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Population and Major Land Use in the Great Barrier Reef Catchment Area: Spatial and Temporal Trends

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Executive Summary
The purpose of this report was to gather geographical and statistical information on the Great Barrier Reef Catchment, the majority of which was compiled in 1998. This information is intended to support future studies on predicting the impact of land-based activities on the Great Barrier Reef.

The Great Barrier Reef extends over 2 000 km along the north-eastern coast of Australia. It is the largest reef system in the world, providing habitat for a diversity of marine life. The Great Barrier Reef Catchment Area lies adjacent to the Great Barrier Reef World Heritage Area and comprises approximately 25 % of the land area of Queensland. Forty drainage basins comprise the Great Barrier Reef Catchment Area which drain directly into the Great Barrier Reef lagoon. Land modification associated with increased population, urban development and agricultural expansion has transformed the Great Barrier Reef Catchment Area. Run-off from these land-based activities has reduced the quality of water flowing into the Great Barrier Reef lagoon and is of great concern to researchers and managers of the Great Barrier Reef Marine Park Authority.

Climate within the Great Barrier Reef Catchment Area ranges from tropical to subtropical, with rainfall distribution being highly variable throughout the area. Coastal areas receive considerably higher rainfall than the uplands, hence more dense settlement and intensive agricultural expansion has been concentrated in the coastal zone, particularly in those basins receiving higher rainfall. The Great Barrier Reef Catchment Area has some of the most topographically diverse terrain on the Australian continent.

Changes in land cover since European settlement (200 years ago), has extensively modified the vegetation communities within the Great Barrier Reef Catchment Area. Native vegetation clearance in Queensland has historically been high, and continues at levels far in excess of other Australian States. The largest land-clearing event has occurred in the brigalow biogeographic region within the Great Barrier Reef Catchment Area. Brigalow communities were estimated to have covered 11 % and 30 % of the Burdekin and Fitzroy basin respectively, but now only cover 2 % and 1 % of these basins. Tropical rainforest vegetation along the accessible coastal river plains have also been cleared for settlement and agriculture. Additionally, the expansion of agriculture and urbanisation has resulted in the loss of wetland vegetation. The estimated area of freshwater wetlands that remain in the Great Barrier Reef Catchment Area is 18 408 km^2. Further threats to wetlands exist, with the rise in use of ponded pastures for grazing, particularly in the central basins of the Great Barrier Reef Catchment Area. The greatest source of sediment and nutrients is derived from the clearing and cultivation associated with agricultural land uses.

Queensland supported a large proportion of Australia's pre-settlement indigenous population. Following settlement, the indigenous population in Queensland declined and European population growth was rapid, with a quarter of a million persons in 1883 to 3 million persons in 1992. Queensland has 18.4 % of Australia's total population. Queensland's population is urbanised and concentrated along the eastern coastal catchments. The concentration of population and infrastructure within the coastal zone impacts on coastal and reef ecosystems.

The soils of the catchment area are typically of low fertility and exhibit poor soil structure, which has resulted in extensive application of fertiliser and conditioner to maintain agricultural productivity. Since the 1960's, there has been a dramatic increase in the application of nitrogenous and phosphate fertiliser use in the Great Barrier Reef Catchment Area. Over half of the total volume of nitrogen and phosphorus fertiliser used in agriculture within the Great Barrier Reef Catchment Area is applied to sugarcane. The area of sugarcane in the Great Barrier Reef Catchment Area since 1930 has increased substantially, and in 1995 was over 360 000 hectares.

Grazing occurs in all basins in the Great Barrier Reef Catchment Area to varying degrees. Approximately 4 900 000 cattle are found in the Great Barrier Reef Catchment Area. The two dominant basins in terms of area for grazing of cattle within the catchment are the Burdekin-Haughton and Fitzroy.

Mineral production is the highest source of export revenue for Queensland. Coal production in Queensland has increased rapidly since the 1960's, from 2.5 million tonnes to just under 100 million tonnes per year. Five statistical divisions within the Great Barrier Reef Catchment have produced 96 % of Queenslands black coal. Port development has been rapid within the Great Barrier Reef Catchment Area and associated with the boom in mineral production. Some of the major ports within the Great Barrier Reef Catchment Area have recorded over 500 vessel arrivals. Major shipping traffic and heavy use by smaller commercial and recreational vessels within the Great Barrier Reef lagoon threaten water quality through potential for shipping accidents and oil spills. Between 1987 and 1997 approximately 186 maritime incidents were reported within the Great Barrier Reef World Heritage Area.

In 1997 there were 123 official weirs and dams within the Great Barrier Reef Catchment in total which have been constructed for the increases in population and agricultural expansion. The dams have a capacity (7 million mega litres) which can potentially capture approximately 10 % of the annual run-off from the Great Barrier Reef catchment. The Burdekin Falls Dam is currently the largest dam in the Great Barrier Reef Catchment Area.

The high variability of Queenslands rainfall and widespread implementation of water regulation schemes has produced a number of irrigation areas for agriculture within the Great Barrier Reef Catchment Area. The area of irrigated agriculture in 1990 was 832 km^2 and total water usage delivered to farms was 343 790 mega litres year. Though not all sugarcane was irrigated it was the largest irrigated crop by area, particularly in the Wide-Bay-Burnett and Northern (particularly in the Burdekin) Statistical Divisions.

There is potential for continuing land-use change of coastal environments and downstream effects from catchment modification on the Great Barrier Reef lagoon. Increased areas of cropping lands, particularly those using high fertiliser applications, may impact the Great Barrier Reef through higher sediment and nutrient run-off levels. Such water quality modification threatens the values of the Great Barrier Reef World Heritage Area.

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1. Introduction

1.1. Great Barrier Reef

The Great Barrier Reef is the largest coral reef ecosystem in the world, with over 2900 reefs and 900 islands (including coral cays). It extends 2 000 km along the Queensland coast from the tip of Cape York Peninsula (9˚00'S, 144˚00'E) to near Bundaberg (24˚30'S; 154˚00'E) (MAP 1). The current reef morphology was initiated during the Holocene (8 000 – 10 000 years before present) following post-glacial (Pleistocene) sea level rise (18 000 to 10 000 years before present) (Hopley, 1982). During this evolution, the North East Australian Drainage Division, (which discharges into the Great Barrier Reef lagoon), was utilised by indigenous Australians under a fairly consistent resource extraction regime. Since the arrival of European settlers (~200 years before present), the catchment area has experienced a significant transformation as a result of increased human population and extensive modifications to land use practices.

Globally, semi-enclosed large marine ecosystems (such as the Great Barrier Reef (GBR) lagoon) are threatened by increases in anthropogenic impacts due to low flushing rates of lagoon water (Sherman *et al.* 1993; Konovalov 1999). Deterioration of water quality within the Great Barrier Reef lagoon, as a result of downstream effects of catchment modification, is of concern to researchers and managers of the Great Barrier Reef World Heritage Area (Hunter *et al.* 1996, Rayment and Neil, 1996; Wachenfeld *et al*. 1998; Zann, 1995). For several decades, water quality research has focused on quantifying the rate and source of terrestrial pollutants entering the waters of the GBR lagoon (Wasson, 1996).

1.2. The scope of the report

This report originated from an identified need to expand the information base available to water quality researchers in terms of the spatial and temporal extent of anthropogenic disturbance within the Great Barrier Reef Catchment Area. A Geographic Information System (GIS) of existing historic and spatial datasets has been compiled to demonstrate trends in population and major land use with a view to providing a framework for current water quality research and in monitoring the Great Barrier Reef lagoon. Elsewhere, GIS has been used to analyse patterns of urbanisation and land use change within the catchments of large semi-enclosed marine ecosystems. The report provides a background to the history of modification of the Great Barrier Reef Catchment based on existing available datasets. The report is structured to give an initial description of the Great Barrier Reef lagoon and catchment area, followed by a description of the main types of catchment modification since settlement.

It is beyond the scope of this report to extrapolate any identified catchment modifications to changes in water quality within the Great Barrier Reef lagoon over space and time. Inherent errors associated with time series data (due to shifts in statutory and census boundaries and data collection methods in particular), have not been dealt with in detail, but these should not significantly detract from the overall trends identified. In some cases, data for the Great Barrier Reef Catchment Area could not be extracted, so time series data for the state of Queensland has been included.

Note that the data that forms the basis of this report is continually being updated in the Great Barrier Reef Marine Park Authority (GBRMPA) GIS library. The data is compiled from government and non-government sources and has been independently verified. It is intended that new data sets, information and analysis will be added to the GBRMPA databases on a continual basis, to establish and maintain a summary of the geographical and statistical information on the Great Barrier Reef Catchment.

2. The Great Barrier Reef Lagoon and Water Quality

The degradation of the world's marine ecosystems, as a result of the downstream effects of increased population and catchment modification, is well documented (Mee, 1992; Turner and Rabalais, 1991). The geomorphic characteristics of semi-enclosed marine ecosystems, such as the Great Barrier Reef lagoon, result in them being particularly susceptible to water quality declines due to low area-to water-volume ratios and slow rates of water exchange with surrounding oceans (Konovalov, 1999). The Great Barrier Reef lagoon is a relatively shallow body of water, defined by the 100 metre isobath of the submerged continental shelf along the outer edge of the reef system (MAP 1). The total volume of water contained within the lagoon is estimated to be 8 000 km^3, covering an area of 225 000 km^2. Reefs are predominantly distributed along the inshore coastal fringe and the outer edge of the lagoon.

Two currents dominate water movement within the lagoon: a south to north wind-driven inshore circulation along the Queensland coast and a north to south movement of water along the seaward rim of the lagoon under the predominate influence of the East Australian Current (Furnas and Mitchell, 1996). This movement of lagoon water is thought to largely confine suspended terrigenous sediments to an inshore area 10-15 km wide along the length of the coast (King, 1995; Belperio, 1983; Carter *et al*. 1993; Wolffe and Larcombe, 1998). Exceptions occur during episodic extreme rainfall events, where turbid flood plumes extend from major rivers to distances of up to 50 km from the Queensland coast (Brodie and Furnas, 1992; Steven *et al.* 1996; Devlin *et al*. 2001). The overall dispersion pattern of dissolved contaminants is less understood.

Factors affecting water quality within the lagoon, as a result of increased population and catchment modification, include increased levels of inorganic sediments, organic and inorganic nutrients, heavy metals, pesticides and petroleum-based contaminants, and alteration of the natural hydrological regime (Wasson, 1996). Extensive areas of vegetation have been cleared to support Queensland's primary industry base, particularly sugarcane cultivation, pastoralism and forestry since European settlement. Diffuse sources of pollution are closely linked to these land uses and agricultural practices (Prove and Hicks, 1991; Moss *et al.* 1993; Gabric and Bell, 1993). Deforestation, grazing, tillage, the application of fertilisers and agricultural chemicals have had a greater impact on the quality of water flowing into the river systems from the Great Barrier Reef Catchment Area drainage basins than that from urban/industrial areas (Moss *et al.* 1993). Urban areas, particularly those in the coastal zone, are the greatest point sources of pollution, with the highest inputs from sewage treatment plant discharges (Brodie, 1991).

Moss *et al.* (1993) found that for nitrogen exports from eastern Queensland, the diffuse sources contributed far higher levels than those from point sources, with the exception of the metropolitan area of Brisbane (Brisbane is not included in the Great Barrier Reef Catchment Area within this study) (Figure 1). Generally, point sources of pollution (such as those associated with urban/industrial sites) are easier to identify and mitigate than diffuse sources, which tend to be cumulative and difficult to regulate. Diffuse sources of pollution are essentially a catchment management issue (Brodie, 1995), requiring the identification of those land uses that contribute excessive loads to the fluvial system and working to reduce exports particularly through changes in land use practices (Creighton *et al.* 1995).

Given the level of clearing and modification of pre-settlement vegetation within the catchment, rates of soil loss are thought to have increased substantially over the last 100 years. Moss *et al.* (1993) have suggested that sediment exports from the Great Barrier Reef Catchment Area are between 3-4 times greater than those of the pre-European settlement river loads. Total nitrogen and phosphorus inputs to the Great Barrier Reef have increased by approximately 30 % (Furnas and Brodie, 1996). Eutrophication of waterways due to the use of artificial fertiliser (ie. phosphorus and nitrogen) for agriculture and pasture improvement, is also of concern. The application of artificial fertilisers commenced early this century, and grew rapidly in response to agricultural expansion and low soil fertility (Pulsford, 1993). Pulsford (1993) calculated that a cumulative total of two million tonnes of nitrogen and 400 000 tonnes of phosphorus had been applied to the Great Barrier Reef Catchment Area up to 1990. It is estimated that of the 80-85 000 tonnes of nitrogen currently applied to the Great Barrier Reef Catchment Area each year at least 50 % is lost from the agricultural system and enters the environment predominantly through the hydrological cycle (Pulsford, 1993). This process is accelerated by the generally poor condition of the State's riparian vegetation and freshwater wetlands (Johnson, 1998; Moller, 1996; QDPI, 1993) which, when left intact, would provide a buffer zone or sink for nutrients, reducing the level entering the waterways.

Some rivers of Great Barrier Reef Catchment Area have a long history of water regulation with the first dam constructed in the1920s. Since settlement, the demand for water to support agriculture and urban growth has steadily increased. In 1997 there were 123 official dams and weirs within the Great Barrier Reef Catchment Area amounting to a total potential regulated capacity of over 7 million mega litres. The construction of dams and weirs reduces river discharge rates and modifies the hydrological environment of downstream wetland and marine ecosystems and vegetation communities (Robertson *et al.* 1996). The extent of changes to the flow of water from the catchment to the lagoon since settlement is difficult to assess. The fact that river gauging stations were not intended to provide before-and-after dam water flow data and the highly variable nature of stream flows in Queensland basins, makes it difficult to demonstrate changes to flow (Moss *et al.* 1993). Elsewhere, the negative impact of river regulation on downstream environments is being increasingly examined (eg. Murray Darling basin). Further research is required to fully understand the implication of the downstream effects of water regulation in the rivers of the Great Barrier Reef Catchment Area, and its effect on water quality in the lagoon (Robertson *et al.* 1996).

