of 62% sedimentary, 34% igneous and 3% metamorphic (Furnas 2003, p. 53). It is the underlying geology of the area, along with the landscape forming functions over time, and climatic conditions that influences the soil types of the region.

The main geological features of the Black Ross (Townsville) WQIP areas are illustrated in Figure 3.7. A key to the geological features is provided in Table 3.1.

Figure 3.7 Main Geological Features



Source: Department of Natural Resources, Mines and Energy (now DERM). Extracted from the Mineral and Energy Resources Location and Information Netowrk (MERLIN) corporate database, July 2004. The data was captured at a scale of 1:25,000. Also applies to Table 3.1

Table 3.1 Geology Key

Dominant Rock	Symbol	Age	Formation	Description
Sand	Qcb	Quaternary		Quartz sand, minor shells (beach barrier deposits)
Alluvium	Qa	Quaternary		Clay, silt, sand, gravel; floodplain alluvium
Granitoid	Cg	Carboniferous		Undivided and/or unassigned granite and granodiorite
	Cgcr		Coane Range Granite Complex	Pink, grey, cream, and orange, fine to coarse-grained, equigranular, seriate, and porphyritic biotite granite and common microgranite; local greisen
	Cgk		Kallanda Granites	Pink, orange, or cream, fine to coarse-grained, porphyritic to seriate biotite granite; common microgranite and abundant greisen and chloritic alteration zones
	Cgn		Clemant microgranite	Grey to pink, abundantly porphyritic biotite microgranite

	Cgrs		Rollingstone Granite	Mottled cream and pink, fine to medium-grained, slightly to abundantly porphyritic biotite granite
	CPgi	Late Carboniferous – Early Permian	Ingham Granite Complex	Pale grey to pale pink, fine to medium-grained porphryritic hornblende-biotite and biotite monzogranite and granodiorite; undivided granites of the northern Ingham Batholith (I-types)
	CPgl	Carboniferous – Early Permian	Leichhardt Suite	Grey biotite and hornblende-biotite granodiorite and granite; microgranite, dacite and volcaniclastic rocks in high-level complexes
Granitoid	Kg	Cretaceous		Hornblende-biotite granodiorite, biotite granite
	ODgr	Ordovician - Devonian	Ravenswood Baotholith	Undivided and/or unassigned granodiorite, tonalite and quartz diorite, minor granite
	Pgw	Permian	Woodstock Supersuite	Pink to red medium-grained, locally miarolitic biotite granite; hornblende-biotite granodiorite, diorite, gabbro
Arenite - Mudrock	Dfc	Middle Devonian	Cultivation Gully Formation	Feldspathic sandstone, yellowish grey to light brown mudstone and siltstone and minor limestone; marine fossils
Sedimentary	Dd	Late Devonian	Dotswood Group	Undivided feldspathic to quartzose sandstone, polymictic conglomerate, and red mudstone and siltstone
	Df	Early - Middle Devonian	Fanning River Group	Undivided calcareous, fossiliferous, feldspathic sandstone, pebbly sandstone and conglomerate, and fossiliferous limestone
Metamorphosed Sedimentary	PLEct	Neo proterozoic - Cambrian	Charters Towers Metamorphics	Mica schist, quartzite, quartz-feldspar-biotite gneiss, hornblende schist; cordierite, andalusite and staurolite hornfelsed, chlorite schist, marble
Mixed siliciclastic carbonate rocks	Dfb	Early - Middle Devonian	Burdekin Formation	Fossiliferous limestone (calcirudite, calcarenite, and lesser calcilutite); minor sandy limestone, calcareous sandstone and mudstone
Mixed sedimentary and felsites	Cd	Early Carboniferous	Mt Douglas Formation	Conglomerate, pebbly sandstone, volcanilithic sandstone, tuffaceous siltstone, rhyolitic ignimbrite and crystal-vitric tuff
Mixed volcanic and sedimentary	CPe	Carboniferous	Ellenvale Beds	Rhyolitic lavas and volcaniclastics, rhyolite breccia, andesite, subgreywacke, feldspathic sandstone, conglomerate, shale, mudstone
Mixed mafites and felsites	Cp	Carboniferous	Percy Creek Volcanics	Basaltic to andesitic lava and volcaniclastics, some rhyolitic ignimbrite
	Pa	Early Permian	Agate Creek Volcanic Group	Basaltic to andesitic lava and volcaniclastics, some rhyolitic ignimbrite
	Pj	Permian	Julago Volcanics	Rhyodacitic welded tuff, agglomerate, andesite, basalt, mudstone, quartzose sandstone
Felsites	Ca	Carboniferous	Paluma Rhyolite	Dark grey, crystal-rich to very crystal-rich rhyolitic ignimbrite

	CPi	Late Carboniferous – Early Permian		Undivided and/or unassigned microgranite, microgranodiorite and granophyre
	CPv	Late Carboniferous – Permian		Unassigned. mainly felsic volcanic rocks, including ignimbrite, lava and epiclastic rocks
	Csg	Carboniferous	Saint Giles Volcanics	Grey to dark grey, sparsely to moderately crystal- and clast-rich, rhyolitic to dacitic ignimbrite, lapilli tuff, and minor breccia; minor flow-banded, spherulitic, moderately porphyritic rhyolite lava
Mixed metamorphosed mafites and sedimentary	PLa/ca	Proterozoic – Early Palaezoic	Argentine Metamorphics	Laminated amphibolite (para?), quartzite, banded-iron-formation, subordinate mica schist

3.3.3 Soils

The dominant soils of the region (78% of all the soils) are saline clays or shallow, sandy loams with a clay substructure (duplex soils). Soil moisture is a major constraint for production in the region. In fact, soil water recharge potential is very limited west of the Bohle River, north of Hervey Range Road and on the Townsville coastal plain. As a result there is limited intensive agriculture in the region with the exception of the area adjoining the wet tropics region i.e. Crystal and Rollingstone Creek sub basins. The areas of the main soil types in the Black and Ross Basins are listed in Table 3.2 and Table 3.3.

Table 3.2 Soil Structure Types

Element (GBRC%)	Black River (117)		Ross River (118)		Black Ross WQIP Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Clay (16.1)			12,300	7.2	12,300	4.5
Duplex (24.9)	46,400	43.9	108,600	63.6	155,000	56.1
Earth (24.7)	57,400	54.4	32,300	18.9	89,700	32.5
Loam (11)			7,300	4.3	7,300	2.6
Sand (11.9)	1,800	1.7	9,800	5.7	11,600	4.2
Unclassified (0.4)			400	0.2	400	0.1
Totals	105,600		170,700		276,300	

Source: Furnas 2003 (pp. 57-58) Table 8 Dominant soil structural types (Source Soils of Australia digital coverage 1999)
Note: Other soil types not mentioned in the Black and Ross Basins: Red, Brown, Yellow (11% GBR), Organic (0.4% GBR) (p. 58)

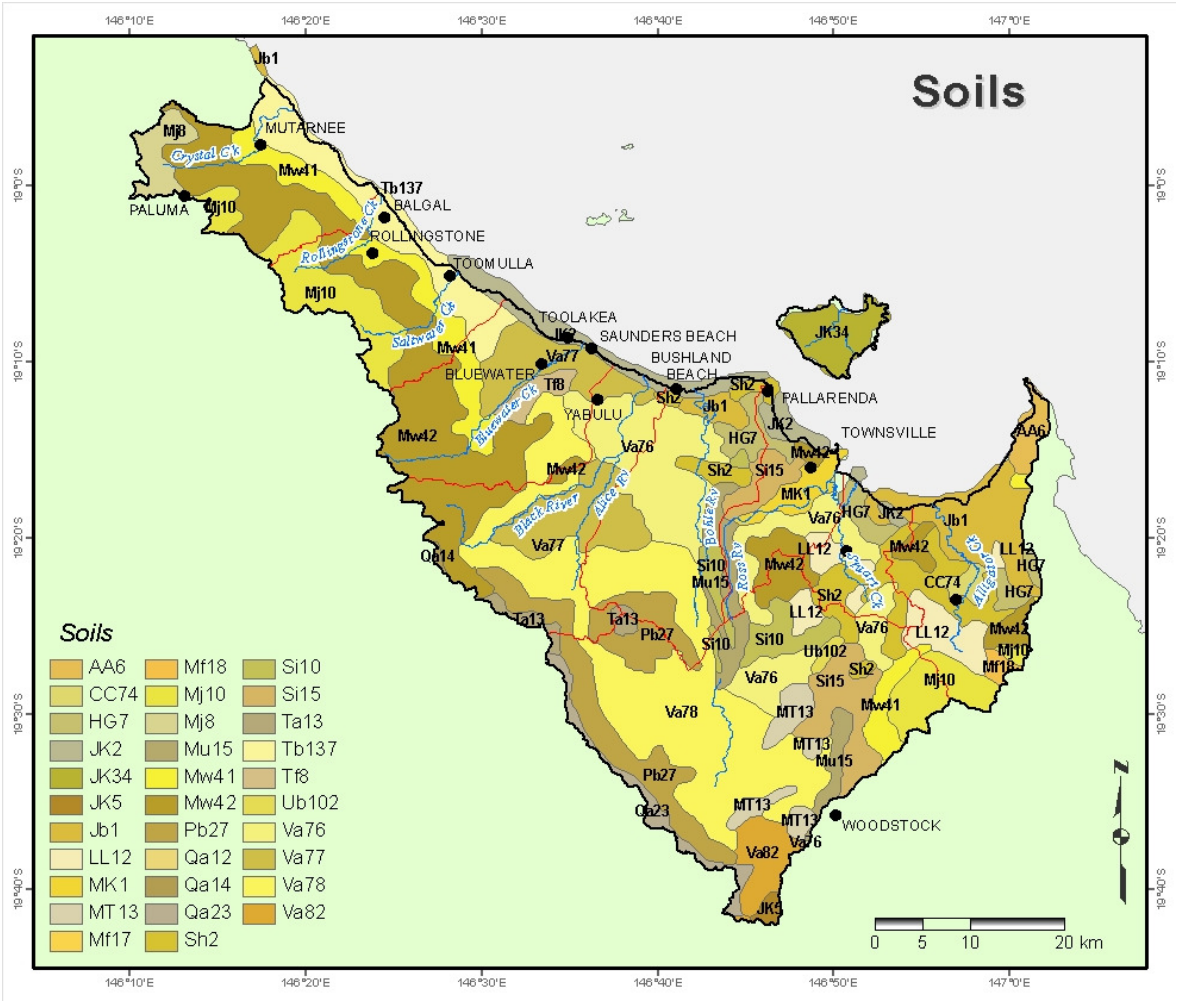
Table 3.3 Australian Great Soil Groups

Soil Group	Black River (117)		Ross River (118)		Black Ross WQIP Area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Alluvial Soil	1,800	1.7	19,900	11.7	21,700	7.9
Grey Clay		0.0	1,300	0.8	1,300	0.5
Gleyed Soil		0.0	4,100	2.4	4,100	1.5
Humic Gley		0.0	11,000	6.4	11,000	4.0
Krasnozem	13,000	12.3	8,900	5.2	21,900	7.9
Red Earth	44,600	42.2	18,700	10.9	63,300	22.9
Solodic Soil	800	0.8	8,700	5.1	9,500	3.4
Red Podzolic	3,200	3.0	12,300	7.2	15,500	5.6
Yellow Podzolic	42,200	40.0	85,500	50.1	127,700	46.2
Unclassified		0.0	400	0.2	4	0.1
Totals	105,600		170,800		276,400	

Source: Furnas 2003 (p. 56) Table 7 Australian Great Soil Groups (Source CSIRO 1999)

Soil type distribution across the Black Ross (Townsville) WQIP area is illustrated in Figure 3.8 with a key to the soil types listed in Table 3.4.

Figure 3.8 Soils



Source: Digital version of the Atlas of Australian Soils at 1:2,000,000 (Northcote et al. 1960-1968). Digital version created by NRIC in 1991 from scanned tracings of the published hardcopy maps. Original survey completed by CSIRO. Also applies to Table 3.4

Table 3.4 Soils Key

Code	Landscape position	Soil general description	Dominant
AA6	Hilly or high hilly lands with very steep slopes	Brownish sands	Uc5.11
CC74	Level alluvial plains with slight to moderate gilgai microrelief	Grey self-mulching cracking clays	Ug5.24
HG7	Level alluvial plains which merge seaward into tidal flats mangrove swamps & salt pans	Hard setting black duplex soils	Dd1.33
Jb1	Salt pans & tidal flats or salt water couch meadows merging into mangrove swamp	Non-cracking plastic clays	Uf6.62
JK2	Low fixed sand dunes paralleling the coastline	Pale sands with a colour B horizon	Uc4.21
JK34	Hilly lands with steep slopes & much granite tor outcrop		Uc4.21
JK5	High hilly lands with steep slopes & high scarped margins		Uc4.2
LL12	Hilly to high hilly lands with very steep slopes narrow ridge crests	Pale loams with a colour B horizon	Um4.21

Mf17	Moderately to strongly undulating or occasionally low hilly plateaux	Yellow smooth-ped earths	Gn3.74
Mf18	High hilly to mountainous lands with much acid or intermediate volcanic rock outcrop		Gn3.74
Mj10	High hilly or mountainous lands often with very steep slopes & precipitous scarps	Red smooth-ped earths	Gn3.14
Mj8	Hilly high plateaux often bounded by precipitous scarps		Gn3.14
MK1	Alluvial delta plains with a complex pattern of present & prior stream channels &levees	Brown or mottled-red massive earths	Gn2.42
MT13	Gently undulating lands	Grey massive earths	Gn2.94
Mu15	Level alluvial plains with numerous old meander channels & terraces	Red massive earths	Gn2.15
Mw41	Gently undulating to undulating outwash slopes & fans		Gn2.14
Mw42	High hilly to mountainous lands with very steep slopes		Gn2.14
Pb27	Extremely steep dissected mountain scarps & steep-sided high hills	Hard setting red duplex soils	Dr2.21
Qa12	High hilly lands with some mountainous areas nearly all hills have steep slopes but crests are often rounded		Dr2.12
Qa14	Moderately or less commonly strongly undulating lands with occasional isolated hills surrounded by strongly dissected steep slopes		Dr2.12
Qa23	Moderately or strongly undulating plateau		Dr2.12
Sh2	Gently undulating to undulating footslopes & outwash fans & some isolated low hills	Hard setting yellow duplex soils	Dy2.32
Si10	Level alluvial plains		Dy2.33
Si15	Level alluvial plains with slightly elevated old levees & shallow prior & present stream channels		Dy2.33
Ta13	Moderately undulating plateau with many low knolls	Hard setting mottled-yellow duplex soils	Dy3.21
Tb137	Very gently undulating alluvial plains rising to gentle outwash slopes & low foothills		Dy3.41
Tf8	Very gently undulating alluvial plains		Dy3.81
Ub102	Very gently undulating plains with many relic stream channels & levees		Dy3.42
Va76	Alluvial plains with some low stream levees & relic infilled stream channels		Dy3.43
Va77	Gently undulating alluvial plains with numerous stream levees & channels		Dy3.43
Va78	Gently undulating to undulating outwash slopes & fans with occasional isolated low hills		Dy3.43
Va82	High hilly to mountainous lands with very steep slopes		Dy3.43

Soil type (including clay content) and structure (including organic content) is significant in terms of water quality as the erodibility, permeability and nutrient content of soils can impact the amount of sediment and nutrients entering waterways. Water availability is also important in the microbial breakdown of soil organic matter with wet tropics soils generally having higher concentrations of organic matter, nitrogen (N) and phosphorus (P) than dry tropic soils. Furthermore the highest concentrations of organic matter, N and P are usually near the surface and throughout the GBR catchment are broadly correlated with the clay content. It is of course these surface areas that are most prone to disturbance and erosion. The amount of vegetation cover is the other key factor influencing erosion potential.

Clay, organic carbon and nutrient content of soils in the Black and Ross Basins are displayed in Table 3.5. It should be noted that there has been limited soil sampling of this kind throughout the GBR catchment and figures are therefore subject to relatively high uncertainties.

Table 3.5 Clay, Carbon and Nutrient Content of Soils

Element	Black River (117)	Ross River (118)
Clay %	12 ± 5	10 ± 6
Organic C %	1.1 ± 0.7	1.2 ± 0.3
Total N (% dry weight)	0.10 ± 0.04	0.08 ± 0.03
Total P (% dry weight)	0.019 ± 0.018	0.014 ± 0.005

Source: Furnas 2003 (p. 61) Table 10 Average (+ 1 standard deviation) clay, organic carbon and nitrogen content of surface soil samples (Sources literature DNRM, DPI, CSIRO)

Note: Average total (of dry soil weight) for GBR catchments of N ~ 0.15% (1500 parts per million) and P ~ 0.05% (500 ppm).

"*Most measurements of erosion from undisturbed land have been made to compare with soil loss rates from experimental cropping or grazing plots. There are considerable differences between soil loss rates from plots (<1 km²) or small catchments (<100 km²) and the net export of sediment from whole river catchments due to short-range soil movements within sub-catchments and sediment storage in catchments. Broad-scale estimates of sediment delivery to the GBR based on relationships between land use and soil loss produce reasonable estimates when they assume that net sediment export is only 10% of the landscape soil erosion rate (delivery ratio = 0.1)*" (Furnas 2003, p.138)

3.3.4 Vegetation

The local vegetation reflects the particular climate and weather patterns of the area and contrasts with the wetter north and drier west. Topography and soils also play an influential role in determining vegetation type and density. Dry tropical and eucalypt dominated savanna vegetation prevails in the lowlands and reaches the coast in places with deciduous vine thickets occurring as a mosaic of isolated patches. Narrow riverbank communities thread through the coastal plain and are heavily populated by Eucalyptus and Melaleucas. Rainforests are prevalent in the high rainfall upland areas of Mount Elliot in the southeast and the Paluma Range in the north.

The percentage groundcover i.e. vegetation cover, has been shown to significantly influence the erosion potential of soils and the likelihood of sediment reaching waterways. The condition of riparian vegetation is also important as it influences the movement of eroded soil and associated nutrients into watercourses.

"*Soil erosion, which begins the movement of soil and nutrients from catchments, is a continuous, but entirely natural part of landscape change and evolution. There is clear evidence, however, that human land use has changed soil erosion rates at the landscape level*" (Furnas 2003, p. 129). The accelerated erosion rates are associated primarily with the reduction of vegetation cover, often associated with the change of land use from natural areas to more intensive uses. The level of disturbance influences the erosion rate and is exacerbated by local and regional topography, soil types and drainage patterns. Estimates of cleared areas in the Black and Ross Basins, compared to the overall GBR catchment, are provided in Table 3.6.