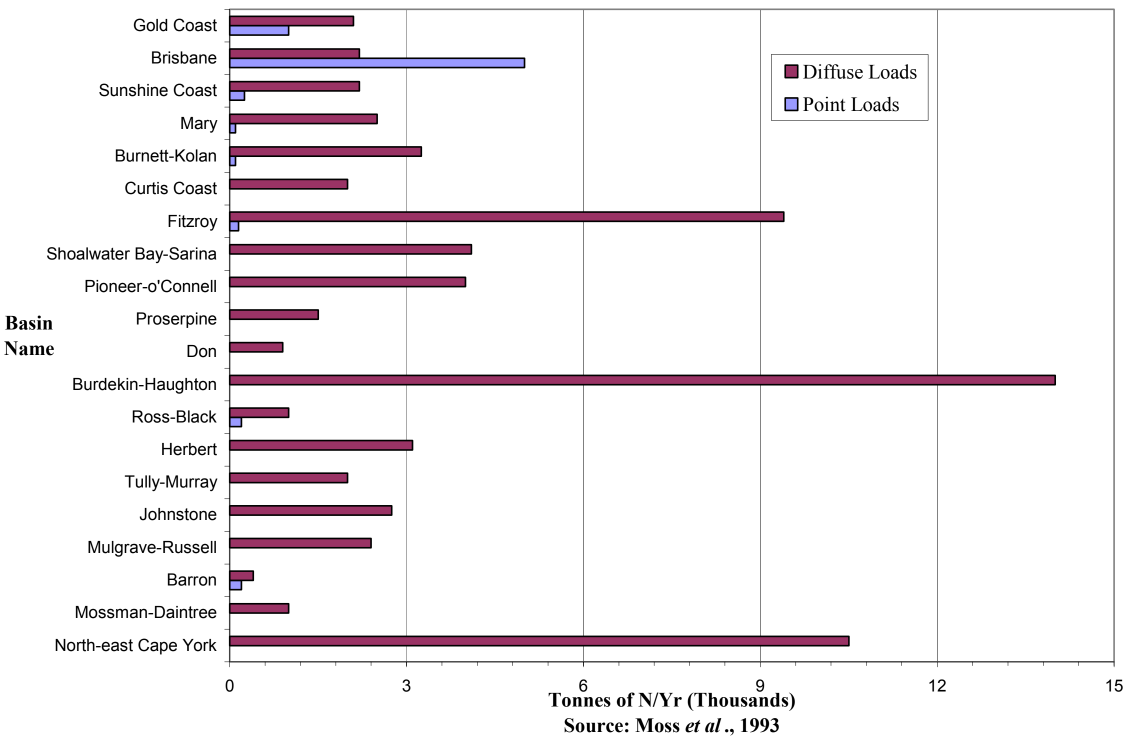

Figure 1. Levels of nitrogen exported from point and diffuse sources in the Great Barrier Reef Catchment Area.

Other issues of concern to water quality managers that will be considered within this report, include pressures resulting from increases in population, urbanisation, tourism, and port development, all of which are placing greater pressure on the environmental quality of the coastal zone (Rayment and Neil, 1996; Tarte *et al.* 1995; Wachenfeld *et al*. 1998).

3. The Great Barrier Reef Catchment Area

3.1 Geomorphology and Soils

The Great Barrier Reef Catchment Area consists of 40 drainage basins covering a total area of 425 964 km^2, which drains directly into the Great Barrier Reef lagoon and extends from latitude 10º S in the north to 24.5º S in the south (MAP 1). The Great Barrier Reef Catchment Area forms 95 % of the total area of Australia's North East Coast Drainage Division and 25 % of the total area of the State of Queensland (Table 1). The size of the non-island catchments varies greatly from the smallest, the Mossman basin at 533 km^2, to the largest, the Fitzroy Basin at 142 460 km^2. The two largest basins, the Fitzroy and the Burdekin, represent 64 % (272 504 km^2) of the total Great Barrier Reef Catchment Area (Table 1).

Table 1. Area of drainage basins within the Great Barrier Reef Catchment Area.

Basin Name	Total Area (km^2)	Basin Name	Total Area (km^2)
Jacky Jacky	2 825	Proserpine	2 499
Olive-Pascoe	4 197	Whitsunday Islands	54
Lockhart	2 848	Whitsunday Islands	102
Stewart	2 679	O'Connell	2 317
Jeannie	3 577	Pioneer	1 582
Normanby	24 624	Plane	2 437
Endeavour	2 065	Fitzroy	142 460
Daintree	1 893	Styx	3 003
Mossman	533	Shoalwater	3 574
Barron	2 135	Waterpark	1 629
Mulgrave-Russell	1 993	Curtis Island	507
Johnstone	2 250	Calliope	2 175
Herbert	9 742	Boyne	2 457
Tully	1 590	Baffle	3 970
Murray	1 042	Burnett	33 274
Burdekin	130 044	Kolan	2 904
Hinchinbrook Island	325	Fraser Island	1 630
Black	1 046	Burrum	3 394
Ross	1 341	Mary	9 450
Haughton	4 353	Noosa	1 908
Don	3 538		
		GBRCA Total	425 964
		Queensland	1 720 959

Source: DPI, 1993.

The most striking characteristic of the Great Barrier Reef Catchment Area is its lack of homogeneity. The drainage area includes some of the most topographically diverse terrain on the Australian continent, including desert uplands, high relief associated with coastal ranges and tablelands, and a retreating escarpment with residual outliers on the coastal alluvial plains. Depositional landforms found on the coastal plains include floodplains, alluvial terraces, deltaic plains, saline alluvial plains, tidal flats and coastal dune systems.

The Great Barrier Reef Catchment Area is delineated to the west by the Great Dividing Range and to the east by the coast immediately adjacent to the Great Barrier Reef World Heritage Area. At its most northern extent (at the top of Cape York Peninsula), the watershed lies close to the lagoon as a series of coastal mountain ranges. Further south, the Great Dividing Range is located over 400 km inland from the coast and, as a relief feature, is barely visible over upland plains. An almost unbroken (north to south) line of escarpments and ranges (known as the Great Escarpment[1]) separates the drier uplands in the west of the Great Barrier Reef Catchment Area from a relatively narrow strip of lowland alluvial plains along the length of the coast. The

[1] The Great Escarpment formed as part of Cainozoic rift valley faulting processes. Except for sections of coastal ranges in the Mulgrave/Russell basin, the associated faults are now offshore but can be seen in the linear chains of continental islands in the lagoon (eg. Whitsunday Islands) (East in Wadley and King 1993). The retreating escarpment, which formed the coastal lowlands, extends for a distance of 2 800 km in Queensland. It averages 200-700 m in height but with sections as high as 1130 m (East in Wadley and King 1993). The Great Escarpment is often misinterpreted as defining the extent of the GBRCA.

lowland coastal plains are comprised of 36 relatively smaller, high rainfall basins while just four large basins (the Normanby, Burdekin, Fitzroy and Burnett basins) dominate the drier Eastern Uplands, representing 77.5 % of the total catchment area.

Geologically, the Great Barrier Reef Catchment Area falls within the east Australian orogenic province, an area with an extensive tectonic history. Repeated uplifting, folding, sedimentation and metamorphism has been complicated by igneous intrusions and basalt flows produced by Cainozoic volcanic activity (MAP 2). This orogenesis combined with geomorphic evolution has contributed to the diverse pattern of soils seen today within the Great Barrier Reef Catchment Area (Isbell, 1986). Generally, the soils of the coastal areas include often bleached, shallow stony soils and deep sands. In the sub-coastal zone, duplex soils with obvious sandy loam A-horizon over clay B-horizon are very common. Cracking clays with associated gilgai development are found extensively in the central and southern inland areas of the Great Barrier Reef Catchment Area. Large areas of massive sesquioxide soils (red earths and yellow earths) are found throughout the north and east, with structured sesquioxides (euchrozems and kraznozems) in smaller areas in the north and the south of the Great Barrier Reef Catchment Area (Isbell, 1986). The soils of the catchment area are typically of low fertility (particularly deficient in phosphorus and nitrogen) and exhibit poor soil structure.

The regional and local occurrence of vegetation communities such as rainforest is not always strongly correlated with soil types *per se*. For example, the northern wet tropical rainforests can be found growing on steep slopes over 3-7m deep kraznozem soils, while in other areas rainforests can occur on poor granitic substrates, with soil permeability being the key pre-requisite (Isbell, 1986). During settlement, the occurrence of rainforest vegetation was often seen as an indication of the presence of fertile agricultural soils. The latter was not always true, and in fact, the low fertility of soils has generally resulted in the extensive application of fertiliser and conditioner to maintain agricultural productivity. Soil problems affecting lagoon water quality resulting from post-settlement land use will be addressed later in this report under agricultural soils.

3.2 Climate and Runoff

The climate within the Great Barrier Reef Catchment Area ranges from tropical to sub-tropical. Rainfall is distinctly seasonal, particularly in the northern half of the Great Barrier Reef Catchment Area where the monsoon influence during the summer months (September to March) produces high rainfall, particularly when associated with the development of tropical cyclones. The winter months are drier and dominated by sub-tropical high-pressure systems. Interruptions to this seasonal barometric pattern may occur over periods of years as a result of the Southern Oscillation. The eastern Queensland basins may experience extended years of drought and decreased cyclonic activity during low-index years (El Niño), followed by periods of exceptionally high rainfall during high-index years (La Nina) (Lough, 1991). During the El Niño drought conditions, there is concern of soil compaction and structure decline on grazing land, due to trampling by hard-hoofed grazing stock, such as sheep and cattle (Robertson *et al.* 1996). The drought is often followed by unusually high rainfall and runoff rates associated with the La Nina cycle. Sheet-wash, rill and gully erosion over large areas of the tropical rangelands contributes high sediment loads to the Great Barrier Reef Catchment Area river systems during La Nina cycles (Robertson *et al.* 1996; QDPI, 1993).

Lough's (1991) analysis of historic climatic data for Queensland has suggested that the years following settlement from 1870-1899, were some of the wettest seasons recorded for central and northern Queensland. The wettest 30-year period recorded was 1891-1920; the wettest 10-

year period recorded was1970-1979, and the wettest year recorded was 1974. High summer rainfall totals were also recorded in the 1950's and 1970's. The driest year recorded was in 1902, the driest 10-year period was 1940-1949 and driest 30-year period recorded was 1922-1951 (Lough, 1991).

Spatially, rainfall distribution is highly variable within the Great Barrier Reef Catchment Area. Cairns (17º S), in the northern section of the Great Barrier Reef Catchment Area (Barron Basin), recorded a mean monthly rainfall of 400-500 mm for the summer months of January, February and March for the years 1958-1992 (Lough, 1995). Further south (24ºS), Rockhampton (Fitzroy Basin) recorded a mean monthly rainfall of 100-150 mm for the same period. However, both centres recorded less than 50 mm for the driest months from June to October (1958-1992) (Figure 2).

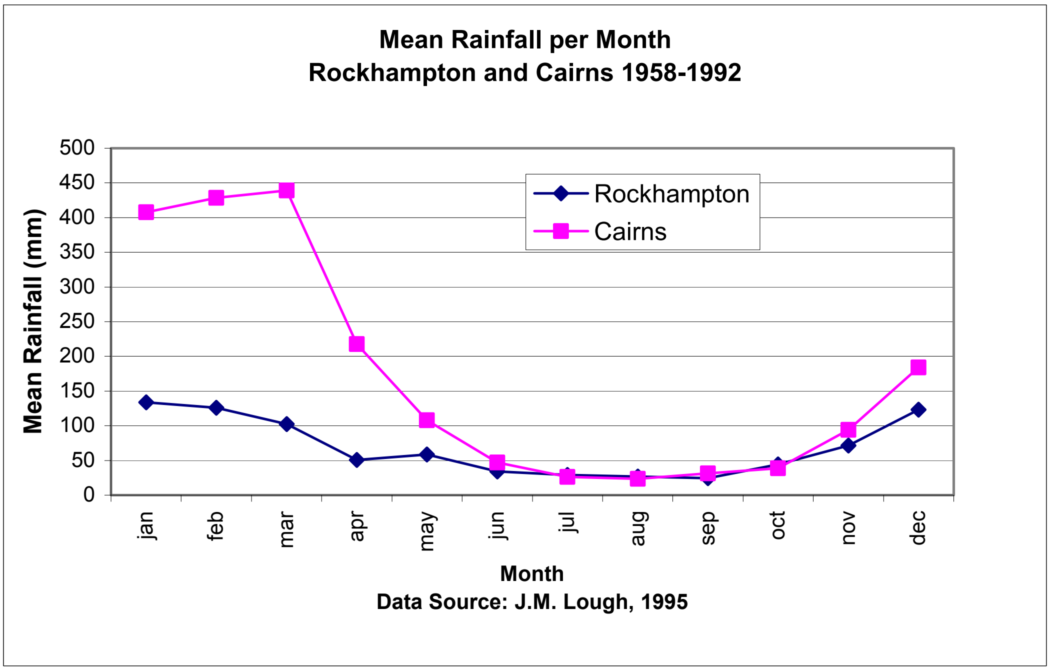

Figure 2. Mean rainfall per month, Rockhampton and Cairns 1958-1992.

The coastal basins receive considerably higher rainfall than the uplands, with a zone of greater than 1 000 mm annual rainfall declining within 100 km of the coastline. The gradient becomes less steep beyond the coastal ranges over the drier uplands to 500 mm in the western extremities of the largest basin (the Fitzroy basin). Consequently, more dense settlement and intensive agricultural expansion is concentrated in the coastal zone, particularly in those basins receiving higher rainfall. Pastoralism is the dominant land use in the drier uplands but also occurs in the wetter coastal basins (QDPI, 1993). Figure 3 and Figure 4 show the Annual and Seasonal rainfall for Cairns and Rockhampton for the period 1958 to 1992. Far higher seasonal rainfall fluctuations occur during the summer months than rainfall recorded during the winter months (Lough, 1995).

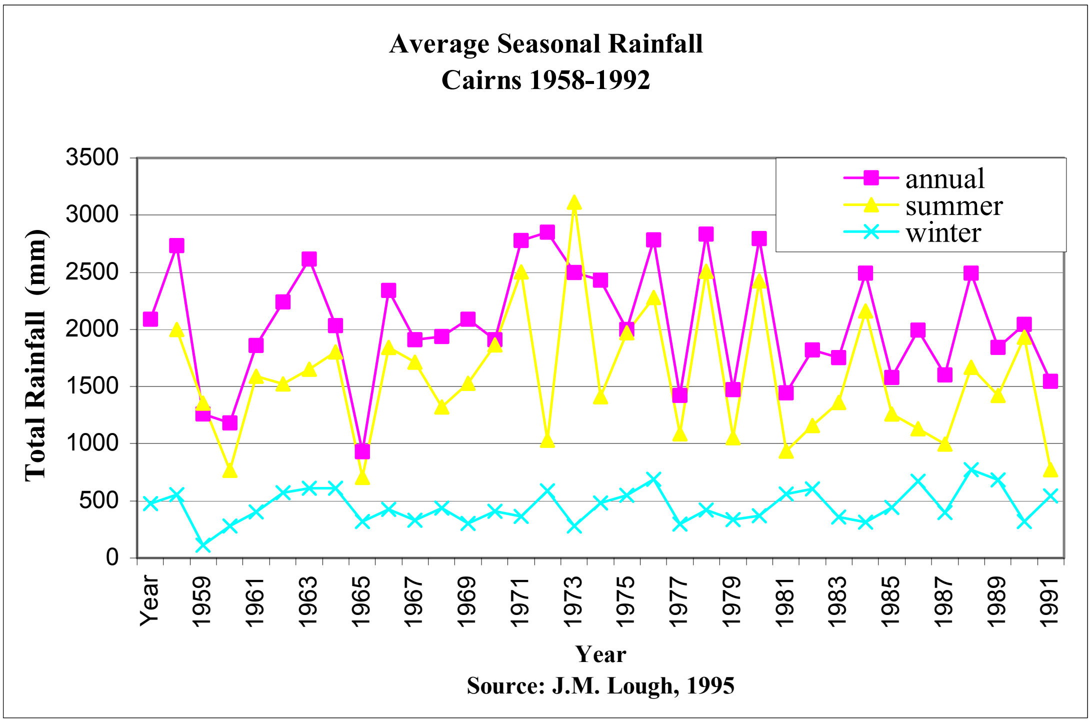

Figure 3. Annual and seasonal rainfall, Cairns 1958-1992.