Table 3.6 Vegetation Cleared

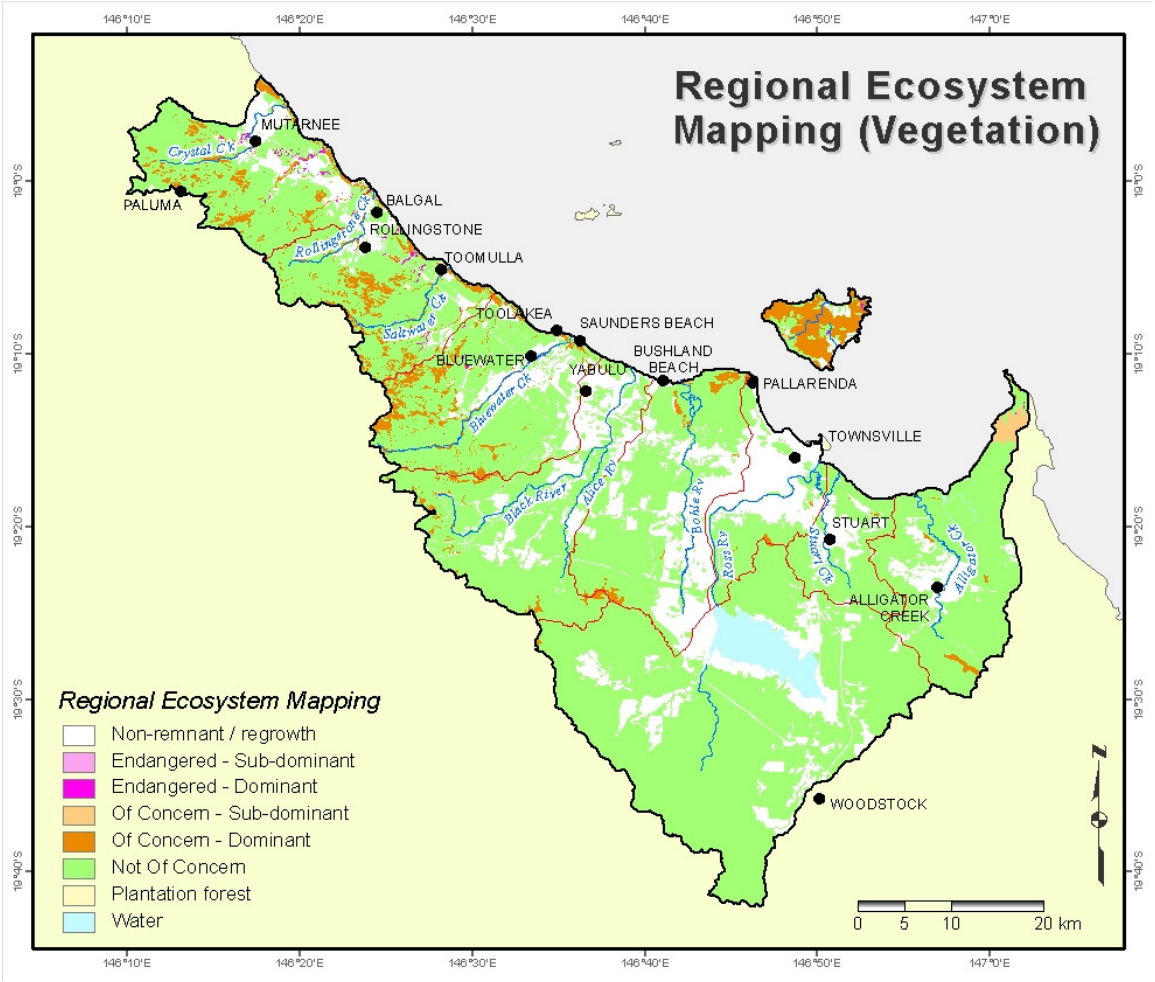
Element	Black River (117)	Ross River (118)	GBR Catchment
Basin area (km²)	1,057	1,707	423,070
Cleared (km²)	55 – 5.2% [16.2%] (17%)	336 – 19.7% [25%] (26.3%)	95,100 - 22% [37.6%] (38.3%)
Thinned (km²)	446	893	147,000 - 35%
Uncleared (km²)	539	442	169,000 - 40%
Intermediate (km²)			9,216 – 2.2%
Unclassified (km²)	17	36	

Source: Furnas 2003, p.140 and 144) Table 25 Estimates of land clearing in GBRC (ca. 1988) from analysis of satellite imagery (p.140) Data Graetz et al 2005 and Table 28 Estimates of remnant vegetation GBRCs.

Note: In general figures are for calculations based on 1988 information and are in square kilometres and percentages of total basin area. Figures in [square brackets] are calculated percentages of cleared areas in 1997 and figures in (brackets) are calculated percentages of cleared areas in 1999.

Remnant vegetation cover and cleared/disturbed areas are shown on the regional ecosystem mapping (DERM/EPA) in Figure 3.9. It should be noted that regional ecosystem mapping does not take into account the condition of vegetation or the actual groundcover and as such is not a good indicator of erosion potential or riparian condition status. It does however provide a starting point for assessment in lieu of more detailed condition assessments.

Figure 3.9 Remnant Vegetation (Regional Ecosystem) Status



3.3.5 Fauna

The fauna of the region also reflects the regions unique combination of climate, topography and coastal location. Arid land species may be found in close proximity to wet tropics species. A key feature of the area is the importance of coastal wetlands for migratory and drought nomadic species. The large and abrupt boundary changes between areas of mono-specific deciduous Eucalypt and Melaleuca woodlands are important to local ecology.

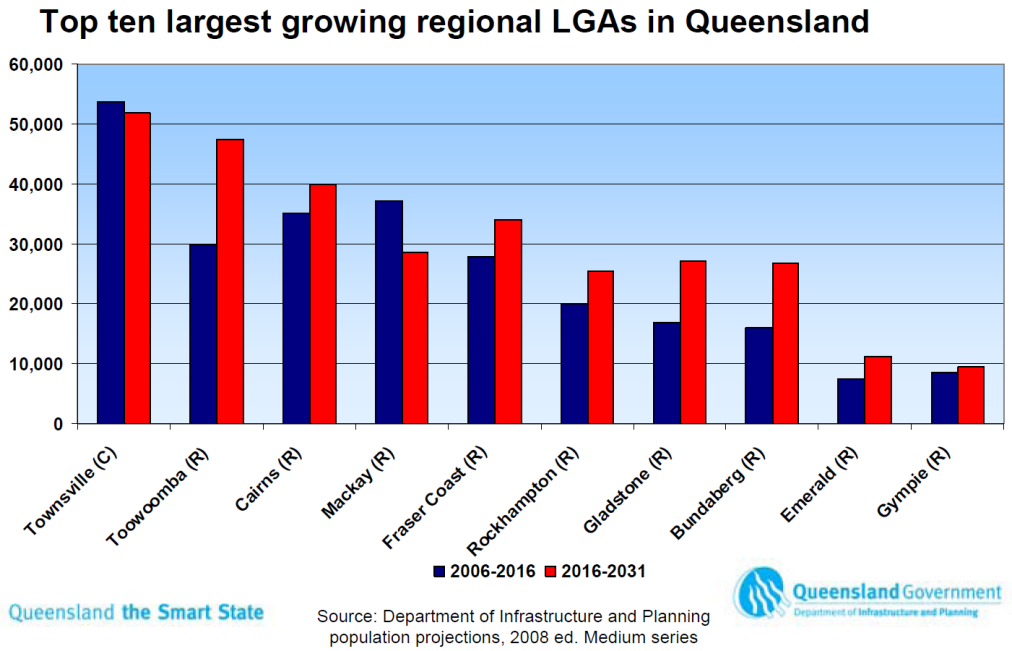
3.4 Socio Economic Summary

The following summary is indicative of the growth being experienced in Queensland and does not reflect a sustainable environmental situation.

3.4.1 People

The amalgamated City of Townsville covers an area of 3,736 square kilometres, encompassing the Black Ross (Townsville) Water Quality Improvement Plan (WQIP) area. Townsville's position as a coastal port town on the Ross River along with mineral processing industry and a large military base means it is well placed as a focal point of the region. Due to its status as a strong and vital regional centre, Townsville attracts and continues to attract growth. Townsville's population growth makes it one of the top ten largest growing regional local government areas in the state (see Figure 3.10).

Figure 3.10 Regional Growth Comparison



In 2005 (the base year for the Black Ross WQIP relative to updated land use mapping) the Estimated Resident Population (ERP) for Townsville stood at 160,220, representing an annual increase of 3.1% from 2004. Estimated resident population (ERP) trends are shown in Table 3.7 and Figure 3.11.

Table 3.7 Estimated Resident Population Growth Trends

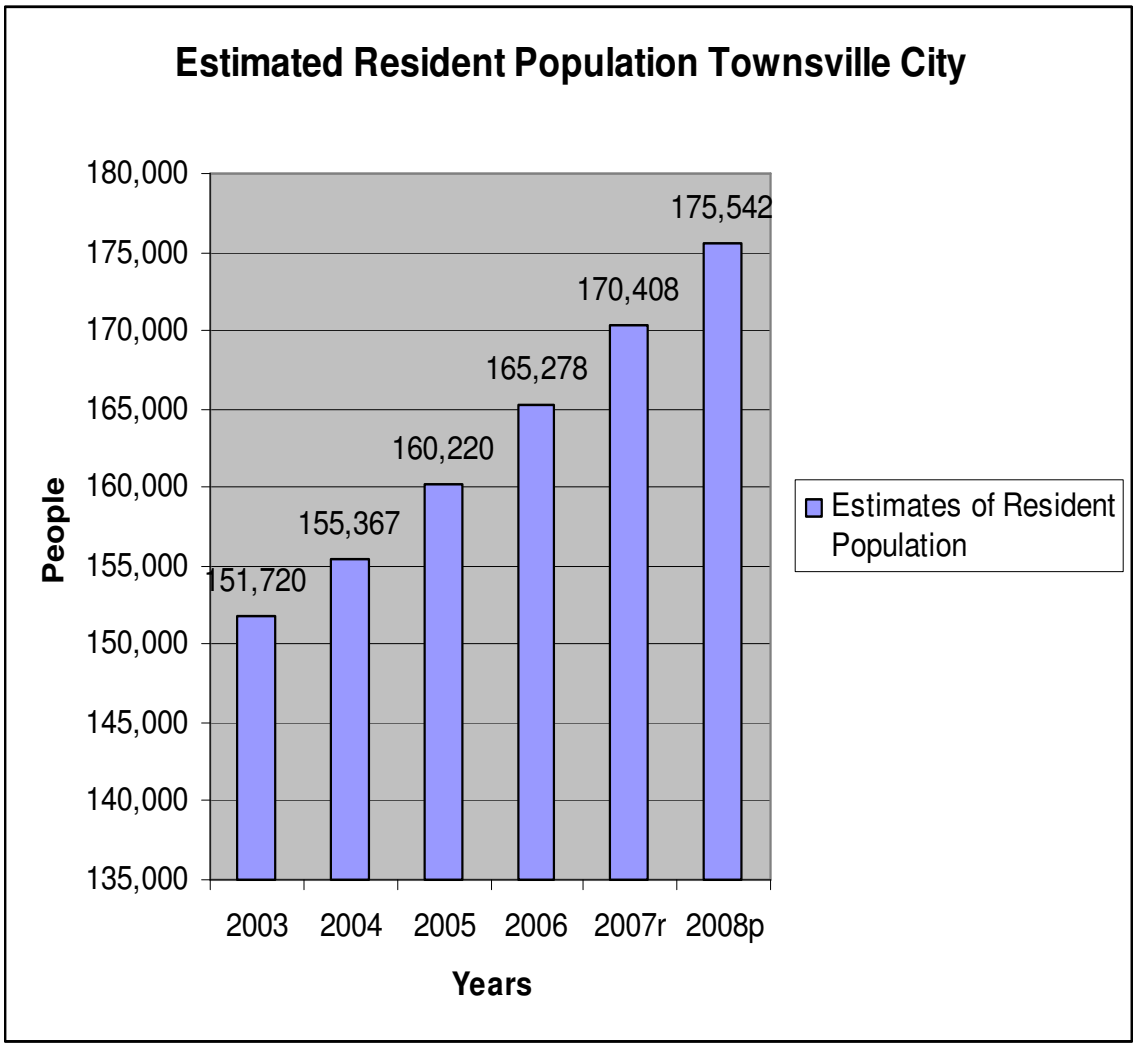
Year at 30 June	Number	Year to 30 June	Number	Percent
2003	151,720			
2004	155,367	2004	3647	2.40%
2005	160,220	2005	4853	3.10%
2006	165,278	2006	5058	3.20%
2007r	170,408	2007r	5130	3.10%
2008p	175,542	2008p	5134	3.00%
2003-2008p			Average	3.00%

Source: Regional Population Growth, Australia, 2007-08 (cat. no. 3218.0) The estimates in the above table are final for 2003 to 2006 and revised for 2007 (denoted 2007r) to align with new June 2007 state totals which were released in September 2008 issue of Australian Demographic Statistics (ABS cat. no. 3101.0). Estimates for 2008 are preliminary (and denoted 2008p).

During the years 2004-2006, Townsville experienced strong population growth. The rate of growth has tapered slightly since that time. As at 30 June 2008, the estimated resident population was 175,542 people, which represents 4.1% of Queensland's population. Townsville's annual increase of 5,134 people over the year to June 2008 represents a 3% growth rate. This compares with an increase of 5,130 people or 3.1% for the year to 30 June 2007.

Between 2007-2008, the growth rate for the state of Queensland was 2.3%. This was the slowest annual growth for Queensland in the five years to June 2008. The average annual rate of change in population in the Townsville local government area, over the five years between 30 June 2003 and 30 June 2008 was 3%, compared with 2.4% for the State.

Figure 3.11 Townsville Recent Population Growth Trend



Source: Australian Bureau of Statistics Catalogue Number: 3218.0 - Regional Population Growth, Australia, 2007-08; released 23 April 2009.

The 1996 Census indicated a median age for Townsville of 31 years. At the 2006 Census, the median age for Townsville increased to 33 years, still significantly younger than the median age for Queensland (36 years) and for Australia (37 years). Projections from the Queensland Department of Infrastructure and Planning indicate the median age of Townsville City Council's population will increase to 39 by 2031 (an increase of 6 years from the 2006 median age.

The 2006 Census showed the average household size for Townsville City to be 2.8 people per dwelling. This is high in comparison with the average household size for Queensland and Australia (both 2.6 people). It is likely that the young population profile for Townsville, which includes significant numbers of families with children, is the main factor contributing to the higher than average household occupancy.

3.4.2 Land and housing

Residential land activity is a strong potential indicator of both population growth and expansion of the urban footprint. In the year to the June quarter 2005, Townsville produced 1,743 residential lots. Lot production has continued to be strong through the years to 2008, however the economic downturn has acted to dampen the volume of recent land sales. Land sales for the year to June 2008 were down significantly from previous years while lot consumption i.e. dwellings being constructed, continued to record strong growth during 2008.

New household formation is an important indicator for population growth. If there is a downturn or upswing in new household formation there is likely to be a corresponding movement in the annual percentage population change.

Coupled with residential land activity, Building Approval data offers a key indicator for population growth. In the year ended March 2009, there were 1,575 residential dwelling approvals in Townsville City Council. These approvals were valued at $495.8 million and represented 5.0% of the overall total for the State.

Table 3.8 Residential and Non-residential Building Approvals

	Dwelling units in new residential buildings	(a) Residential building value	(b)Total residential building value	(b)Total non-residential building value	(b)Total building value	Proportion of total value that is residential (c)
		$,000s				
Townsville City Council	1,575	457,455	495,802	265,209	761,011	65.2%
Queensland	32,170	8,767,555	9,973,341	7,935,870	17,909,210	55.7%
Townsville as % of Qld	4.9	5.2	5.0	3.3	4.2	na

Notes: Townsville City Council for the 12 months ending 31 March 2009.

na = not applicable

(a) Excludes alterations, additions and conversions.

(b) Including alterations, additions and conversions.

(c) Represents total residential building value as a proportion of total building value.

Based on ASGC 2006.

Data for Reformed Local Government Area(s) are based on concorded Statistical Local Area data (ASGC 2006). The concordance is population based and has been derived from Planning Information and Forecasting Unit within the Department of Infrastructure and Planning.

Source: Australian Bureau of Statistics, Building Approvals, Queensland (Cat. no. 8731.3)

3.4.3 Labour force and income

Townsville's role as the primary urban centre serving the Northern Region has helped the City develop its diverse economy. The strength and diversity of the Townsville economy is reflected in the high employment levels (Table 3.9) and broad range of industries of employment (see Table 3.10).

The labour force in the Northern labour force region, encompassing the City of Townsville, grew by 3.2% in the 2005 calendar year, while the labour force participation rate was generally higher than overall participation rates for Queensland and Australia. At the time of the 2006 Census of Population and Housing in the Townsville City local government area (LGA), there were 3,523 unemployed persons. With a labour force consisting of 79,849 persons, this corresponded to an unemployment rate of 4.4% compared to 4.7% for Queensland as a whole.

Table 3.9 Labour Force Status

Characteristic	Townsville (people)	Queensland (people)
People aged 15 years and over	121,120	3,097,998
Labour force status (a):		
Employed, worked full-time (b)	51,262	1,180,889
Employed, worked part-time	19,797	530,501
Employed, away from work (c)	5,278	113,607
Unemployed, looking for work	3,513	90,950
Total labour force	79,849	1,915,947
Not in the labour force	33,326	971,829
Unemployment rate (d)	4.4%	4.7
Labour force participation rate (e)	65.9%	61.8
Employment to population rate (f)	63.0%	58.9

Source: Australian Bureau of Statistics 2006 Census of Population & Housing, Community Profile Series (Cat No: 2001.0)
Notes: (a) Applicable to people aged 15 years and over.
(b) 'Employed, worked full-time' is defined as having worked 35 hours or more in all jobs during the week prior to Census Night.
(c) Includes employed people who did not state their hours worked.
(d) The number of unemployed people expressed as a percentage of the total labour force.
(e) The number of people in the labour force expressed as a percentage of people aged 15 years and over.
(f) The number of employed people expressed as a percentage of people aged 15 years and over.

Table 3.10 Employment by Industry

Industry	%
Public Administration and Safety	12.6
Retail Trade	11.0
Health Care & Social Assistance	10.9
Construction	9.9
Manufacturing	8.2
Education and Training	8.0
Accommodation and Food Services	6.8
Transport, Postal & Warehousing	5.1
Professional, Scientific and Technical Services	4.3
Other Services	3.5
Wholesale Trade	3.2
Administrative and Support Services	2.8
Mining	2.6
Financial and Insurance Services	1.8
Rental, Hiring and Real Estate Services	1.8
Information Media & Telecommunications	1.6
Electricity, Gas, Water and Waste Services	1.4
Arts and Recreation Services	1.3
Agriculture, Forestry and Fishing	0.8

Source: ABS, Census of Population and Housing, 2006
Notes:(a) Based on place of usual residence. (b) Based on 2006 ANZSIC

The median weekly individual income for Townsville at the 2006 Census was $ 531.00, median weekly household income $1,101.00 and family income $ 1,237.00. Median household income levels in Townsville were significantly higher than the medians for Queensland and Australia.

3.4.4 Economy

Townsville is widely regarded as the capital of North Queensland and is home to many State and Federal Government agencies, as well as many primary and secondary industries, the mining, commerce and retail sectors, and community and cultural services. The diversity of the eonomy is relected in the Business Numbers for Townsville 2006/2007 (see Table 3.11).

Table 3.11 Townsville Business Numbers and Employees

Industry	Non employing	Employing Persons			Total
		1 to 4	5 to 19	20+	
Agriculture Forestry And Fishing	435	90	27	21	573
Mining	39	12	9	9	69
Manufacturing	249	147	108	51	555
Electricity Gas And Water Supply	12	0	3	0	15
Construction	1,419	798	354	117	2,688
Wholesale Trade	117	141	72	24	354
Retail Trade	513	480	327	111	1,431
Accommodation Cafes And Restaurants	90	78	87	78	333
Transport And Storage	615	135	54	30	834
Communication Services	48	51	6	0	105
Finance And Insurance	336	102	51	9	498
Property And Business Services	1,743	627	243	90	2,703
Education	78	24	9	3	114
Health And Community Services	288	228	84	42	642
Cultural And Recreational Services	135	45	21	21	222
Personal And Other Services	246	126	87	24	483
Total	6,363	3,084	1,542	624	11,619

Source: Australian Bureau of Statistics, Counts of Australian Businesses, including Entries and Exits, Jun 2003 to Jun 2007, (Cat no. 8165.0).

The regional economy of Townsville, expressed in Gross Regional Product (GRP), has increased by 12% over 2004/05 to reach $10.2 billion, representing 7.2% of Queensland's Gross State Product. Manufacturing (in particular minerals processing) contributes 16.6% to the GRP with other major contributions from Government Administration and Defence (11.3%) and Construction (8.5%).