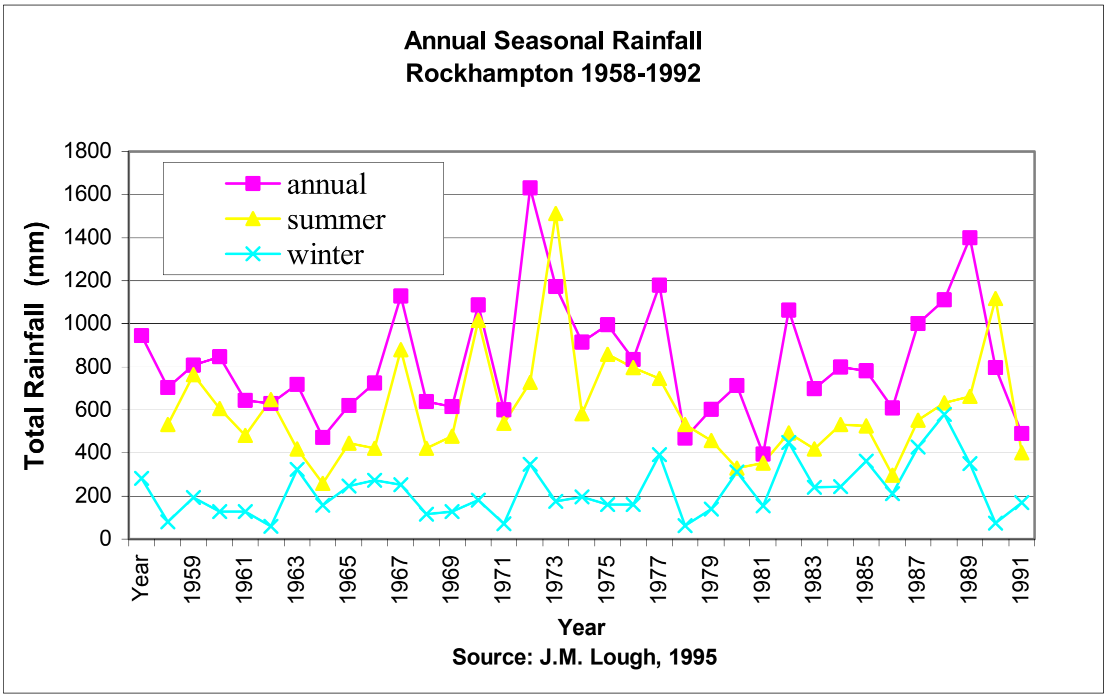

Figure 4. Annual and seasonal rainfall, Rockhampton 1958-1992.

Several estimates of the total volume of runoff from the Great Barrier Reef Catchment Area to the lagoon are identified in the literature. Mitchell and Furnas (1996) estimate the total average annual freshwater volume to be 40 km^3. The smaller coastal basins, (particularly the Mulgrave-

Russell, Johnstone, Tully and Murray River basins), have the highest rainfall/runoff ratio (Table 2). Peak river flows occur during the months of February and March with lowest flows recorded during August /September (Lough, 1995). Inter-annual variation in these summer flows is greatest in the larger, more arid basins, particularly the Fitzroy and the Burdekin (Lough, 1995). Australian rivers generally display a higher variation in annual flows than rivers of other continents; this phenomenon is particularly marked in the larger non-coastal basins (Robertson *et al.* 1996). Consequently, water regulation through the construction of dams and weirs has been prolific on most Australian river systems including the more arid basins within the Great Barrier Reef Catchment Area (Robertson *et al.* 1996; Powell, 1991).

Table 2. Mean annual rainfall and runoff for in the Great Barrier Reef Catchment Area.

Basin Name	Mean Annual Rainfall (mm)	Mean Annual Runoff (000 mega litres)	Run-off/Rainfall ratio (%)	Proportion of basin gauged (%)
Daintree	2 576	3 560	65	5
Mossman	2 459	687	57	0
Barron	1 447	1 153	37	89
Mulgrave-Russell	3 233	4 193	64	45
Johnstone	3 405	4 698	59	57
Tully	2 907	3 683	74	87
Murray	2 485	1 628	57	14
Herbert	1 331	4 991	37	87
Black	1 510	509	31	33
Ross	1 071	372	19	50
Haughton	923	756	22	67
Burdekin	640	10 100	12	99
Don	1 022	689	17	33
Proserpine	1 562	1 431	37	14
O’Connell	1 705	1 668	40	30
Pioneer	1 418	994	47	93
Plane	1 499	1 370	34	16
Styx	1 157	825	23	0
Shoalwater	1 102	832	20	0
Waterpark	1 317	700	29	7
Fitzroy	702	7 127	7	95
Calliope	889	340	17	61
Boyne	1 031	401	15	99
Baffle	1 173	750	17	37
Kolan	1 162	464	13	80
Burnett	765	1 743	7	98
Burrum	1 104	718	20	52
Mary	1 158	2 309	21	81

Source: Pulsford 1993.

4. Pre European-Settlement Vegetation

Prior to settlement, anthropogenic land cover disturbance within the catchment area seems to have been largely confined to Aboriginal burning of land, a practice that commenced before the Holocene, and so therefore, will not be discussed as part of this report (Singh *et al.* 1981; Singh, 1982). Furthermore, the presence of extensive areas of sclerophyll (floristic dominance of two genera: *Acacia* and *Eucalyptus*) in the Great Barrier Reef Catchment Area is indicative of a widespread natural fire regime occurring over the last 10 000 years under the relatively stable Holocene climate (Kershaw, 1982). However, there can be no doubt that changes to land cover in the last 200 years since European settlement has extensively modified the pre-European settlement vegetation communities within the Great Barrier Reef Catchment Area.

Under the terrestrial biogeographic regions and provinces classification scheme (adopted by the Queensland Department of Environment), generalised pre-European settlement vegetation types can be inferred from the seven biogeographic regions falling within the Great Barrier Reef Catchment Area (MAP 3). North to south, these include the Cape York Peninsula bioregion, which is characterised by *Eucalyptus* sp. woodlands and open forest. Structurally, the Cape York Peninsula open woodlands has an understorey of tall grasses, shrubs and small trees with *E. miniata* and *E. tetrodonta* being the dominant tree species. Further south along the Wet Tropical Coast, mixed closed rainforest communities (10-30 m high) predominate. To the west of the wet tropics, the *Eucalyptus* sp. woodlands and open woodlands of the Einasleigh Uplands dominate with patches of *Acacia* sp. open forests, which tend to dominate over *Eucalyptus* sp. in lower rainfall areas. Further south and inland, *Eucalyptus* sp. woodlands and open woodlands typically with a hummock grass understorey distinguish the Desert Uplands bioregion.

The largest biogeographic region within the Great Barrier Reef Catchment Area is *Acacia sp.* woodlands and open forests of the Brigalow Belt occupying 56 % of Great Barrier Reef Catchment Area. The Brigalow Belt extends in a broad band from near Townsville to beyond the southern limit of the Great Barrier Reef Catchment Area (Table 3). Typically, the Brigalow Belt was dominated by *Acacia harpophylla* ('Brigalow') with mixed *E. populnea* ('Poplar Box') and *Casuarina cristata* ('Belah'). Sandwiched between the Brigalow and the coast is the Central Queensland Coast bioregion of *Eucalyptus* sp. woodland and open woodland. Similarly, *Eucalyptus* sp. woodland and open woodland dominate the southern-most bioregion of south-east Queensland (Queensland Department of Environment and Heritage, 1995).

Table 3. Biogeographic regions – area within the Great Barrier Reef Catchment Area.

Biogeographic Region	Total Area with the GBRCA (km^2)	Percentage of GBRCA (%)
Cape York Peninsula	38 958	9
Wet Tropics	18 284	4
Brigalow Belt	236 575	56
Einasleigh Uplands	52 353	12
Central Queensland Coast	14 021	3
Desert Uplands	27 091	6
Southeast Queensland	38 594	9

Source: Data provided by Queensland Environment Protection Agency, 1998.

Wetland and littoral vegetation communities are found predominantly in relatively narrow bands along the coastal lowlands and include *Melaleuca* and mangrove forests, sedge and heath lands, samphire flats, and grasses associated with dune systems. Forests and woodlands ranging structurally from closed to open and sparse with some grassland, dominated the Great Barrier Reef Catchment Area prior to European settlement. The western area of the State (outside the Great Barrier Reef Catchment Area) was dominated by semi-arid grasslands and shrublands.

4.1 Land clearing within the Great Barrier Reef Catchment Area

Native vegetation clearance[2] in Australia, has historically been high. However, it has been estimated that in the last 50 years just as much land has been cleared during the previous 150 years since settlement (DEST, 1995). Graetz *et al*. (1995) describes the history of alteration to natural vegetation in Queensland as "one of intervention on a massive scale, a transformation almost unthinkable in today's world of conservation awareness and environmental impact assessments". Forests originally covered 21 % of the State, (an area of 355 540 km^2) and woodlands covered 28 % of the State (Government of Queensland, 1990), with a significant proportion of these forests and woodlands located within the Great Barrier Reef Catchment Area. By 1984, 110 000 –150 000 km^2 of woodland forests were cleared for agriculture which represents over half of the area of Queensland forests (Government of Queensland, 1990). During the last 50 years, clearing for pastoral expansion has by far surpassed clearing for any other landuse (Graetz *et al.* 1995). (For clearing histories for brigalow, rainforest and wetland vegetation communities see later sections in this report).

Landcover disturbance for the Australian continent has been quantified by Graetz *et al.* (1995) using Landsat MSS (satellite) data. Graetz *et al.* (1995) found that over 51.9 % (1 030 000 km^2) of the pre-settlement landcover on the Australian continent within the Intensive Landuse Zone (ILZ) had been cleared or thinned[3] over the 200 year period since settlement. Landcover clearing and thinning was most extensive in the southern part of the continent extending along the East Coast into the central Queensland catchments of Fitzroy and Burdekin (MAP 4). The majority of the clearing in the central Queensland area is associated with the removal of Brigalow vegetation for improved pastures (Graetz *et al.* 1995). Within the ILZ in Queensland (a total area of 62 % of the state), 40.2 % of vegetation remained uncleared, 26.7 % was cleared and 25.8 % was thinned (ie. a cleared and thinned total of 52.5 %) (Graetz *et al.* 1995).

Obtaining statistics on the rates of vegetation clearance over time is difficult, but trends which have been identified indicate that clearance rates in Queensland were historically high (see Brigalow, rainforest and wetland vegetation sections in this report) and continue at levels far in excess of other Australian states. The 1994 National Greenhouse Gas Inventory Committee Report estimated that in the 10-year period between 1988 and 1998, in excess of 50 000 km^2 of

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[2] Native vegetation clearance in this study is defined as "the removal of a significant proportion of one or more of the major vegetation strata in an ecosystem by mechanical or chemical means. It includes removal of woody vegetation such as forests and woodland communities, the loss of grasslands, and drainage of wetland ecosystems" DEST Biodiversity Series, Paper No. 6 p. 15 1995.

[3] Three key classes were used in the interpretation of the Landsat data: Uncleared – where the spectral signature of the canopy was intact, Cleared – where the spectral signature of the intact canopy was replaced by that of understorey. Thinned –intermediate step between cleared and uncleared based on the spectral signature, and Indeterminate – no assessment could be made. (Graetz *et al.* 1995)

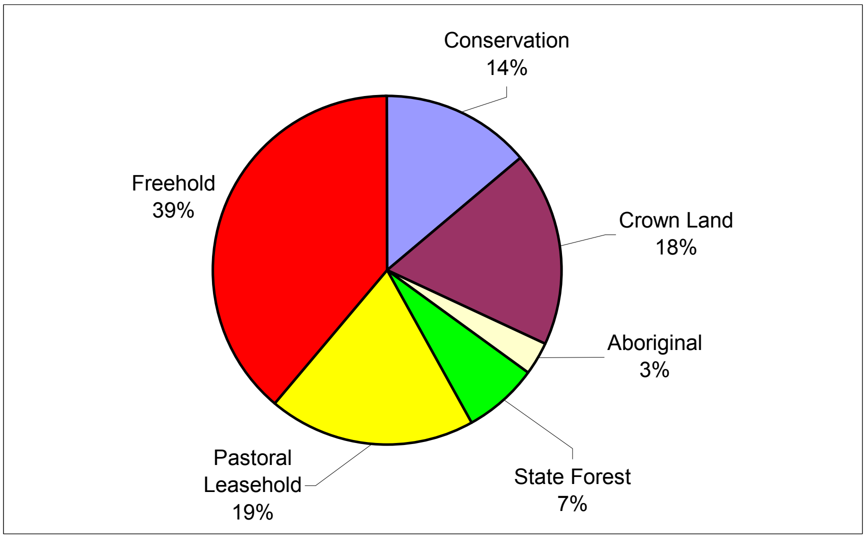
land was cleared in Australia, with an estimated 30 000 km^2 of the clearing occurring in Queensland. The 1975-1986 clearance rate of 5.6 % for the brigalow belt west of Mackay increased to 9.1 % for the period 1986-1990 (Queensland Department of Environment and Heritage, 1995). Most of the clearing in Queensland is now occurring on marginal agricultural land, particularly in central Queensland, where soil fertility (such as phosphorus) is considered to be inadequate for intended agricultural purposes (Ahern *et al.* 1994).

A large proportion of the tree clearing permits issued in central Great Barrier Reef Catchment Area are for the clearing of regrowth on previously cleared land. From 1990 to 1995, 45 % of the 8 462 km^2 of tree clearing permits issued in the Shires of Bauhinia, Belyando, Emerald, Jericho and Peak (located in the Desert Upland and Brigalow bioregions), was for the clearing of regrowth (Queensland Department of Environment and Heritage, 1995). Permits issued in Jericho and Belyando shires between 1987 and 1994 represented 25 % of the total land area of these shires (Queensland Department of Environment and Heritage, 1995).

4.1.1. Vegetation Clearing and Land Tenure

Graetz *et al.* (1995) analysed vegetation clearing with respect to land tenure types for the Australian continent. The results showed that the majority of landcover disturbance occurred on freehold and pastoral leasehold land (58 %) (Figure 5). Within the Great Barrier Reef Catchment Area, freehold land tenure is most extensive in the coastal lowlands north to the Daintree basin and the southern inland Fitzroy and Burnett basins. Leasehold tenure shows greatest representation in the Burdekin and remote basins of Cape York Peninsula (MAP 5). Other land tenure types, such as Aboriginal land, unused land (Crown land), state forests and conservation areas accounted for 42 % of the continent's land cover disturbance. Within the Great Barrier Reef Catchment Area, National Estate and State Forests account for 12.25 % (52 000 km^2) of land tenure by area, a similar figure to the national proportion of 13 % identified by Graetz *et al.* (1995).