The Port of Townsville exports a diverse range of goods including sugar, copper, lead, zinc, fertilizer, timber, sand gravel, and general purpose oils which are worth $3 billion annually.
(Source: AEC Group - Report on the Townsville Regional Economy Third Quarter 2005. Townsville Enterprise Limited - Townsville and North Queensland)

"*There are significant social and economic benefits to Australia from the Great Barrier Reef. The major activities that occur on the Great Barrier Reef are tourism, recreation and commercial fishing. During 2005, 1.9 million people visited the Great Barrier Reef using tourism services and it is estimated that there are a further 6 million recreational visits to the Great Barrier Reef annually. Recreation includes activities such as fishing, snorkelling, diving, sightseeing, adventure sports and sailing. Tourism is a major activity on the Great Barrier Reef and is estimated to contribute as part of regional tourism $6.1 billion to the Australian economy annually. The tourism industry also employs an estimated 63,000 people. Commercial fishing activity undertaken in the Great Barrier Reef has a gross value of production of $119 million annually and employs an estimated 3,600 people or 0.94 percent of the Great Barrier Reef coastal labour force. Recreational fishing and boating contribute $640 million annually to the region and comprise a major recreational activity for residents and visitors to the region.*

The value of agricultural production from Great Barrier Reef coastal communities is in the order of Australian $1.7 billion annually. The resources sector contributes Australian $14.5 billion annually in exports from the 11 ports located in the Great Barrier Reef region . Of these exports, 94 percent are for mineral products, primarily coal and metal ores, and the remaining 6 percent agricultural and manufactured products.

The key regional centres of Cairns, Townsville, Mackay, Rockhampton and Gladstone provide services to inland mining and agricultural industries. Townsville is the largest major centre in the Great Barrier Reef region with considerable government, education and defence activities servicing state and national interests.

Limiting the effects of people, within and adjacent to the Great Barrier Reef is the challenge presented to marine managers, communities, industries and governments when considering how best to manage the Great Barrier Reef. The nature of the interactions people have with the Great Barrier Reef are shaped by the demands they have to meet. For each ecosystem the type of management applied to maintain its functional status, as a 'healthy' ecosystem is directly dependent on the social, economic and institutional context of the society that interacts directly and indirectly with the ecosystem.

The length of time that humans have interacted with the Great Barrier Reef provides an appropriate historical context for understanding current social, economic, institutional and political issues involved in the management of the Great Barrier Reef. Unlike many other tropical marine ecosystems , the Great Barrier Reef exists in close proximity to a region that has experienced intensive farming and pastoral activities as well as substantial urban development for close to one hundred and fifty years. Apart from the Cape York region, which has experienced much less land based development; coastal and catchment regions bordering the Great Barrier Reef bear witness to the progressive development of the region's ocean, land and mineral resources.

The infrastructure for supporting the growing regional population of approximately 836,000 people with associated manufacturing, agricultural and urban services from Bundaberg in the south to Cairns in the north represents a substantial modification of the Great Barrier Reef's coastal and catchment landscape. The effect of 68,000 personal watercraft, active commercial fisheries, 1.9 million tourist visits annually, defence activities and development of infrastructure to support visitors and residents accessing and enjoying the Great Barrier Reef combines to make an extensive ecological footprint. This will affect the Great Barrier Reef in far more complex forms than tropical marine ecosystems that are more isolated." (Johnson and Marshall (eds) 2007, pp.6-8)

Figure 3.12 Population Growth Impacts the GBR

3.4.5 Land Use

In conjunction with the physical environment it is land use and associated management practices that influence the potential for pollutants to enter waterways and waterbodies. General land use categories are shown in Table 3.12 and Table 3.13 with a more detailed breakdown by sub basin in Table 3.14. Land use patterns are illustrated in Figure 3.13 and Figure 3.14.

Table 3.12 Black Ross WQIP Area Land Use 2005

Land use (Secondary/tertiary)	Hectares	%
Nature conservation	61,815	23.03
Other minimal use	35,467	13.21
Grazing natural vegetation	133,450	49.72
Forestry	73	0.03
Cropping	188	0.07
Perennial horticulture	16	0.01
Irrigated cropping	485	0.18
Irrigated sugar	1,748	0.65
Irrigated perennial horticulture	235	0.09
Irrigated tree fruits	913	0.34
Irrigated tree nuts	9	0.00
Irrigated fruits	375	0.14
Irrigated vegetables & herbs	51	0.02
Poultry	14	0.01
Aquaculture	266	0.10
Manufacturing and industrial	2,369	0.88
Urban residential	9,232	3.44
Rural residential	7,229	2.69
Services	2,817	1.05
Electricity generation/transmission	31	0.01
Airports/aerodromes	970	0.36
Railways	106	0.04
Mining	610	0.23
Waste treatment and disposal	112	0.04
Reservoir/dam	4,530	1.69
River	648	0.24
Channel/aqueduct	7	0.00
Marsh/wetland	4,634	1.73
Total hectares	268,400	

Note: The dominant landuse is shaded in yellow, 2nd in blue, 3rd in green, and 4th in pink.

Table 3.13 Principal Land Use Categories (2005)

Secondary and Tertiary Land Use	Adopted Land Use Groups	Hectares	%
Nature conservation, Other minimal use	Conservation and natural areas	98,527	36.7
Grazing natural areas, Production forestry	Grazing	132,209	49.3
Residential.	Rural residential	8,173	3.0
Cropping, Perennial horticulture, Plantation forestry, Irrigated cropping, Irrigated horticulture (perennial and seasonal), Intensive animal production.	Intensive agriculture	4,108	1.5
Residential, Manufacturing and industrial, Services, Utilities, Transport and communication, Waste treatment and disposal, Mining.	Urban	15,565	5.8
Channel/aqueduct, Marsh/wetland, Reservoir/dam, River.	Water and wetlands	9,819	3.7

Table 3.14 Land Use by Sub Basin 2005

Land Use	Crystal		Rollingstone		Bluewater		Black		Bohle		Lower Ross		Upper Ross		Stuart		Alligator		Magnetic Is	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Nature Conservation	11,786	49.2	15,865	72.1	1,645	5.7	1,962	6.5	3,197	9.9	944	7.0	8,218	10.9	1,366	13.2	14,194	53.6	2,639	52.9
Other minimal use	7,365	30.7	2,863	13.0	3,133	10.8	1,962	6.5	2,053	6.4	4,584	34.0	7,461	9.9	1,704	16.4	3,663	13.8	1,924	38.6
Grazing Natural Vegetation	2,287	9.5	2,382	10.8	21,893	75.4	23,063	75.9	19,018	59.0	316	2.3	54,082	71.7	5,054	48.7	4,111	15.5		
Production Forestry	1	0.0	2	0.0																
Plantation Forestry			70	0.3																
Cropping	10	0.0	28	0.1			103	0.3	4	0.0							43	0.2		
Irrigated Cropping	1,697	7.1	52	0.2			7	0.0	88	0.3			63	0.1	299	2.9	26	0.1		
Irrigated Perennial Horticulture	88	0.4	70	0.3	77	0.3	58	0.2	299	0.9			323	0.4	56	0.5	185	0.7		
Irrigated Seasonal Horticulture	178	0.7	215	1.0									35	0.0			15	0.1		
Perennial Horticulture	4	0.0							10	0.0							3	0.0		
Intensive Animal Production			40	0.2	117	0.4			101	0.3					23	0.2				
Residential	171	0.7	253	1.1	1,473	5.1	2,081	6.9	4,755	14.8	4,046	30.0	647	0.9	191	1.8	2,439	9.2	383	7.7
Manufacturing and industrial					48	0.2	564	1.9	1007	3.1	381	2.8	11	0.0	353	3.4			5	0.1
Services	25	0.1	34	0.2	45	0.2	58	0.2	532	1.7	2,004	14.9	75	0.1	32	0.3			27	0.5
Transport and Communication	85	0.4	15	0.1			7	0.0	485	1.5	416	3.1			68	0.7				
Utilities									21	0.1	9	0.1			2	0.0				
Waste treatment and disposal			5	0.0	4	0.0			17	0.1					62	0.6			13	0.3
Mining	4	0.0			177	0.6			110	0.3	21	0.2	173	0.2	116	1.1	11	0.0		
Channel/Aqueduct					7	0.0														
Reservoir/Dam	2	0.0	5	0.0	20	0.1	5	0.0	3	0.0	149	1.1	4,332	5.7	14	0.1				
River	61	0.3	10	0.0	58	0.2	343	1.1	16	0.0	91	0.7	27	0.0			43	0.2		
Marsh/Wetland	205	0.9	96	0.4	341	1.2	165	0.5	514	1.6	515	3.8	12	0.0	1,033	10.0	1,755	6.6		
Total (hectares)	23,969		22,003		29,037		30,377		32,229		13,475		75,460		10,371		26,489		4,990	

Note: The dominant landuse is shaded in yellow, 2nd in blue, 3rd in green, and 4th in pink. Bohle land use has been calculated for modeled sub catchments also (results in BBN Report)