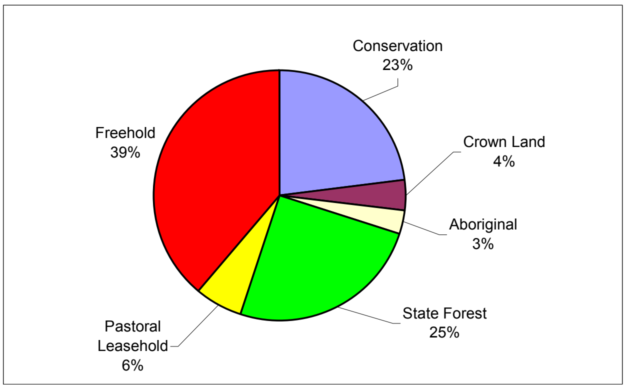
Graetz *et al.* (1995) also predicted future vulnerability of vegetation types under the six tenure classes. Figure 6 represents the future vulnerability under tenure types with some of the major vegetation communities represented within the Great Barrier Reef Catchment Area. General trends can be identified for the Great Barrier Reef Catchment Area from this national scale dataset. Closed forest communities (other than those dominated by *Eucalyptus* and *Acacia* sp.) such as wet tropical rainforests and tall, medium and low Eucalypt forests are most threatened under freehold and forestry tenure. Within the Great Barrier Reef Catchment Area, rainforests were extensively cleared in the coastal lowlands for more dense settlement and agriculture, particularly sugarcane. Timber exploitation has occurred in both rainforest and Eucalypt forests within the Great Barrier Reef Catchment Area. The remaining rainforest (an estimated two-thirds of the original cover), is found on steep mountain slopes and has been protected under Wet Tropics World Heritage listing since 1988. The north Queensland rainforests under Wet Tropics World Heritage management (9 000 km^2) currently include 27 different types of land tenure. National Estate and forestry covers large areas while freehold tenure covers 2 % and leasehold 14 % (Wikers, 1997).



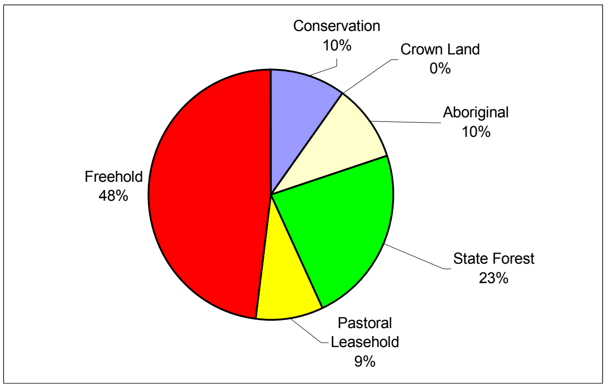
Source: Graetz *et al.* (1995).

Figure 5. Land cover disturbance by tenure types for the Intensive Land use Zone (ILZ), Australia.

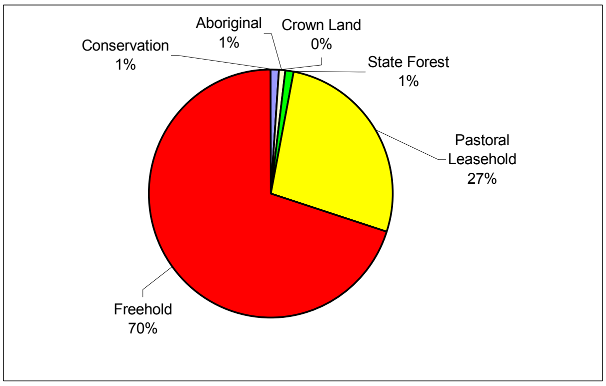
In contrast, the tall, medium and low *Acacia* forests (Brigalow) are heavily impacted (97 %) within freehold and pastoral land tenure types. Within the Great Barrier Reef Catchment Area brigalow vegetation has been largely celared for improved pasture, particularly in the Fitzroy and Burdekin basins. Similarly, Medium Sparse Forests where the dominant overstorey genus is *Eucalyptus* rated a combined freehold and pastoral tenure risk of 98 %. Graetz *et al.* 1995 has shown that clearing for pastoral expansion has greatly exceeded the area of land cleared for crops, particularly since the Second World War. Most of the clearing of the Australian continent for pastoralism over this time has occurred in Queensland (Graetz *et al.* 1995). The brigalow vegetation has virtually been completely cleared for pastoralism and is detailed in section 4.2 of this report.



a. Rainforest Vegetation Communities:
Closed Forests Tall, medium and low closed forest: dominant overstorey genus is other than *Eucalyptus* or *Acacia* (Rainforest communities).



b. Eucalyptus Communities:
Tall, medium and low forest: dominant overstorey genus is *Eucalyptus*.



c. Brigalow Communities:
Tall, medium and low forest: dominant overstorey genus is *Acacia.*

Figure 6. Potential for future disturbance based on tenure type for the major vegetation communities in the Great Barrier Reef Catchment Area.
Source: Graetz *et al.* 1995

4.1.2. National Estate and State Forest

Tenure provides a means for governments to manage landuse. Land assigned to National Estate and World Heritage tenures would be expected to experience relatively low levels of disturbance, however, disturbance within these areas was identified by Graetz et al. (1995) for the Australian ILZ. Historically, the gazettal of National Parks in Queensland has been very slow. By the 1930s, Queensland had gazetted 32 parks, occupying an area of 653 km^2, which were located on land deemed unsuitable for agricultural development or timber extraction, and generally excluded the coastal zone (Fitzgerald, 1984). National Park area remained static for the following 35 years, until the 1970s, when the area under National Park gazettal doubled to 10 000 km^2 (Queensland Year Book, 1975). By 1975, National Parks still only covered 1.28 % of Queensland land area, with almost one quarter of the area of these parks falling within the Simpson Desert in the State's west and outside of the Great Barrier Reef Catchment Area (Fitzgerald, 1984).

The first National Parks were often small, fragmented, surrounded by conflicting land use and were often not viable as self-sustaining ecosystems. For an example, the Fairy Bower National Park (0.88 km^2) near Rockhampton (Fitzroy Basin) had its 1908 National Park gazettal revoked thirty years later due to "degradation beyond restoration" (Fitzgerald, 1984). National Park status was often only inferred on areas of "scenic beauty" rather than to preserve ecosystems, vegetation communities or biodiversity. Of the brigalow vegetation communities (despite originally covering over 60 000 km^2 in Queensland), only a fraction are conserved (0.5 %) in Parks due to the widespread alienation of brigalow lands to freehold and pastoral leasehold tenures. Most Parks in the brigalow bioregion were gazetted for aesthetic landscape values and today, the conservation of the Brigalow depends on preserving remnant communities currently outside National Estate tenure (Sattler and Webster, 1984).

These limitations underlying National Estate gazettal, are being addressed with the recognition of biodiversity through the adoption of biogeographical regions and sub-regional provinces by the Queensland Government. *The Nature Conservation Act (1992)* recognised 11 classes of protected areas with a range of management principles, including coordinated management involving indigenous and landholder groups. These are: National Park, National Park (scientific), National Park (Aboriginal land), National Park (Torres Strait Islander land), Conservation Park, Resources Reserve, Nature Refuge, Coordinated Conservation Area, Wilderness Area, World Heritage Management Area and International Agreement Area. The level of resource use within these areas varies significantly between classes of protected areas.

At June 1996, Queensland had 210 National Parks covering 641 44 km^2 (3.7 % of the State), 154 Conservation Parks covering 284 km^2, 36 Resources Reserves covering 3 255 km^2, two Nature Refuges (0.90 km^2) and one Coordinated Conservation Area of 11.7 km^2 (MAP 6). The area under National Estate tenure in Queensland has remained significantly lower than the land under State Forest tenure (Table 4). The area of Permanent State Forests and Timber Reserves rapidly increased from approximately 25 000 km^2 in 1935 to 40 000 km^2 by 1975. In 1996, 30 000 km^2 were under State Forest and Timber Reserve tenure within the Great Barrier Reef Catchment Area (Table 5 and MAP 7).

The use of forest resources has a long tradition of conflict with conservation in natural forest areas. National Park boundaries were drawn to exclude areas where forestry may be developed in the future. For example, the Daintree National Park (565 km^2) excluded the upland rainforests of the Mount Windsor Tablelands and rainforest in the east of the Daintree catchment area. Despite the Mount Windsor Tablelands being declared by Queensland

Government as one of three possible sites as a wilderness area, these upland rainforests were intensely logged in the early 1980s.

Table 4. Total area of National Estate (NE) per basin within the Great Barrier Reef Catchment Area (km^2).

Basin Name	Total NE Area (km^2)	NE % of Basin Area	Basin Area (km^2)	% of NE GBRCA
Baffle	219	6	3 970	0.99
Barron	47	2	2 135	0.21
Black	95	9	1 046	0.43
Boyne	72	3	2 457	0.32
Burdekin	1 321	1	130 044	5.95
Burnett	138	0	33 274	0.62
Burrum	227	7	3 394	1.02
Calliope	3	3	2 175	0.02
Curtis Island	10	2	507	0.05
Daintree	558	29	1 893	2.51
Don	107	3	3 538	0.48
Endeavour	73	4	2 065	0.33
Fitzroy	5 189	4	142 460	23.36
Fraser Island	820	50	1 630	3.69
Haughton	468	11	4 353	2.11
Herbert	1 114	11	9 742	5.01
Hinchinbrook Is.	322	99	325	1.45
Jacky Jack	1 045	37	2 825	4.71
Jeannie	1 431	40	3 577	6.44
Johnstone	301	13	2 250	1.36
Kolan	2	2	2 904	0.01
Lockhart	265	9	2 848	1.19
Mary	91	1	9 450	0.41
Mossman	87	16	533	0.39
Mulgrave-Russell	620	31	1 993	2.79
Murray	243	23	1 042	1.09
Noosa	646	34	1 908	2.91
Normanby	5 479	22	24 624	24.66
O'Connell	145	6	2 317	0.65
Olive-Pascoe	191	5	4 197	0.86
Pioneer	106	7	1 582	0.48
Plane	62	3	2 437	0.28
Proserpine	315	13	2 499	1.42
Ross	73	5	1 341	0.33
Shoalwater	26	1	3 574	0.12
Stewart	0	0	2 679	0.00
Styx	4	4	3 003	0.02
Tully	29	2	1 590	0.13
Waterpark	98	6	1 629	0.44
Whitsunday Islands	127	82	156	0.57
GBRCA Total	22 170		425 964	100.00

Source: Queensland Environmental Protection Agency.

Table 5. Area of State Forest (SF) within the basins of the Great Barrier Reef Catchment Area.

Basin Name	Total SF Area	SF % of Basin Area	Basin Area (km^2)	% of GBRCA
Baffle	481	12.12	3 970	1.60
Barron	794	37.23	2 134	2.65
Black	205	19.65	1 046	0.68
Boyne	307	12.50	2 457	1.02
Burdekin	1 275	0.98	130 043	4.25
Burnett	4 864	14.62	33 273	16.20
Burrum	906	26.71	3 394	3.02
Calliope	158	7.27	2 174	0.53
Curtis Island	72	14.23	50	0.24
Daintree	658	34.77	1 892	2.19
Don	1	0.03	3 538	0.00
Endeavour	337	16.36	2 064	1.12
Fitzroy	9 896	6.95	142 459	32.96
Fraser Island	0.2	0.01	1 629	0.00
Haughton	31	0.73	4 352	0.11
Herbert	996	10.23	9 741	3.32
Hinchinbrook Is	0	0.00	324	0.00
Jacky Jacky	0	0.00	2 825	0.00
Jeannie	0	0.00	3 577	0.00
Johnstone	595	26.47	2 249	1.98
Kolan	389	13.40	2 904	1.30
Lockhart	36	12.93	2 848	1.23
Mary	2 780	29.42	9 450	9.26
Mossman	149	28.07	532	0.50
Mulgrave-Russell	344	17.30	1 992	1.15
Murray	355	34.09	1 042	1.18
Noosa	471	24.71	1 908	1.57
Normanby	493	2.00	24 623	1.64
O'Connell	179	7.75	2 317	0.60
Olive-Pascoe		0.00	4 196	0.00
Pioneer	361	22.82	1 582	1.20
Plane	114	4.69	2 436	0.38
Proserpine	252	10.10	2 499	0.84
Ross	46	3.43	1 341	0.15
Shoalwater	13	0.38	3 573	0.05
Stewart	716	26.74	2 678	2.39
Styx	51	1.71	3 002	0.17
Tully	1 083	68.18	1 589	3.61
Waterpark	192	11.83	1 628	0.64
Whitsunday Islands	0	0.00	156	0.00
Grand Total	30 022		425 964	100.00

Source: Queensland Department of Natural Resources.

Wetlands assessed as significant have been included in the National Estate or designated as Fish Habitat Areas/Reserves. Conservation status has been gazetted for only 50 of the 142 significant wetlands in Queensland, and often this protection only extends over sections of the wetland (QDPI, 1993). Spatially, this protection occurs predominantly in the coastal sections of the basins (Johnson *et al*. 1997) with freshwater wetlands such as the Melaleuca swamps receiving considerably less protection. Wetlands designated within these classes may still be threatened by landuse practices immediately adjacent to the systems (Johnson *et al*. 1997). Within the Great Barrier Reef Catchment Area, the wetlands of Bowling Green Bay, Shoalwater and Corio Bays have been listed under the Convention on Wetlands of International Importance (RAMSAR Convention). Historical clearing and draining of wetlands and other impacts are presented in later sections of this report. Other internationally recognised protected areas include the Great Barrier Reef, the Wet Tropic Rainforests and Fraser Island World Heritage Areas.

4.2. History of Major Vegetation Disturbance

Within the Great Barrier Reef Catchment Area, the brigalow biogeographic region covers 235 575 km^2 (56 %), most of which occurs in the Fitzroy and the Burdekin basins. Originally brigalow communities were estimated to have covered 11 % of the area of the Burdekin basin and 30 % of the Fitzroy basin. As a result of clearing, this brigalow area is now less than 2 % in the Burdekin and 1 % in the Fitzroy (QDPI, 1993). Grazing is the dominant land use in both basins occurring over a combined area of 240 000 km^2 (QDPI, 1993). Soil erosion associated with grazing is widespread in both basins and dryland salinity problems are also prevalent (QDPI, 1993). The two basins are drained by ten rivers that collectively discharge approximately 17 230 000 mega litres annually into the Great Barrier Reef lagoon.

4.2.1. Brigalow Vegetation

The largest land-clearing event in terms of total area of a single vegetation community impacted since European settlement in the Great Barrier Reef Catchment Area, occurred in the brigalow biogeographic region (Sattler and Webster, 1984). Dominated by brigalow (*Acacia harpophylla*) and belah (*Casuarina cristata*) species, the brigalow forests were distributed in a mosaic-like pattern over a broad band from west of Townsville and extending south beyond the Queensland border, covering an estimated area of over 60 000 km^2 (Payne, 1959). Virtually all of the brigalow open forests have been cleared this century with less than 1 % of the original forests now conserved on Crown land (QDPI, 1993) (MAP 4).

Two intensive phases of brigalow clearing have occurred since settlement. The first phase, clearing for settlement and grazing, commenced earlier this century within the brigalow belt, particularly in the southern-most areas of Queensland. By 1953, an estimated one third of the total area of brigalow was cleared (initially south of the Great Barrier Reef Catchment Area in the Darling Downs, and then northwards) by ringbarking and burning (Fitzgerald, 1984; Wildlife Preservation Society of Queensland, 1985). The second phase of brigalow clearing commenced in 1962 in response to demand for land to convert to exotic pastures for grazing. The Fitzroy Basin Brigalow Land Development Scheme was jointly funded by the State and Federal Governments and anticipated the clearing of 45 000 km^2 of brigalow country for settlement/agriculture and beef grazing. By 1975, over 20 000 km^2 had been cleared in the southern brigalow belt north of Roma (Dawson and Nogoa River areas), followed by 26 235 km^2 in the MacKenzie-Isaacs River area of the Fitzroy basin (Fitzgerald, 1984; QDPI, 1993). Clearing in this phase was achieved by aerial spraying with the herbicides, 2,4-D and 2,4,5-T, and felling with machinery. Fitzgerald (1984) describes the rate of clearing of brigalow lands during the second phase: *"In order to capitalise fully on the Commonwealth loan, brigalow clearing proceeded very rapidly … Two large D8 tractors, dragging a ball and chain, were capable of flattening ten to twelve hectares an hour. The policy of rapid clearing, dictated by the reliance on external funds, was questioned by a number of sources. Conservationists argued that little thought was given to the systematic preservation of brigalow communities: moreover, premature destruction of the environment encouraged erosion and sucker regrowth"* (Fitzgerald, 1984).

Sattler and Webster (1984) state that only 0.5 % (303 km^2) of the original brigalow forests are conserved within National Estate. More recently, the Queensland Department of Environment (1990) stated that the representation of brigalow in conservation areas has been "ineffective" and that the clearing of over 60 000 km^2 of brigalow has been unique in the scale at which clearing occurred over a relatively short period of time (Government of Queensland, 1990).

The Payne Report (1959) on the proposed second development phase, stated the known limitations to agriculture carried out on brigalow soils as:

- the eventual loss of soil structure under cultivation resulting in erosion;
- the presence of extensive gilgais or melonholes (soils high in clay) in brigalow country; and
- the presence of "salt" and minerals in the surface layers.

Further soil degradation resulted when sheep were introduced to graze on sucker regrowth causing soil compaction and erosion. In other cases, cycles of spraying and ploughing were recommended to help control regrowth. Despite the introduction of improved pastures such as rhodes, panic and buffel grasses, the brigalow belt suffered severe sheet and gully erosion. By 1968, the Queensland Department of Agriculture was recommending that all slopes over 3 % in brigalow country have full contour banking applied (Fitzgerald 1984).

4.2.2. Tropical Rainforest Vegetation

Prior to brigalow development, land clearing began in the Great Barrier Reef Catchment Area along the accessible coastal river plains in the later decades of the 1800s. The high-rainfall basins dominated by rainforest communities were selectively logged while being cleared for closer settlement and agriculture, particularly bananas, sugarcane and grazing. From 1874 timber-getters were operating in the Cardwell, Tully and Johnstone River basin areas. The Daintree and Mossman Rivers were also subject to intensive logging, where one party is reported to have felled 700 000 feet of timber between July and September 1874 (Fitzgerald, 1982). The success of parties' of cedar cutters drew the attention of timber companies who proceeded to systematically harvest the coastal catchments (Fitzgerald, 1982). While premium rainforest species were targeted, *Eucalyptus* forests were also harvested for general-purpose timber (Graetz *et al*. 1995).

Graetz *et al*. (1995) suggests that early selective timber extraction had minimal impact on the change to the total area of rainforest, claiming that it was the clearing for agriculture/grazing that followed (and later the forestry industry) that caused the greatest loss. One third of the total rainforest in the study area has been cleared including virtually all of the lowland coastal rainforests, especially in the Johnstone, Mulgrave-Russell and Barron basins. The inaccessible rainforest on the steep slopes of the upper reaches of the coastal basins generally escaped major disturbance. The Atherton tablelands in the Barron basin were an exception, as this area was logged for timber and cleared for agriculture by the 1930s.

Harvesting of highly valued tropical rainforest species extended throughout all areas with the exception of those which were geographically inaccessible. Earlier, the river systems were used to float timber to ports. During forest clearing, makeshift timber trails were created to allow the removal of logs which were initially transported by bullocks and later by timber lorries. In 1880, Burns Philp contracted timber-getters to cut 15 million feet of cedar from the Atherton Tablelands. The difficulties involved in transporting timber from the then remote Tablelands to the coast were demonstrated when several million feet of timber were floated over the Barron Falls during a flood event; only 1 million feet were recovered with the remaining timber being destroyed beyond use. The remaining harvested cedar were left to decay in stockpiles on the Atherton Tablelands (Bolton, 1970). During this period, concerns were growing at the wasteful use of timber resources. Fitzgerald (1982) cites Barton, who in 1885, severely criticised government policy at the time for allowing "*indiscriminate plunder [of forests] by anybody who owns a team of bullocks and chooses to pay a trifling license fee*" (Fitzgerald, 1982).

Queensland's lack of appropriate reforestation plans meant that rainforests were harvested at a rate which exceeded their ability to replenish. In 1938, over 74 timber mills were located in the Northern Queensland forestry area processing some 27.5 million super feet of timber in that year alone (Queensland Official Year Book, 1975). Timber extraction from the rainforests of the Mount Windsor Tablelands in the early 1980s proceeded at a rate never before seen in a State Forest in Australia. The Queensland Department of Forestry was allowing extraction rates from rainforest areas of North Queensland at an unprecedented rate. *"Eighty-four percent of productive rainforest areas under Departmental exploitation had already been depleted of large trees and were in late 1982 regarded as deficit areas. In the remaining sixteen per cent, timber was being removed at an estimated ten times the rate of regrowth"* (Fitzgerald, 1984). The rainforests were continuously logged until protected by World Heritage listing in 1988 (See section 7.4 in this report).

Generally, deep soil profiles develop *in-situ* under rainforest vegetation in the wet tropics sediment, protected from fluvial transport by a dense canopy and a high organic biomass layer above and within the soil surface. Given the relatively steep morphology of these high-rainfall coastal basins, the labyrinth of timber trails may well have suffered erosion in high rainfall events, potentially contributing high-nutrient-laden sediment loads to the creeks and rivers of logged catchments. It is reasonable to assume that given the particularly high rainfall in North Queensland during the decades following settlement (Lough, 1995), timber extraction would not have been without impact on the water quality of nearby creeks and river systems. The more recent construction of the Cape Tribulation road in the Daintree basin demonstrated the problem of erosion from unsealed roads in rainforest areas.

However, the greatest source of sediment and nutrients from basins within the wet tropics area is derived from the clearing and cultivation associated with agricultural lands of the coastal lowlands. During two flood events associated with cyclonic activity in 1994, 193 000 tonnes of sediment were transported from the agricultural lands in the Herbert basin (Wong, 1996). Clearing of lowland riparian rainforest in the Herbert basin was most rapid between settlement and 1943, (in conjunction with sharp rises in the area of sugarcane and grazing) and recent analysis demonstrated a five-fold loss of rainforest in the area since settlement (Johnson *et al*. 1997). The high productivity of rainforest was generally mistaken as an indication of fertile agricultural soils and in some areas this is the case (Isbell, 1986). However, it is the unique nutrient recycling capacity of rainforests that allows them to exist on even sandy substrate such as the rainforests of Fraser Island. In the long term, many of the rainforest soils under agriculture suffer high erosion and require large inputs of phosphorus and nitrogen fertilisers to maintain agricultural productivity. This is illustrated by the exceptional declines in sugarcane productivity during the initial years of establishment (refer to section 7.1 Soil Fertility). The deep weathered soil profile created by rainforest is also vulnerable to erosion and mass movement in tropical regions following vegetation disturbance.

4.2.3. Wetland Vegetation

Wetland vegetation communities perform a valuable role in maintaining water quality in the Great Barrier Reef lagoon through their role as sinks, filtering sediment, nutrients and chemicals from land runoff, as well as stabilising soils at the interface between the land and the river and coastal waterbodies (Arthington and Hegerl, 1988). A further important role is their contribution to the regulation of water by dampening the effect of flooding during high rainfall events (Johnson *et al*. 1997). Over the past 50 years, the pressure on wetland ecosystems has increased as a result of alterations to hydrodynamic regimes within catchments and by clearance schemes for the expansion of agriculture and urbanisation (Johnson *et al*. 1997). High population growth in some major urban centres such as Cairns has resulted in traditional cane land being acquired for urban developments such as housing estates, often on relatively productive agricultural soils. Between 1970 and 1976, approximately 20 % (7 km^2) of the wetlands of Trinity Inlet at Cairns were drained and put under sugarcane (Fitzgerald, 1984; QDPI, 1993). The area today suffers serious acid sulfate soil problems and no longer supports agriculture (QDPI, 1993).

In 1997, an estimated area of 18 408 km^2 of freshwater wetlands remained in the Great Barrier Reef Catchment Area (Table 6). The least disturbance to freshwater wetlands has occurred in the North-east Cape York Peninsula basins due to their remoteness, and the Shoalwater Bay area which has been isolated under Australian Defence Force tenure (Johnson *et al*. 1997). Together, these two wetland areas contain 68 % of the total freshwater wetlands in the Great Barrier Reef Catchment Area. The extent of freshwater wetlands within the remaining basins prior to settlement is largely unknown, except for a few basins where detailed research has been undertaken (Johnson *et al*. 1997; Russell and Hales, 1993).

While the remaining wetlands in the Great Barrier Reef Catchment Area are in reasonable condition, the native riparian vegetation is severely degraded except within National Estate (Johnson *et al*. 1997). Russell and Hales (1993) reported wetland losses of over 60 % in a 40-year period (1951-1993) in the Johnstone basin resulting from agricultural infringement. The most severe impact has been on the Melaleuca wetlands which have been reduced by 78 %. Other freshwater wetlands experienced losses in excess of 50 % of their area, while mangrove wetland areas remained stable (Table 7). Johnson *et al.* (1997) found the Melaleuca wetlands in the Herbert River area had suffered a two-fold decrease in extent between settlement and 1943. Rapid cane expansion in the Herbert between 1977 and 1996 increased this Melaleuca wetland loss to 6-fold. Mangrove wetlands were largely undisturbed. Johnson *et al*. (1997) suggests that if the current land practices and trends identified for wetlands in the Herbert are not halted, there will be little remaining freshwater wetlands in the future. A similar pattern appears to exist for wetlands in most basins where agricultural expansion is occurring.

Table 6. Estimated area of freshwater wetlands in the Great Barrier Reef Catchment Area.

Basin Name	Wetland Area (km^2)	Basin Name	Wetland Area (km^2)
North-east Cape York	8 376	Pioneer-O'Connell	263
Shoalwater Bay-Sarina	4 127	Proserpine	214
Burdekin-Haughton	1 494	Mulgrave-Russell	124
Fitzroy	1 329	Johnstone	116
Ross-Black	719	Don	110
Tully-Murray	504	Mossman-Daintree	61
Herbert	499	Barron	10
Curtis Coast	462	GBRCA Total	18 408

Source: Johnson *et al*. 1997 (adapted from Anonymous, 1993; Blackman *et al*. 1996)

Mangrove forests and saltmarsh vegetation occupy approximately 4 000 km^2 of the coastline bordering north-east Queensland and within the Great Barrier Reef World Heritage Area (Duke, 1997). Since European settlement, some significant losses of mangrove wetlands have occurred on a local scale, however compared to other wetland types (ie. *Melaleuca* wetlands), mangrove wetlands have not changed significantly throughout Queensland (Environmental Protection Agency, 1999).

Further threats to wetlands can be expected with the recent rise in the use of ponded pastures for grazing, particularly in the central basins in the Great Barrier Reef Catchment Area (Fitzroy and Broadsound area). Levees and embankments are being constructed to restrict the tidal influence in the coastal zone, allowing cattle to be grazed on these lands. Recent estimates of 260 km^2 (Widlin and Chapman, 1987) are considered by the QDPI to probably understate the real extent, with 65 km^2 occurring in the Broad Sound area alone (Zeller, 1998). The floodplains of the Fitzroy River currently support extensive areas of ponded pasture systems (Zeller, 1998).

Table 7. Change in wetland vegetation area in the Johnstone Basin 1951-1993.

Wetland	1951 (km^2)	1992 (km^2)	Net Change (km^2)
Mangroves	1.76	2.02	0.26
Melaleuca forests	12.77	2.82	-9.95
Mixed Melaleuca communities	4.62	2.58	-2.04
Palm/Pandanus	4.39	1.60	-2.79
Freshwater Swamps/Reeds	4.99	2.25	-2.74
Total Wetlands	28.53	11.27	-17.26

Source: Russell and Hales (1993).

5. Population of the Great Barrier Reef Catchment Area

5.1. Census Data

Census counts of Queensland population have been conducted since 1861. Temporal and spatial intervals of data collection have varied, making it difficult to calculate historic population trends for a geographically defined area such as the Great Barrier Reef Catchment

Area. Within this report several sources of historical population statistics have been used. ABS Census of Population and Housing (1986, 1991) (in Australian Bureau of Immigration and Population Research 1993) has been used to illustrate population growth in the Great Barrier Reef Catchment Area since 1859 (population history). The regions of North Queensland and Central and Southern Queensland have been combined to represent the Great Barrier Reef Catchment Area while excluding the South East Queensland region (MAP 8). The population figures presented in Table 10 and Figure 7 will be slightly higher than the actual population within the Great Barrier Reef Catchment Area. However, the figures are not considered unrealistic as the western regions of the state have been sparsely populated when compared with the coastal zone. It must be noted that prior to 1961, Aboriginal and Torres Strait Islander persons were not included in census counts.

Since 1961, the Australian Census of Population and Housing has been conducted mid-year every five years. The basic census collection unit is the Collection District which represents approximately 200 households. In urban areas there may be a higher number of households in a Collection District, whereas in rural areas Collection Districts may cover a far larger spatial area than the urban Collection District's in order to approximate the 200 household unit (MAP 9). The census enumeration comprises all persons who spent the census night in Australia, including all persons in private dwellings, visitors staying in non-private housing / accommodation and persons on-board ships and aircraft within Australian ports. Exclusions to the census count are foreign diplomatic personnel and Australian residents overseas on the census night. The *census count at the place of enumeration* for 1996 is shown for Queensland Collection District's in MAP 9 and gives a "snapshot" of the total number of people present in the State at that point in time.[4]

The *census count at the place of enumeration* is significant for understanding population within the Great Barrier Reef Catchment Area as the census is conducted during the State's peak tourist visitor period. For the purposes of the impact of population on the environment and water quality, the census data represents population number close to the highest number of persons, however this total is not consistent throughout the year. Similarly, it does not include residents who are temporarily absent on the census night. For example, the 1981 *census counts at the place of enumeration* for Queensland included 70 923 visitors while excluding 23 856 residents who where absent and therefore enumerated elsewhere. In this case, the usual resident population was overstated by 47 067 persons (Australian Bureau of Immigration and Population Research, 1993).

Population counts are also calculated based on the population's *usual place of residence,* but are only available at the larger Collection District aggregations of Statistical Local Areas, ie. data are not available per Collection District. The *Census count by place of usual residence* gives a better estimate of the resident population without the interference of seasonal factors such as interstate and overseas visitation. The *Census count by place of usual residence* provides the basis for ABS official *Estimated Resident Population* (ERP)[5], which is also calculated annually between census years. Within this report both types of data are used in the following discussion.

5.2. Historic Population and Settlement Patterns

While it is difficult to obtain estimates of indigenous population at the time of settlement, it

[4] GBRMPA holds census data for 1991 and 1996 at the Collection District (CD) level.