Figure 3.13 Land Use 2005

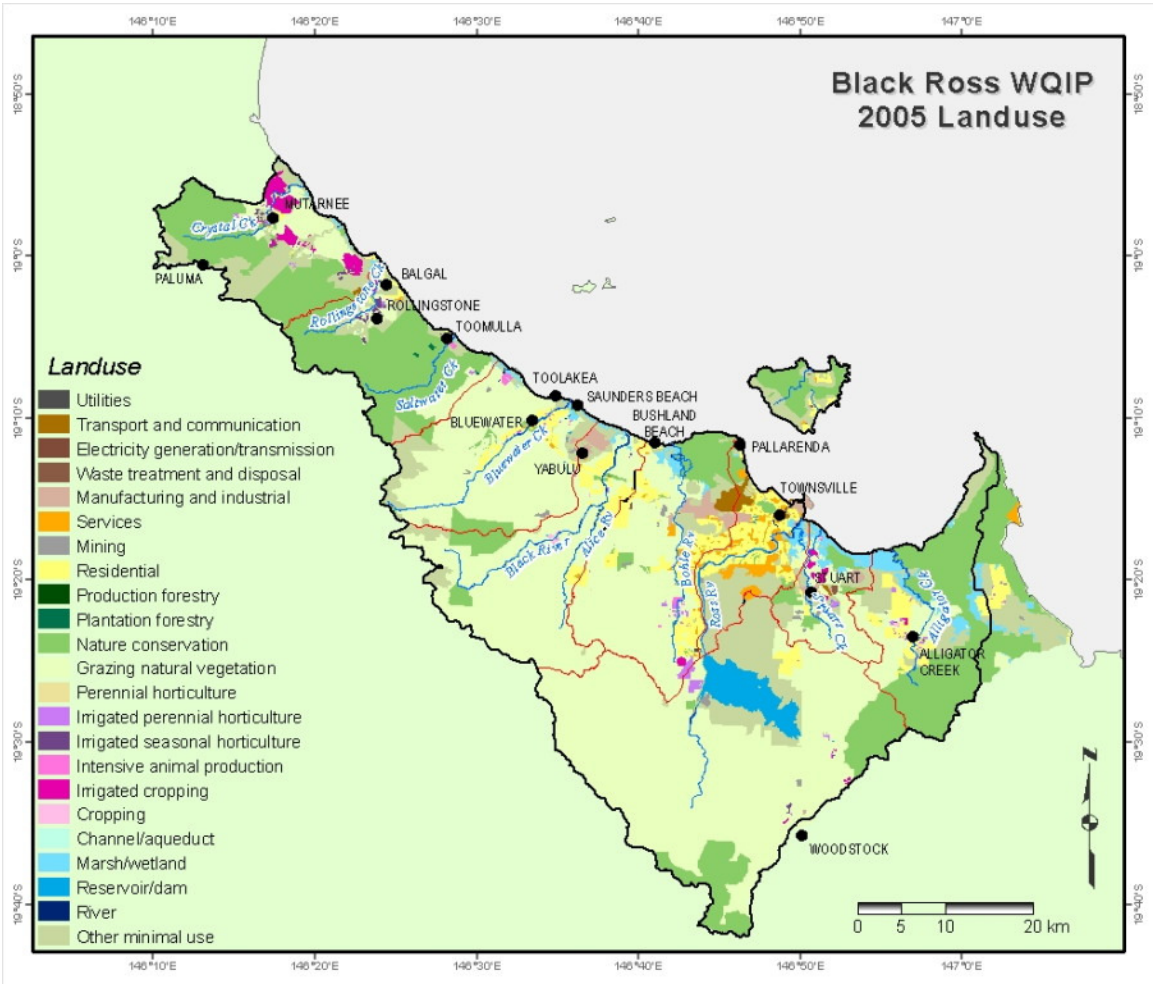
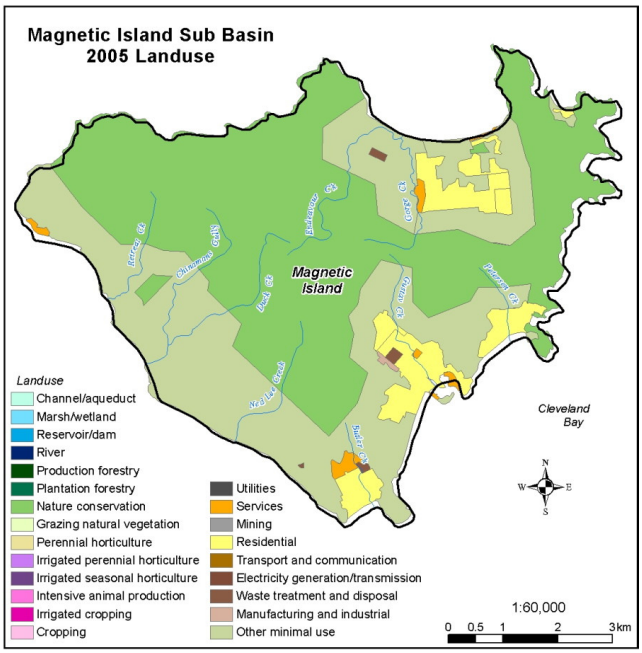


Figure 3.14 Magnetic Island Land Use 2005



Land use categories have been grouped and subdivided for different studies as part of the process of developing the Black Ross WQIP. This was seen as necessary as the urban component of the study area is a significant factor in determining water quality condition and pollutant loads. Various land use divisions adopted for elements of the Black Ross WQIP, and their relationship to each other, are shown in Table 3.15.

Table 3.15 Initial Land Use Divisions by Study

Pollutant source identification	WaterCAST Modelling	Bayesian Belief Network (BBN)
Rural		
Minimal Use/Natural Areas	Greenspace (includes forestry)	Natural areas/minimal use *
		Forestry
Intensive agriculture	Agriculture (intensive)	Intensive agriculture/Horticulture
Rural (with rural residential)	Grazing	Grazing
Urban		
Urban/residential	Traditional i.e. houses Dense i.e. units etc	Traditional residential * High density residential
Commercial	Commercial	Commercial/Light industrial *
Industry (includes ports and railways)	Industry (includes manufacturing, services, utilities, transport and waste treatment and disposal)	Heavy industry (includes manufacturing, some services, some utilities, ports, railways, airports and waste disposal)
	Other	**Low urban**
		Formal parkland
	Rural residential	Peri-urban/Rural residential *
	Mining	Mining
		Bare ground (developing urban) *
	Water	(Water to be separated from natural areas/minimal category)

Note: Separate rows are assigned to the landuse category adopted for each of the studies. The BBN project has adopted three primary land use categories i.e. rural, urban and low urban, and placed the sub categories within these. Low urban is conceptualised as the zone between urban and rural areas where the next 'wave' of development is likely to take place. *Primary land use categories used by ACTFR in event monitoring 2006-2008 – Established urban, developing urban, light industrial, urban industrial, rural residential, minimal use and conservation.

3.5 Current Water Quality Condition

A desktop review of the current condition of water quality in each catchment in the Black Ross WQIP area was undertaken (Connell Wagner 2008) utilising an integrated ecological assessment process developed by the EPA (EPA 2006).

Of the sixty catchments found in the Black Ross WQIP area the integrated assessment of current condition found that fifteen were slightly impacted, three moderately impacted and eleven were heavily impacted. The remaining catchments either had no data (23) or insufficient data (8) to make an assessment (Connell Wagner 2008).

Similarly at the waterbody reach level, eighteen waterbody reaches were found to be slightly impacted, fifteen moderately impacted and nineteen were heavily impacted. Of the remaining waterbody reaches 84 have no data and 12 have insufficient data to make an assessment.

A draft Report Card format has also been produced by Connell Wagner (2009) (now Aurecon) and the report (*Development of a Report Card Format for the Waterways of the Black/Ross Basins*) can be viewed on the Creek to Coral website (www.creektocoral.org).

4. Basins, Sub Basins and Catchments

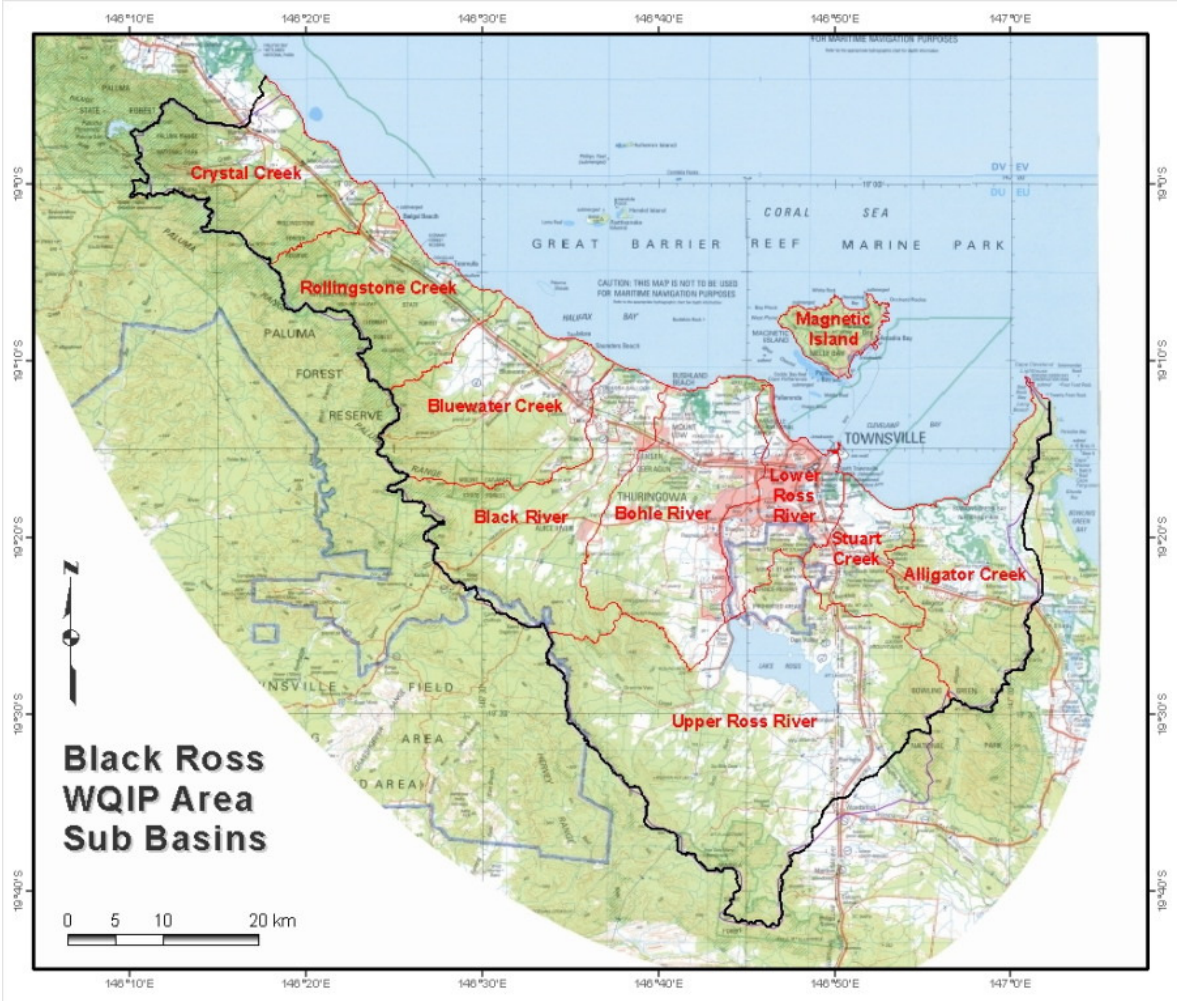
4.1 Components of the WQIP Area

The coastline of the Black Ross (Townsville) WQIP area (including Magnetic Island) is approximately 130 kilometres, which is equivalent to approximately 6% of the total GBR catchments coastline.

The total land area of the catchments that flow to Cleveland and Halifax Bays is 268,400 hectares (~2,700 square kilometers). This represents approximately 0.6% of the total area of the GBR catchments. While not a large area in terms of the GBR catchment the Black Ross (Townsville) WQIP area is home to approximately 20% of the GBR catchment population.

As previously described the land area of the Black Ross (Townsville) WQIP consists of the Black and Ross River Basins and Magnetic Island. The land area has been further divided into 10 sub basins (see Figure 4.1) and 47 catchments and sub catchments (see Figure 4.5). These divisions have been established to assist with condition assessment, monitoring, modelling and reporting. The individual areas of the basins and sub basins are listed in Table 4.1 and catchment areas are listed in Table 4.5.

Figure 4.1 WQIP Area Sub Basins



The remainder of this report provides an overview of the Black River and Ross River Basins, sub basins, catchments, sub catchments and associated waterways and wetlands in the Black Ross WQIP area.

Table 4.1 Basin and sub basin areas

Basin	Sub basin No.	Sub basin	Hectares	km²	% land area
Black River	1	Crystal Creek	23,969	240	8.9
Black River	2	Rollingstone Creek	22,003	220	8.2
Black River	3	Bluewater Creek	29,037	290	10.8
Black River	4	Black River	30,377	304	11.3
		Black River Basin sub total	105,386	1,054	
Ross River	5	Bohle River	32,229	322	12.0
Ross River	6	Lower Ross River	13,475	135	5.0
Ross River	7	Upper Ross River	75,460	755	28.1
Ross River	8	Stuart Creek	10,371	104	3.9
		Ross River Basin sub total	131,535	1,315	
Haughton River	9	Alligator Creek	26,489	265	9.9
	10	Magnetic Island	4,990	50	1.9
		Total	**268,400**	2,684	

Note: Total area of the Black Ross WQIP area equals the area of the Black and Ross Basins plus the area of part of the Haughton River Basin (Alligator Creek sub basin) and Magnetic Island sub basin.

4.2 Drainage Basins

It should be noted that the Drainage Basins as defined by the predecessors of the Queensland Department of Natural Resources and Water (DNRW) are not the same as the Australian Water Resource Council (AWR) Basins. The DNRW Ross Basin is larger than the AWR basin and includes part of the AWR Haughton Basin. The DNRW Ross Basin is 1,707 km² compared to the AWR Ross Basin area of 1,315 km² (difference = 392 km²). Variation in figures associated with the Ross Basin is generally a result of this discrepancy, along with smaller standard errors associated with GIS calculations.

Some general statistics for the Black and Ross Basins are list in Table 4.2 with additional material on each basin provided in sections 4.3 and 4.4.

Table 4.2 General Statistics Black and Ross Basins

Element	Black River (117)	Ross River (118)
Area (km²)	1,057	1,707
% gauged	33	56
Annual runoff km³ Average	0.38	0.49
Annual runoff km³ Maximum	1.54	3.37
Annual runoff km³ Minimum	0	0.01
Ave annual rainfall mm	1,530	1,027
Ave annual runoff mm	360	287
% runoff	23	28
Population	10,605 *	140,072 *
Clearing (km²)	501	1,229
% Cleared	47	72
Area under Grazing (km²)	802	1,481
Area under Sugar (km²)	9.7	<10
Area under Horticulture (km²)	4.2	<10
Surface water storages capacity (ML)	487	422,060
Number of production bores	987	1,081
Irrigated sugarcane (ML per annum)	6,000	
Irrigated horticulture (ML per annum)	2,700	3,800
Irrigated crops (ML per annum)		800

Sources: Furnas 2003 (p.43) From Table 4 Average rainfall was calculated from the long-term average isohyet distribution within basin boundaries. Basin areas and gauged runoff from DNRM. Rainfall data from BOM. River Basins Summary (Australian Government - Bureau of Rural Sciences, Bureau of Meteorology and CSIRO), Great Barrier Reef Water Quality Action Plan (GBRMPA 2001). * ABS 2006

4.3 Black Basin

"*The Black River catchment covers an area of 1,057 km². Grazing is the dominant land use occupying 802 km². Other land uses are; sugarcane farming covering approximately 10 km² and horticulture 4 km². Total forests occupy 220 km² and protected areas, including the Wet Tropics World Heritage Area, cover 231 km². Sediment export is classified as low risk, and total nitrogen and total phosphorus exports are classified as medium risk in the Black River catchment*".

"*Issues in the catchment:*

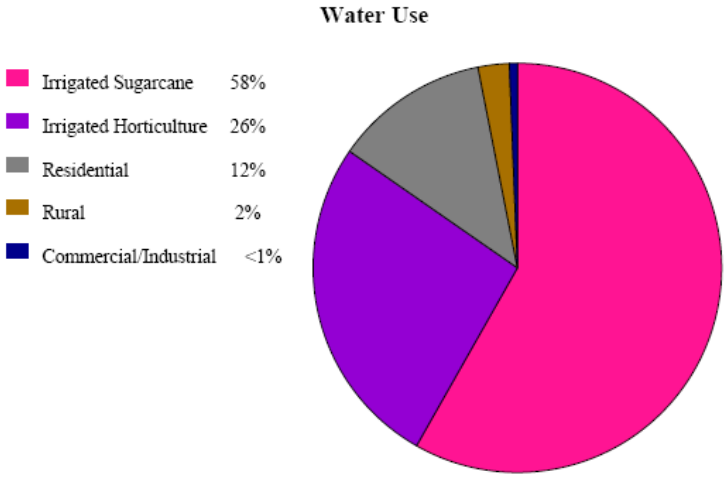
- *There are problems of ground water supplies in the Black River;*
- *Significant quantities of sand and gravel are extracted from the Black River for the Townsville market, creating an in-stream environmental impact;*
- *The riverbanks are severely eroded;*
- *Significant area of the Catchment has been cleared for grazing;*
- *Some fauna species have been subjected to pressure in the catchment;*
- *Approximately 22% of the catchment is within protected areas;*
- *Expansion of cultivated agriculture;*
- *Increasing contribution of nutrient and pesticides;*
- *Commercial and recreational fishery; and*
- *Recreational marine use*" (Brodie et al 2001, p.86).

Table 4.3 Non-Marine Wetland System Summary

System	# Wetlands	Area (km²)	% Wetlands Area	% Total Area
Estuarine	82	13.53	22.5%	1.3%
Lacustrine	87	6.46	10.7%	0.6%
Palustrine	148	4.81	8.0%	0.5%
Riverine	334	35.33	58.7%	3.3%
Total non-marine	651	60.13	100.0%	5.7%

Source: Wetland Summary Information (Qld EPA - http://www.epa.qld.gov.au/wetlandinfo)

Figure 4.2 Average Annual Water Use by Sector



Source: River Basins Summary (Australian Government - Bureau of Rural Sciences, Bureau of Meteorology and CSIRO)

4.3.1 Water Quality Condition

Overall the analysis of water quality condition (Connell Wagner 2008) indicated that the Black River Basin was generally slightly impacted with nine of the nineteen catchments in the basin being assessed as slightly impacted to ecologically healthy and one catchment rated moderately impacted. Of the remaining catchments, eight have no data and one catchment has insufficient data to make an assessment.

More specifically the data indicated a general trend toward low dissolved oxygen relative to guideline values and high total suspended solids for the waterbody reaches across the whole Basin.

4.4 Ross Basin

"The Ross River catchment covers an area of 1,707 km². Grazing is the dominant land use occupying 1,481 km². State forests and timber reserves occupy 48 km² and protected areas cover 245 km². Other land uses at a much smaller scale include horticulture and sugarcane (both less than 10 km²). Sediment export is classified as low risk, whilst total nitrogen and total phosphorus exports are classified as medium risk in the Ross River catchment."

"Issues in the catchment:

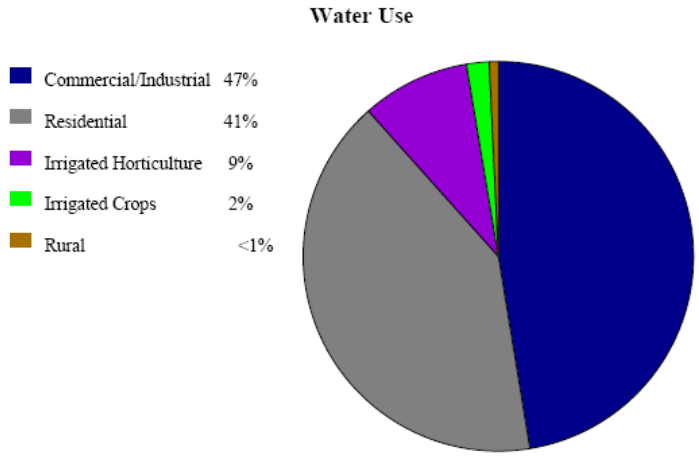
- *Grazing lands are in reasonably good condition with only minor gully and sheet erosion;*
- *Most native grasses are still present;*
- *The Ross River Dam is a major source of the Townsville water supply;*
- *The catchment contains the heavily urbanised City of Townsville and its small surrounds and small areas of sugarcane where suitable soils permit;*
- *Significant alteration of the river has occurred through extractions of sand and gravel to supply construction sites in Townsville and for water storage;*
- *Presence of heavy industry;*
- *Significant area of the catchment has been cleared for grazing;*
- *Approximately 14% of the catchment is within protected areas;*
- *Some fauna species have been subjected to pressure in the catchment;*
- *Commercial and recreational fishery;*
- *Marine tourism;*
- *Commercial port; and*
- *Close proximity to seagrass and dugong protection areas'"* (Brodie et al 2001, p.88).