[5] Estimated Resident Population (ERP) includes adjustments for under-enumeration and Australians overseas on the census night.

does appear that Queensland supported a large proportion of Australia's pre-settlement indigenous population. Following settlement, aboriginal population saw a dramatic decrease but no official records exist regarding this decline. In contrast, Queensland's non-aboriginal population has grown rapidly. European settlement began with the declaration of the penal settlement at Moreton Bay in 1824. The first population count for the Moreton Bay and Darling Downs districts were held in 1845, and registered 1 599 persons. By 1859, when Queensland separated from New South Wales, the State population was 23 520 persons and in 1883 the population was 250 000 (Australian Bureau of Statistics, 1999). This figure doubled in the following five years and by Federation in 1901, the State population was 500 000. The period between 1860 and Federation saw an increase in settlements and towns throughout central, western and northern Queensland. This increase was driven by pastoralism, the discovery of gold and the establishment of agriculture, particularly sugarcane (Fitzgerald 1982; Queensland Year Book, 1998). By 1938, Queensland's population had reached 1 million, in the next 36 years it doubled to 2 million and 18 years later in 1992, it reached 3 million persons (Queensland Year Book, 1999).

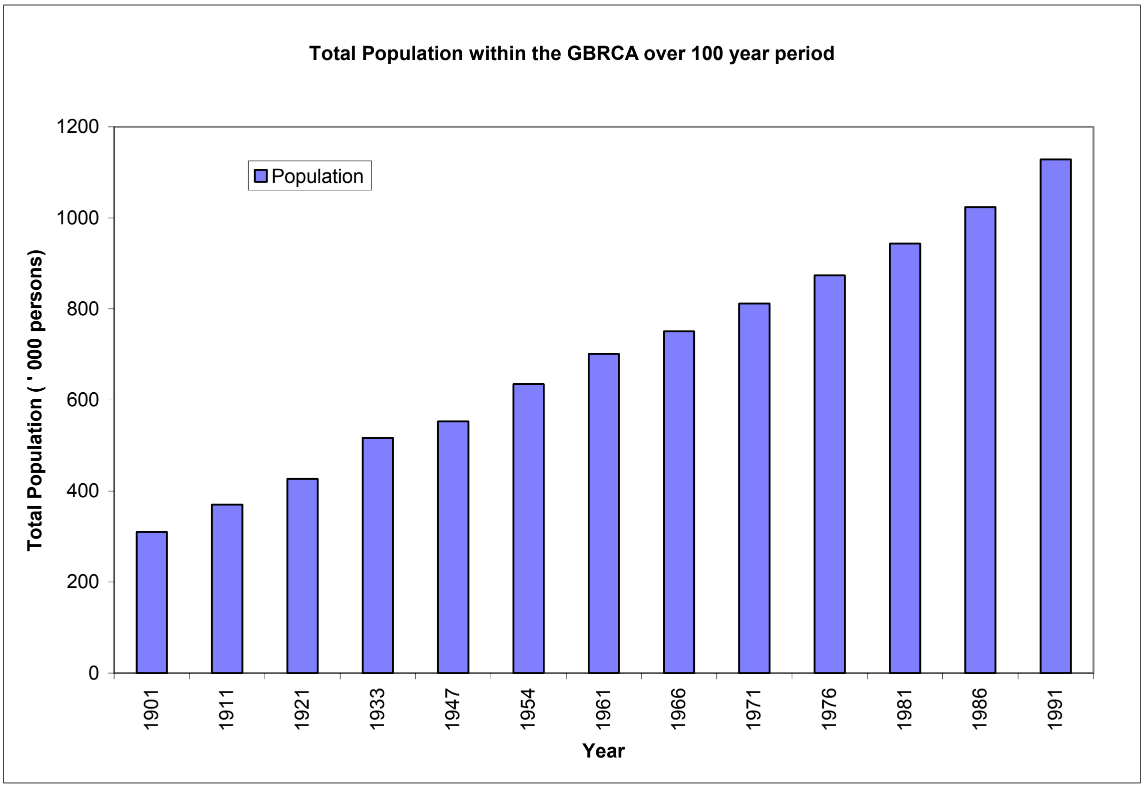


Figure 7. Total population within the Great Barrier Reef Catchment Area 1901 to 1991.

Four main phases of population growth can be identified in Queensland's history. Table 8 summarises these main phases and the predominate source of population growth within Queensland as identified by the Australian Bureau of Immigration and Population Research (1993). Currently, Queensland is experiencing a large influx of people from other Australian states. The tropical and subtropical climate (once considered in colonial days to be unfit for people of European origin) provides the impetus for high migration rates from other states. This migration is unevenly spread over Queensland, concentrated in the south east of the State and in the coastal zone of the Great Barrier Reef Catchment Area. Seasonal increases in population in the form of high visitation rates by international and interstate tourists, adds to the population density in many tourist destinations in the Great Barrier Reef Catchment Area.

(Table 9).

Table 8. Main sources of population growth in Queensland since settlement.

Population Growth Period	Main Source Of Population Growth
Separation to Federation	Immigration from Overseas and interstate. 1871-1900 over 171 000 immigrants arrived from UK/Ireland alone. South Sea Islanders indentured labour.
Federation to World War II	Natural increase represented 84 % of total increase. Immigration had slowed with high proportion of southern European immigrants.
Early Post War Decades	Rapid rise in population due to baby boom era, post-war immigration schemes, and interstate migration.
The 1970s and beyond	Acceleration in population growth rates due to large increase in population migration from other states. Immigration accounting for 59 % of total growth, with 40 % of that from interstate.

Source: Australian Bureau of Immigration and Population Research, 1993.

Table 9. Domestic visitor nights to regions of the Great Barrier Reef Catchment Area.

REGION	1993-94 (000s)	1994-95 (000s)	1995-96 (000s)	Percentage Increase 1993/4 – 1995/6
Gympie/Maryborough	2 981	3 162	3 605	21
Bundaberg	994	1 182	1 470	48
Fitzroy	3 509	4 015	3 955	13
Mackay	1 449	2 252	2 290	58
Whitsunday Islands	779	1 593	1 491	91
Northern	2 863	3 721	3 403	19
Far North	6 177	5 584	6 813	10
Northern Reef Islands	269	676	579	115
GBR Catchments Total	19 021	22 185	23 606	24
Data from September quarter 1994 are not directly comparable with data from earlier periods.				

Source: Bureau of Tourism Research, Visitors to Regions of Queensland in Queensland Year Book 1998.

5.3. Population, Growth and Projections

Since settlement of the colony of Moreton Bay in 1824, Queensland's European population growth has been rapid. Population analysis (Queensland Year Book, 1999) shows that

Queensland currently supports approximately 18.4 % of Australia's total population. By the year 2021, Queenslands population is projected to be between 4.7 - 5 million and between 6-6.5 million by 2051 (Queensland Year Book, 1999). The latter projection will identify Queensland as the second most-populated state in Australia, after New South Wales which has 31-33 % of the total National population (Queensland Year Book, 1999). Based on continued interstate migration rates, Queensland is expected to experience the highest population growth rates of all the Australian states for this period.

In 1996, Queensland's total Estimated Resident Population (ERP) was 3 339 109, with (28 %) located within the 5 Statistical Divisions (SD's) within the Great Barrier Reef Catchment Area (Table 10). Population growth in the Great Barrier Reef Catchment Area has not been as rapid as that recorded for the Moreton Bay / Brisbane Statistical Division's in the south east of the State. However, while all Great Barrier Reef Catchment Area Statistical Divisions have recorded population growth, significant annual average growth rates of 2.8 % and 3 % (years 1991-1996) have been recorded in Wide Bay-Burnett and the Far North Statistical Divisions respectively (Table 11). Within these areas, several provincial cities in particular have experienced rapid population growth rates for that period. (Table 12).

Table 10. Total enumerated and estimated resident population per statistical division in the Great Barrier Reef Catchment Area 1996.

Statistical Division	Total Enumerated Population 1996	Estimated Resident Population 1996	% of State Estimated Resident Population 1996
Wide Bay-Burnett	226 580	224 209	6.7
Fitzroy	180 194	178 046	5.3
Mackay	125 361	120 262	3.6
Northern	194 176	192 373	5.8
Far North	233 847	210 695	6.3
GBRCA Total	962 154	927 581	27.7
Remainder of Queensland		2 411 528	72.2

Source: Regional Population Growth, Australia (3218.0) In Qld Year Book 1998 ABS C-data 1996.

Table 11. Population and growth in Great Barrier Reef statistical divisions 30 June 1996.

Statistical Division	Estimated Resident Population	Annual Average Growth Rate 1991-1996
Wide Bay-Burnett	224 209	2.8
Fitzroy	178 046	1.1
Mackay	120 262	1.7
Northern	192 373	1.1
Far North	210 695	3

Source: Regional Population Growth, Australia (3218.0) in Qld Year Book 1998.

Table 12. Population and growth in statistical districts, Great Barrier Reef Catchment Area at 30 June 1991, 1996.

Statistical District	1991	1996	Average Annual Growth Rate, 1991 to 1996
Bundaberg	49 305	54 032	1.8
Rockhampton	63 598	64 496	0.3
Gladstone	33 447	37 381	2.2
Mackay	54 454	61 020	2.3
Townsville	114 063	122 587	1.5
Cairns	86 294	106 563	4.3

Source: Regional Population Growth, Australia (3218.0) in Qld Year Book 1998.

5.4. Aboriginal and Torres Strait Islander Population

Indigenous people were not included in census counts until 1961. Methodologies for accurately enumerating the Australian indigenous population are still being developed. The estimated resident indigenous population in Queensland for 1996 was 104 800 Aboriginal and Torres Strait Islander persons. This represented 27.2 % of the national total indigenous population and 3.1 % of Queensland's total population (Australian Bureau Statistics, 1998). The five regions of the Aboriginal and Torres Strait Islander Commission (ATSIC) regions adjacent to the Great Barrier Reef World Heritage Area support 54.9 % of the State's total estimated resident indigenous population. The highest proportion (77.7 %) of indigenous resident population within the Great Barrier Reef Catchment Area was enumerated in the three ATSIC regions of Cairns, Townsville and Rockhampton (Table 13).

Table 13. Estimated resident indigenous population per ATSIC region as at 30 June 1996.

ATSIC REGION	Estimated Resident Indigenous Population	% of Queensland Estimated Resident Indigenous Population
Cairns	16 144	15.4
Cooktown	6 184	5.9
Rockhampton	12 436	11.9
Torres Strait Area	6 654	6.3
Townsville	16 107	15.4
GBR Region Total	57 525	54.9
Brisbane	30 325	28.9
Mount Isa	7 306	7.0
Roma	9 661	9.2
Sub-Total	162 342	54.1
Queensland Total	104 817	100

Source: Experimental Estimates of the Aboriginal and Torres Strait Islander Population Australian Bureau of Statistics 1998.

5.5. Spatial Distribution of Population

5.5.1. The Coastal Zone

Queensland is generally considered to be one of the least centralised states in Australia, and has a population distribution which is distinctly urbanised and concentrated along the eastern coastal catchments of the State. The concentration of population along the coastal zone is a global phenomenon and not unique to Australia. Currently, up to 60 % of the world's population lives within the coastal zone and it has been estimated, based on current coastal population growth rates, that by the year 2000, 75 % of global population will be residing within 60 km of the coastal zone (Viles and Spencer, 1995). The distribution of population adjacent to the Great Barrier Reef World Heriatge Area is also concentrated on the coast. Seventy percent of Queensland urban residents live within 50 km of the State's four largest cities namely Brisbane, Gold Coast City, Townsville and Cairns (Environmental Protection Agency, 1999). The population of various urban centres (Australian Bureau of Statistics, 1997) and their localities are scattered along the Queensland coast (Table 14 and MAP 10). There are numerous small urban centres with populations less than 50 000 (ie. Cardwell, Sarina, Bowen, Hervey Bay) and a few larger urban centres with populations greater than 50 000 (ie. Townsville, Cairns, Mackay and Rockhampton) (Table 14).

Table 14. Estimated population in coastal areas of Queensland - 1997.

Population Centres	Population
Cairns	116 392
Cardwell	9 447
Townsville	133 407
Bowen	13 096
Mackay	73 015
Sarina	9 583
Rockhampton	59 721
Gladstone	27 005
Bundaberg	43 915
Hervey Bay	40 019
Maryborough	24 933

Source: Australian Bureau of Statistics, 1997.

5.5.2. Impacts of Population Growth in the Coastal Zone

The concentration of population and associated infrastructure within the coastal zone ultimately impacts on coastal and reef ecosystems. Hamilton and Cocks (1994) identified the three main threats to coastal environments as 1) the demand for housing land; 2) infrastructure; and, 3) waste disposal resulting from increasing resident population. These factors combined with the increase in tourism in Queensland, particularly reef tourism located along the length of the coast, suggests the Great Barrier Reef Catchment Area is experiencing considerable pressure from these threats.

Urban expansion often involves the removal of coastal vegetation communities such as mangrove and Melaleuca wetlands. In some areas of Queensland, urban housing estates are being developed on agricultural land, which in turn places pressure on agricultural establishments to move into more marginal land such as those present in the coastal zone. Construction associated with housing and tourist facilities are generally poorly monitored in terms of their impact on the environment and water quality (Hamilton and Cocks, 1994). Coastal settlements are generally built on sandy substrates of coastal dune systems. Sources of pollution from coastal settlements include seepage from septic systems into groundwater and streams. Many of the existing coastal settlements within the Great Barrier Reef Catchment Area still operate under septic effluent disposal methods. Similarly, garden and lawn fertiliser, pesticide applications, heavy metals and litter find their way through the stormwater system into the hydrological cycle within coastal areas with these highly permeable soil types.

Some islands within the Great Barrier Reef Catchment Area support urban populations (e.g. Magnetic Island and Palm Island) and there are numerous resort islands which support large numbers of seasonal visitors.

6. Port Development

The major threats to water quality resulting from port development include grounding and sinking of vessels resulting in spills of fuel or hazardous cargo, accidental spills particularly in fuel and mineral bulk handling ports, dredging to maintain channel depth, and general water quality declines associated with bilge disposal, ballast water, anti-fouling paints, and sewage and litter disposal (Tarte *et al*. 1995).

The earliest ports in the Great Barrier Reef Catchment Area were established at Gladstone, Rockhampton, and Maryborough prior to 1859, to serve the pastoral industry. Between 1870 to 1899, further ports were established at Cooktown, Cairns and Port Douglas (serving the mining industry during the northern gold rushes) and at Innisfail, Mourilyan and Dungeness (serving the sugar industry). Lucinda was later developed as a bulk sugar handling facility. Earlier ports such as Townsville and Rockhampton were gazetted over other harbours (that boasted far better navigational entry conditions) due to the locational advantage to service nearby hinterlands; these ports required constant improvements to maintain accessibility. Constant dredging is still required to maintain sufficient water depth for large vessels in many ports within the Great Barrier Reef Catchment Area. The ports of Hay Point and Abbot Point were established to handle bulk coal exports after the 1960s mineral boom. In 1994/5, Hay Point received the highest number of shipping arrivals (599) for the Great Barrier Reef Catchment Area (Table 15). The ports of Cairns, Gladstone, Hay Point near Mackay, and Townsville dominat the study area, each recording over 500 vessel arrivals for 1994/5. The movement of ships within the Great Barrier Reef lagoon is not without incident and a major oil spill is a constant threat (Raaymakers and Storrie, 1996).

Other than major shipping traffic, the lagoon experiences heavy use by smaller commerical and recreational vessels (associated with tourism, fishing, yachting and recreation) resulting in a plethora of minor spills and incidents. In a ten year period between 1987 to 1997, approximately 186 maritime incidents within the Great Barrier Reef World Heritage Area, (including vessel grounding, sinking and spills) (MAP 11), were reported to the Australian Maritime Safety Authority. The majority of these were located within the lagoon where commercial and recreation vessel use is highest (MAP 11). Map 12 identifies the major ports and shipping routes within the Great Barrier Reef World Heritage Area.

Table 15. Shipping arrivals and piloted arrivals by ports in the Great Barrier Reef World Heritage Area 1985/6 to 1994/5.
a. Total arrivals are the number of vessels arriving at Queensland ports;
b. Piloted arrivals are the number of piloted vessels arriving at Queensland ports.

Year	1985-86		1987-88		1989-90		1991-92		1993-94		1994-95	
Port	Total arrivals	Piloted arrivals	Total arrivals	Piloted arrivals	Total arrivals	Piloted arrivals	Total arrivals	Piloted arrivals	Total arrivals	Piloted arrivals	Total arrivals	Piloted arrivals
Hay Point	419	419	495	495	452	452	519	519	556	556	599	599
Gladstone	506	396	560	411	588	441	737	520	711	504	771	555
Townsville	291	267	374	351	387	352	352	328	547	518	606	544
Cairns	242	96	378	178	385	182	425	186	448	190	585	279
Mackay	134	123	125	114	147	133	100	86	153	134	174	153
Abbot Point	64	64	80	80	82	82	81	81	63	63	76	76
Port Alma	55	46	58	50	66	63	70	60	57	46	70	62
Cape Flattery	36	-	23	23	35	35	40	40	46	46	51	51
Mourilyan	27	27	32	29	25	25	25	25	35	35	37	37
Bundaberg	53	37	48	19	41	14	42	20	50	25	48	33
Lucinda	28	28	23	23	19	19	16	16	26	26	22	22
Thursday Island	206	17	321	51	163	30	193	41	103	1	112	13
Port Douglas	-	-	-	-	-	-	-	-	1	1	5	5
Cooktown	-	-	-	-	-	-	1	1	2	2	-	-
Total	2061	1520	2517	1824	2390	1828	2601	1923	2798	2147	3156	2429

Source: Queensland Government, 1996.

7. Agriculture

Queensland's agricultural base was founded on pastoralism, grains and sugar. Today, a much more diversified intensive cropping base has augmented these industries. In 1996/7, crops such as sugarcane, bananas, cotton, nursery production and other intensive crops accounted for $5 677 million of the States total agricultural production value (Queensland Year Book, 1999). Crop production contributed $3 509 million of the total value of agricultural production. Livestock value was at $1 614 million and livestock products $554 million (Queensland Year Book, 1999). Nationally, Queensland produced 36 232 tonnes of Australia's sugarcane, 144 tonnes of bananas, 123 tonnes of pineapples, 458 tonnes of cotton (seed) and 43 % of the nation's cattle for meat production (10 130 000 tonnes) (Queensland Year Book, 1999). While the area under cropping for the State has decreased in recent decades, the area under sugar production has continued to rise (Queensland Year Books, Australian Bureau of Statistics).

The number and size of agricultural establishments in each Statistical Division in the Great Barrier Reef Catchment Area reflects the dominant agricultural type (Table 16). The Fitzroy

Statistical Division, dominated by grains and cattle, has a greater proportion of larger sized (20-200 km^2) agricultural operations (Queensland Year Book, 1999) (Table 16). The Far North is dominated by intensive crops such as sugarcane and bananas on operations of less than 2 km^2, with a few larger cattle operations over 200 km^2 (Queensland Year Book, 1999). The number of agricultural establishments growing sugarcane occur fairly evenly over all statistical divisions except in the Fitzroy Statistical Division (Table 16). The southern-most Statistical Divisions of Wide Bay-Burnett and Fitzroy dominate as grain growing areas.

7.1. Soil Fertility

Runoff from agricultural land affects water quality downstream and ultimately the Great Barrier Reef lagoon by contributing sediments, nutrients (particularly phosphorus and nitrogen), insecticides and herbicides, and heavy metals.

Table 16. Total number of operations growing crops per statistical division in the Great Barrier Reef Catchment Area 1996.

	Total Number of Operations growing crops per Statistical Division					
Agriculture Type	Wide Bay-Burnett	Fitzroy	Mackay	Northern	Far North	GBR Total
Sugarcane	910	0	1302	1237	1213	4662
Barley	158	69	5	0	2	234
Wheat	147	324	31	2	1	505
Grain Sorghum	376	553	112	2	15	1058
Maize	236	16	3	3	130	388
Sunflower	6	96	34	1	0	137
Cotton	2	94	3	1	0	100
Potatoes	21	1	1	5	54	82
Tomatoes	75	15	4	42	17	153
Pineapples	69	32	6	5	12	124
Bananas	33	7	9	8	289	346
Meat Cattle	3958	2631	1096	681	1012	9378
Milk Cattle	479	107	55	14	226	881
Sheep	54	27	3	7	5	96

Source: Australian Bureau of Statistics 1998 - Agriculture.
Note: Operations may be included in more than one category

The agricultural soils of the Great Barrier Reef Catchment Area have a relatively low nutrient status resulting in high artificial fertiliser applications under both cropping and improved pasture for grazing (Table 17 and 18). Severe decreases in productivity in the caneland near Mackay were reported before the turn of the century. *"By the last decade of the nineteenth century, deterioration was such that, while average yields in the 1870s were in the order of 100 to 1.25 tonnes per km^2, Mackay, one of Queensland's leading cane production areas, could manage only 0.24 tonnes per km^2"* (Fitzgerald, 1982).

In recent years yield decline in cane has also been a significant problem in many areas and particularly in the Wet Tropics (Garside *et al*. 1997). The decline in sugar extracted from cane in the sugar mill has been variously attributed to greater extraneous matter in the cane, parts of the harvested cane (particularly suckers) having low sugar content, root pathogens and weather patterns. The decline is serious enough to threaten the viability of the industry in some areas.

Pulsford (1993) estimated that since settlement, a total cumulative volume of two million tonnes of nitrogen and 400 000 tonnes of phosphorus had been applied to the Great Barrier Reef Catchment Area up to 1990. In 1995/6, 305 973 tonnes of fertiliser were applied to 7 911 km^2 of agricultural land in the five Statistical Divisions in the Great Barrier Reef Catchment Area. Pulsford (1993) showed that the increase in nitrogen and phosphorus fertilisers in the Great Barrier Reef Catchment Area has been most dramatic since the 1960s (Figure 8 and 9). Over half of the total volume of nitrogen and phosphorus fertiliser used in agriculture within the Great Barrier Reef Catchment Area is applied to sugarcane (Figure 10).

Soils under agriculture in the Great Barrier Reef Catchment Area are prone to acidity, particularly where ammonia based fertilisers are used. Lime is the main soil conditioner used to counter soil acidity. In the Great Barrier Reef Catchment Area in 1995/6, 155 088 tonnes of soil conditioners (ie. lime, gypsum) were applied to 626 km^2 of land, with particularly high volumes (over 100 000 tonnes) in the North and Far North Statistical Divisions, where acid soils are more likely to occur naturally (Figure 11).

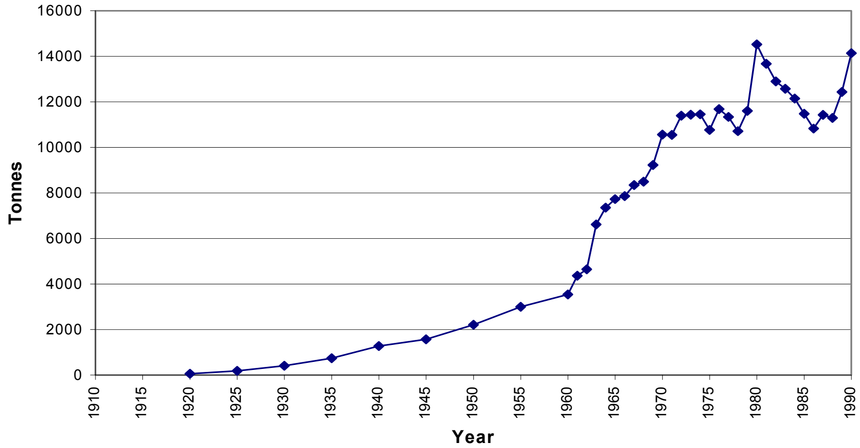


Figure 8. Total phosphorus fertiliser applied (as tonnes P) annually in the Great Barrier Reef Catchment Area 1910-1990.

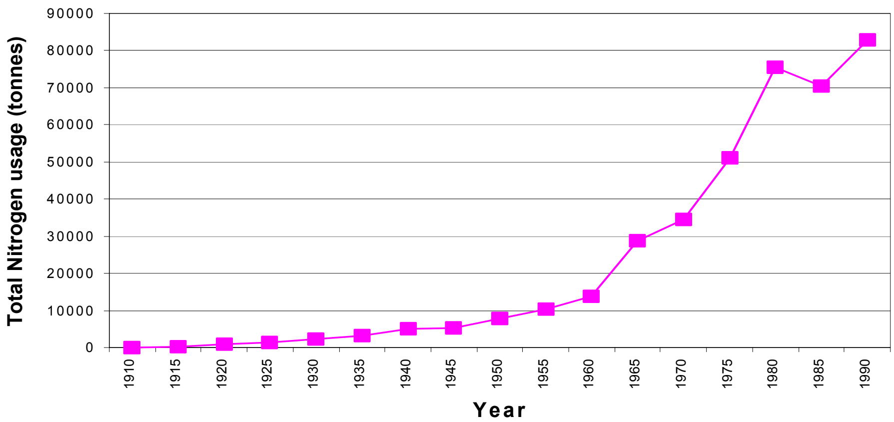


Figure 9. Total nitrogen fertiliser (as tonnes N) applied annually in the Great Barrier Reef Catchment Area 1910-1990.

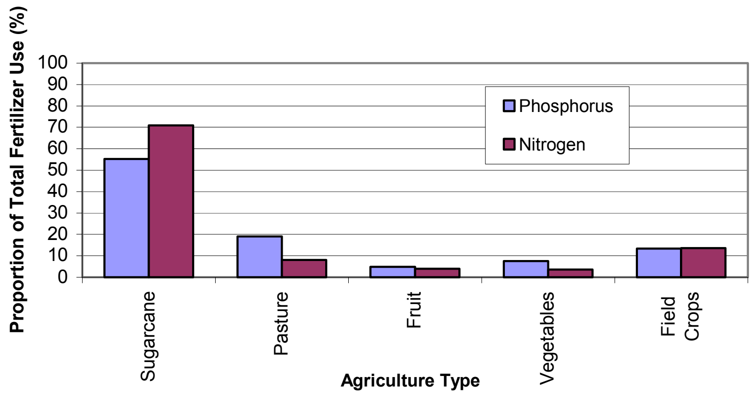


Figure 10. Fertiliser usage for major agriculture types for the statistical divisions of the Great Barrier Reef Catchment Area 1990.

Table 17. Basins recording the highest proportion of phosphorus usage (tonnes) in the Great Barrier Reef Catchment Area in 1990. Proportion of phosphorus applied to selected agriculture types (%).

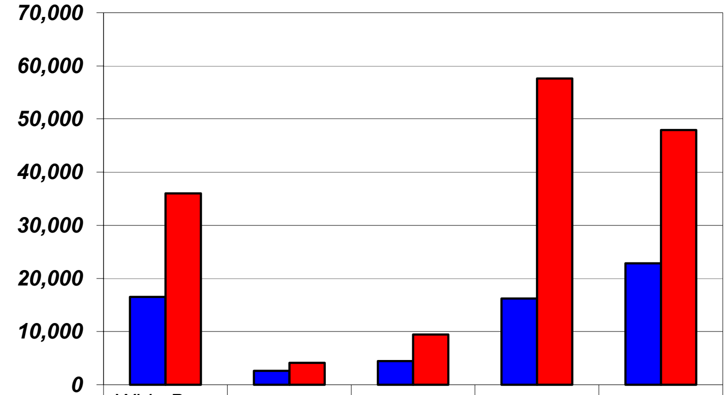
Basin Name	Total Usage (tonnes) All Agriculture	Sugarcane (%)	Pasture (%)	Field Crops (%)
Johnstone	1700	53	38	0
Herbert	1330	77	18	2
Burnett	1160	21	11	52
Mary	1050	17	52	17
Plane	995	94	6	0
Fitzroy	786	0	15	85

Source: Pulsford 1993.

Table 18. Basins recording the highest proportion of nitrogen usage (tonnes) in the Great Barrier Reef Catchment Area in 1990. Proportion of nitrogen applied to some agriculture types (%).

Basin Name	Total Usage (tonnes) All Agriculture	Sugarcane (%)	Pasture (%)	Field Crops (%)
Herbert	9800	90	8	0
Haughton	8805	88	0	6
Plane	7685	97	3	0
Johnstone	7300	67	25	0
Fitzroy	7290	0	2	95
Pioneer	5490	84	16	0

Source: Pulsford 1993.



	Wide Bay-Burnett	Fitzroy	Mackay	Northern	Far North
Area treated (ha)	16,536	2,603	4,459	16,204	22,836
Amount used (tonnes)	35,977	4,123	9,443	57,608	47,937

Statistical Division

Figure 11. Soil conditioner (ie. lime, gypsum) use per statistical division 1996.

7.1.1. Acid Sulfate Soils

Acid sulfate soil (ASS) is emerging as one of the biggest environmental problems facing Queensland agriculture and environmental managers in the coastal zone. Acid sulphate soils occur naturally throughout an estimated 23 000 km^2 in Queensland on the coastal lowlands less than 5 m above sea level. In the Great Barrier Reef Catchment Area, they have been identified on Cape York Peninsula, central Queensland and in areas of the Wet Tropics, with comprehensive mapping of the occurrence of these soils commenced for the Great Barrier Reef Catchment Area between Cooktown and Mackay (QDPI, 1998). ASS are harmless when they remain in an undrained state. However, when acid sulphate soils are drained or disturbed, iron sulfides oxidize when exposed to air, producing large volumes of sulfuric acid – up to 1.5 tonnes for every tonne of ASS oxidised (QDPI, 1998). Leaching from these soils into waterways can cause acidification of nearby waterbodies (pH as low as 2), and the release of toxic heavy metal concentrations (iron and aluminium). The impact on surrounding coastal biota and habitats is severe, including fish kills and red-spot disease in the fisheries (QDPI, 1998).

7.2. Sugar Industry

Sugarcane was introduced to Queensland in the 1840s and was first grown commercially in 1863. Under the incentives provided by the Coffee and Sugar Regulations of 1864, sugarcane plantations spread from the south east of the State into the coastal river plains of the Great Barrier Reef Catchment Area. The industry grew quite rapidly in the following decade with plantations established at Mackay (Pioneer Basin) in 1865, Cardwell (Murray Basin), Tully (Tully Basin), Johnstone River (Johnstone Basin), Daintree (Daintree Basin), Bowen (Don Basin), Townsville (Ross Basin), Rockhampton (Fitzroy Basin) in the 1870s. Soon after, plantations were established at Ingham (Herbert Basin), Bundaberg (Burnett Basin), Cairns (Mulgrave-Russell Basin) and Port Douglas (Mossman Basin). By 1869, 28 mills were crushing cane from approximately 5 000 acres (20 km^2) of caneland (The Queensland Official Year Book, 1901).