Table 4.4 Non-Marine Wetland System Summary

System	# Wetlands	Area (km²)	% Wetlands Area	% Total Area
Estuarine	108	137.14	49.4%	8.0%
Lacustrine	171	58.33	21.0%	3.4%
Combined Lacustrine/Palustrine	2	0.31	0.1%	0.0%
Palustrine	266	30.14	10.9%	1.8%
Combined Palustrine/Riverine	1	0.00	0.0%	0.0%
Riverine	256	51.78	18.6%	3.0%
Total non-marine	804	277.70	100.0%	16.3%

Source: Wetland Summary Information (Qld EPA - http://www.epa.qld.gov.au/wetlandinfo)

Figure 4.3 Average Annual Water Use by Sector



Source: River Basins Summary (Australian Government - Bureau of Rural Sciences, Bureau of Meteorology and CSIRO)

4.4.1 Water Quality Condition

The analysis of water quality condition (Connell Wagner 2008) in the twenty catchments of Ross River Basin showed a much worse set of results than the Black River Basin. Only two catchments were rated as slightly impacted to ecologically healthy, one catchment rated moderately impacted and seven catchments rated as heavily impacted. Of the remaining catchments, nine have no data and one catchment has insufficient data to make an assessment.

In general nutrient levels are high and in the Bohle River sub-basin the levels of phosphorus are extremely high compared to the EPA guidelines for lowland streams. Of the nitrogen species, ammonia was consistently high however total nitrogen was generally within or just above the guidelines.

Water quality condition is provided for each of the sub basins in the following sections.

Figure 4.4 Bohle River February 2010

4.5 Sub Basins and Catchments

Catchments are shown by sub basin in Figure 4.5 and Figure 4.6 with areas listed in Table 4.5. Catchment profiles are provided by sub basin in chapters 5 to 14, commencing from the northern end of the WQIP study area.

Figure 4.5 Black Ross Sub Basins and Catchments

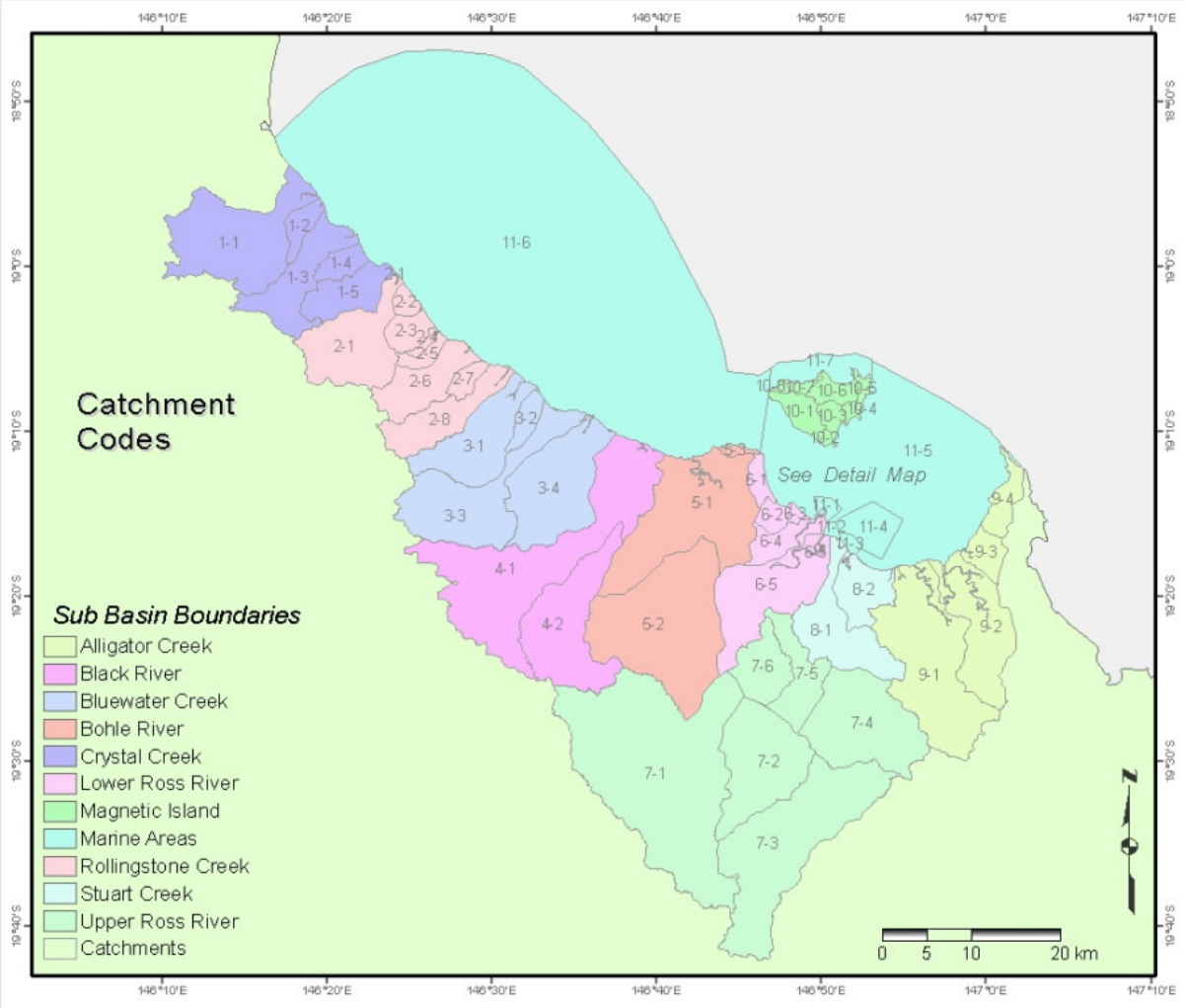


Table 4.5 Black/Ross WQIP catchment areas

AWRC Basin	Sub Basin	No.	Catchment	Hectares	km²	% area
Black River	Crystal Creek	1-1	Crystal Creek	11,592	116	4.3
Black River	Crystal Creek	1-2	Lorna Creek	1,424	14	0.5
Black River	Crystal Creek	1-3	Ollera Creek	5,769	58	2.1
Black River	Crystal Creek	1-4	Scrubby Creek	1,467	15	0.5
Black River	Crystal Creek	1-5	Hencamp Creek	3,716	37	1.4
Black River	Rollingstone Creek	2-1	Rollingstone Creek	7,732	77	2.9
Black River	Rollingstone Creek	2-2	Unnamed	731	7	0.3
Black River	Rollingstone Creek	2-3	Surveyors Creek	1,674	17	0.6
Black River	Rollingstone Creek	2-4	Wild Boar Creek	344	3	0.1
Black River	Rollingstone Creek	2-5	Station Creek	882	9	0.3
Black River	Rollingstone Creek	2-6	Saltwater Creek	4,662	47	1.7
Black River	Rollingstone Creek	2-7	Cassowary Creek	997	10	0.4
Black River	Rollingstone Creek	2-8	Leichhardt Creek	4,981	50	1.9

Black River	Bluewater Creek	3-1	Sleeper Log Creek	7,169	72	2.7
Black River	Bluewater Creek	3-2	Two Mile Creek	1,338	13	0.5
Black River	Bluewater Creek	3-3	Bluewater Creek	10,492	105	3.9
Black River	Bluewater Creek	3-4	Deep Creek	10,057	101	3.7
Ross River	Black River	4-1	Black River	20,389	204	7.6
Black River	Black River	4-2	Alice River	9,988	100	3.7
Ross River	Bohle River	5-1	Bohle River	14,583	146	5.4
Ross River	Bohle River	5-2	Bohle River 2	17,289	173	6.4
Ross River	Bohle River	5-3	Shelly Beach	357	4	0.1
Ross River	Lower Ross River	6-1	Pallarenda	963	10	0.4
Ross River	Lower Ross River	6-2	Mundy Creek	971	10	0.4
Ross River	Lower Ross River	6-3	Esplanade	292	3	0.1
Ross River	Lower Ross River	6-4	Ross Creek	2,225	22	0.8
Ross River	Lower Ross River	6-5	Ross River (btd)	9,023	90	3.4
Ross River	Upper Ross River	7-1	Ross River (atd)	30,247	302	11.3
Ross River	Upper Ross River	7-2	Six Mile Creek	9,625	96	3.6
Ross River	Upper Ross River	7-3	Toonpan Lagoon	16,935	169	6.3
Ross River	Upper Ross River	7-4	Antill Plains Creek	10,726	107	4.0
Ross River	Upper Ross River	7-5	Sachs Creek	4,130	41	1.5
Ross River	Upper Ross River	7-6	Mt Stuart	3,798	38	1.4
Ross River	Stuart Creek	8-1	Stuart Creek	6,727	67	2.5
Ross River	Stuart Creek	8-2	Sandfly Creek	3,644	36	1.4
Haughton River	Alligator Creek	9-1	Alligator Creek	14,767	148	5.5
Haughton River	Alligator Creek	9-2	Crocodile Creek	7,995	80	3.0
Haughton River	Alligator Creek	9-3	Cocoa Creek	1,716	17	0.6
Haughton River	Alligator Creek	9-4	Cape Cleveland	2,011	20	0.7
	Magnetic Island	10-1	West Coast	1,632	16	0.6
	Magnetic Island	10-2	Picnic Bay	177	2	0.1
	Magnetic Island	10-3	Nelly Bay	777	8	0.3
	Magnetic Island	10-4	Arcadia	264	3	0.1
	Magnetic Island	10-5	Radical Bay	372	4	0.1
	Magnetic Island	10-6	Horseshoe Bay	1,223	12	0.5
	Magnetic Island	10-7	Five Beach Bay	386	4	0.1
	Magnetic Island	10-8	Rollingstone Bay	159	2	0.1
			Total	**268,419**	**2,684**	100.0
Marine Area	**Name**	**No.**		**Hectares**	**km²**	**% area**
Townsville Harbour		11-1		458		
Ross River Near Shore		11-2		233		
Sandfly Creek Near Shore		11-3		327		
Ross Offshore		11-4		2,448		
Cleveland Bay		11-5		33,543	370	22.5
Halifax Bay		11-6		124,883	1,250	75.9
Magnetic Island Near Coastal		11-7		2,716	27	1.6

Source: Derived from catchments defined by Connell Wagner for Creek to Coral CCI WQIP using modified QLUMP 1999 data to reflect 2005 land use from aerial photography (TCC) and SPOT imagery (NQ Dry Tropics).

Notes: Cleveland Bay km² total is the sum of areas 11-1 to 11-5. btd is below the dam and atd is above the dam. % of area is the catchment area in relation to the total Black Ross (Townsville) WQIP area.

Figure 4.6 Magnetic Island Catchments and Marine Areas Detail