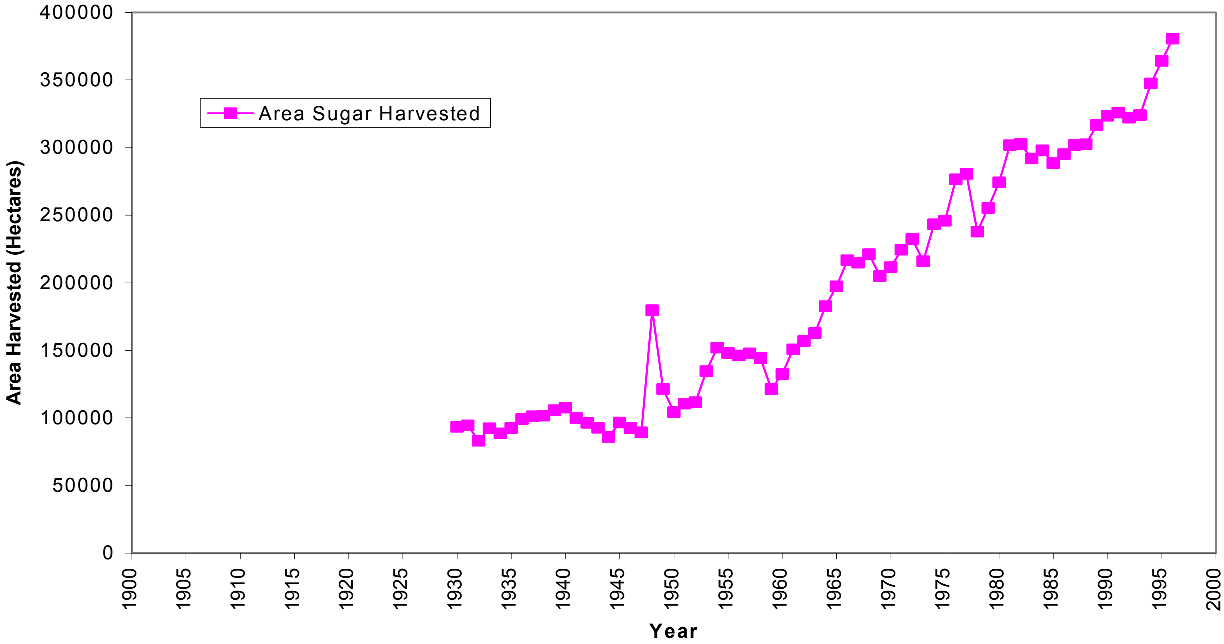


Figure 12. Total area of sugarcane in the Great Barrier Reef Catchment Area since 1930. Source: Canegrowers

The outbreak of the fungal “rust” disease in 1875 temporarily slowed the industry’s growth. By the late 1870s, the introduction of hardier varieties of cane, combined with readily available finance for expansion, created a boom period. At this time, the Colonial Sugar Refining Company (CSR Limited) developed a central sugar mills system which crushed cane for independent farmers. Statistics for 1883-4 show 176 km^2 of cane were grown, with 112 km^2 crushed for the year. In 1880, there were 157 sugar mills operating in Australia (Table 19) (Griggs, 1999). The impact of the 1884 price collapse and uncertainty about labour supply affected the sugar industry in Australia. Numbers of operational mills fell as the smaller and inefficient factories closed. Nearly 120 factories closed between 1885 and 1890 in Australia, 65 of those were in Queensland (Table 19) (Griggs, 1999). Millers installed the latest innovations in milling practises in order to manufacture as much sugar as possible and reduce the number of mill workers. The technology was so expensive in some instances that it could only be afforded by milling companies with substantial capital banking (Griggs, 1999). The sugar industry grew steadily. At the turn of the century large central factories equipped with continuous processing technologies and owned by farmer co-operatives or corporations dominated the Australian milling sector. By 1915, only 48 sugar mills were operating in Australia, 45 were in Queensland (Table 19) (Griggs, 1999). As a result of mill closures and new technologies, average sugar output per Australian mill rose rapidly (Table 20). The average amount of sugar produced by Australian mills in the late 1880’s was under 500 tonnes per year and by the early 1910’s this increased eightfold (4023 tonnes) in Queensland (Table 20) (Griggs, 1999).

Table 19: Number of sugar mills in Australia and Queensland, 1864-1915.

Year	Australia	Queensland
1864	2	1
1868	19	10
1872	136	65
1880	157	83
1885	260	166
1890	134	101
1900	73	65
1915	48	45

Source: Statistics of Queensland.

Table 20: Average output per mill (tons of sugar) in Queensland for the period 1870-1915.

Period	Output per mill in Queensland (tons of sugar)
1870-74	105.9
1875-80	218.2
1880-84	192
1885-89	373
1890-94	934
1895-99	1876
1900-04	2037
1910-14	4023

In the Great Barrier Reef Catchment Area, Mackay continued to lead in sugar production. However, the industry was generally suffering from pests and soil fertility problems that impelled the Queensland Government to establish the Department of Agriculture and a series of scientific research stations to assist the industry counter declining productivity yields.

It was at this time that industry protection was afforded to growers in the form of a six pounds per ton sugar import duty. In 1917, 635 km^2 were allocated to the soldier settlement scheme at Innisfail for sugar cultivation. The total area of sugarcane harvested in the Great Barrier Reef Catchment Area in 1930 was 100 000 hectares (Figure 12). By 1965, the area of harvested sugarcane doubled to 200 000 hectares and in 1995 was over 360 000 hectares (Figure 12) (personal communication CANEGROWERS Queensland). Data prior to 1930 for the area harvested in the Great Barrier Reef Catchment Area is not available.

In 1989, the Australian Federal government replaced the embargo on the importation of raw and refined sugar with an import duty tariff of $115 per tonne. Over the following years, this tariff was reduced, until in July 1997, when the tariff was completely removed on sugar imports. However, intense domestic market competition has seen the level of imports decrease from 13 000 tonnes in 1990/91 to 4 500 tonnes in 1996/97. Contemporary sugar growing areas are presented in MAP 13.

7.2.1. Green Cane Harvesting

Since 1981, the Queensland sugar industry has adopted the practice of green cane harvesting and trash blanketing of fields. Green harvesting allows extraneous biomass to be returned to the soil which in turn increases soil moisture content, adds nutrients and protects against compaction and erosion during rain events. Prove *et al*. (1997) found that green cane harvesting, trash blanketing and zero tillage reduced erosion from 1.5 tonnes/ km^2 to .05 tonnes/ km^2. Substantially smaller loss of phosphorus and nitrogen were also recorded. Trash blanketing has the added advantage of inhibiting weed growth, thereby requiring fewer herbicide applications. North Queensland in particular, has seen a dramatic increase in green harvesting with over 90 % of all cane harvested in 1996 by this method (Figure 13). In the central and southern sugar regions, approximately 50 % of the cane cut was harvested green (Figure 13). This percentage is rising as technical problems associated with green harvesting in these areas are overcome (Queensland Sugar Corporation, 1997).

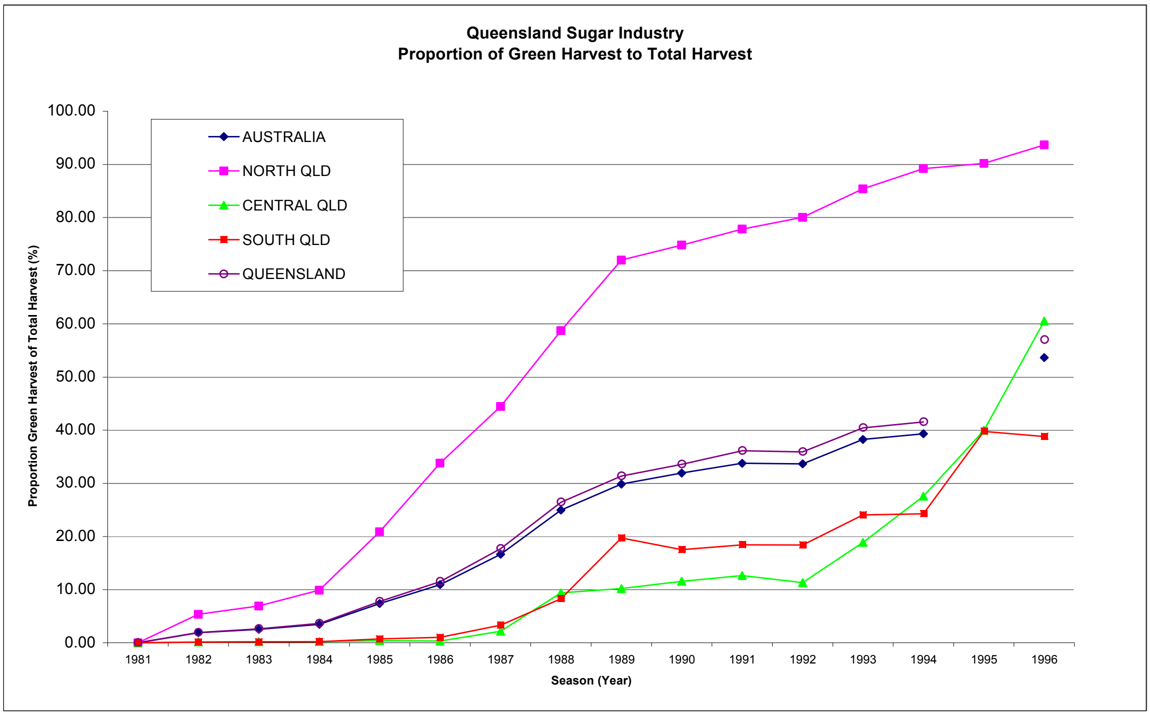


Figure 13. Green cane harvest by area per region in Queensland.

7.3. Cattle Industry

Pastoralism has been the mainstay of Queensland's production base since settlement. The discovery of the Darling Downs and Cunningham's Gap in 1827-8 opened the State of Queensland to rapid pastoral expansion. Between 1840 and 1862, pastoralists occupied available land in the Moreton, Darling Downs, Wide Bay, Burnett, Fitzroy, Kennedy and Bowen areas. At Kennedy near Cardwell, 454 leases had been granted on 81 585 km^2 of land by 1864 (Fitzgerald, 1982). This was followed by another phase of rapid expansion between 1862 and 1866, when pastoral land was taken up from the Fitzroy, north to Kennedy and westwards.

In 1894, the expansion of the State was completed with the northern pastoral area of Cook being opened to speculators (Fitzgerald, 1982).

Sheep were found to be unsuitable to the coastal plains and increasingly pastoralism shifted to raising cattle in the coastal catchments. In the decade after 1868, sheep numbers in Queensland fell from approximately 8.5 million to 5.5 million, while cattle increased rapidly to 3 million (Fitzgerald, 1982). Two phases of rapid increases in the cattle industry have been identified. The first phase was spurred by increases in population following the discovery of gold in the 1860s and continued until the mid 1890s (with the development of overseas markets) when the herd totalled 7 million. The depression, disease and the severe droughts in the decade prior to the turn of the century reduced the cattle stock to 2.5 million. Over the subsequent 60 years, the number of cattle in Queensland fluctuated between 4-7 million largely in response to drought. The second rapid expansion phase resulted from the Fitzroy Basin Brigalow development scheme instigated during the 1960s. The cattle stock increased from 7 million in 1970 to 11 million by the late 1970s. Since that time, the cattle stock has decreased by 2 million due to drought and increased beef prices which have seen cattle stocks harvested for export. Today, there are 10 million beef cattle in Queensland with approximately half of the cattle stock located within the five Statistical Divisions of the Great Barrier Reef Catchment Area. (Note: the latter figure is an estimate due to the Far Northern Statistical Division falling partly outside of the Great Barrier Reef Catchment Area). However, the eastern section of Cape York supports the lowest cattle densities (MAP 14).

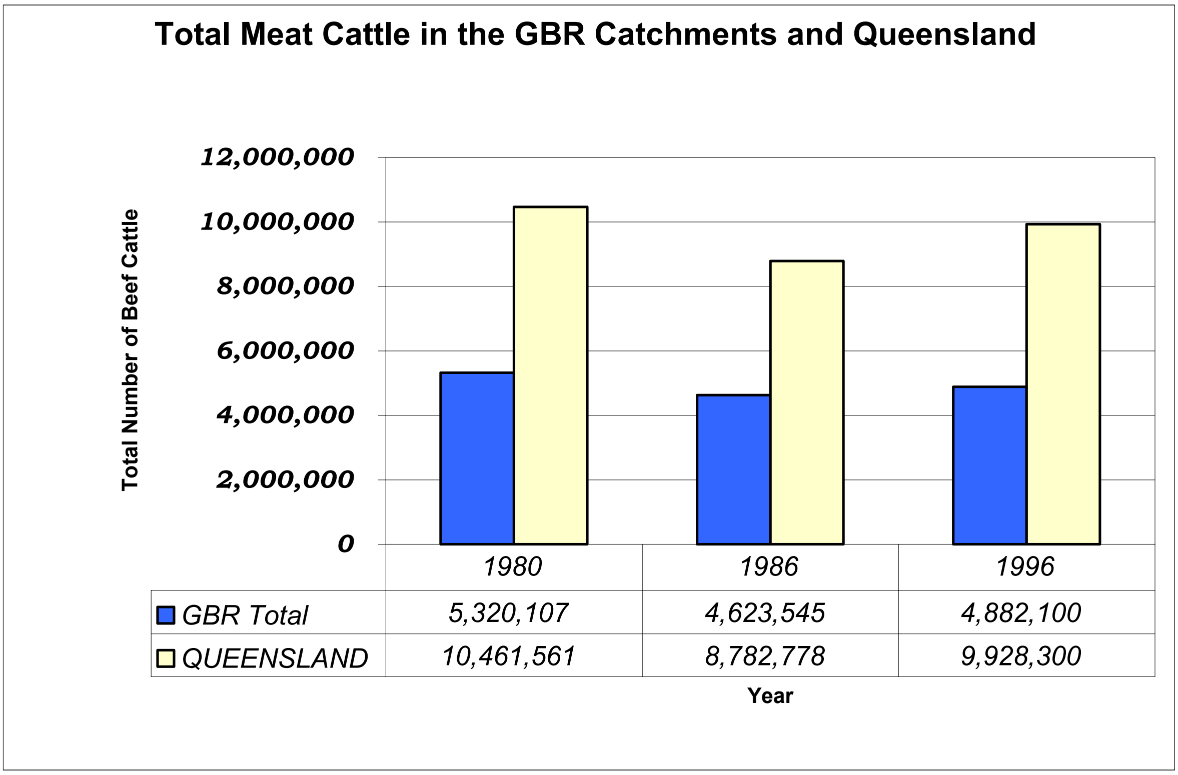


Figure 14. Total beef cattle in the Great Barrier Reef Catchment Area and Queensland.

Table 21. Area of land under grazing in the Great Barrier Reef Catchment Area (June 1991).

Basin Name	Area of Grazing Land (km^2) *	Proportion of basin grazed (%)
North-East Cape York Jacky Jacky, Olive, Pascoe, Lockhardt, Stewart, Normanby, Jeannie, Endeavour	26 720	62
Mossman-Daintree	930	36
Barron	1 200	55
Mulgrave-Russell	160	8
Johnstone	570	24
Tully-Murray	530	19
Herbert	7 970	66
Ross-Black	850	29
Burdekin-Haughton	118 060	88
Don	3 850	97
Proserpine	1 679	67
Pioneer, O'Connell	1 940	49
Shoalwater, Plane, Styx, Waterpark	4 970	44
Fitzroy	119 320	84
Baffle, Boyne, Calliope	6,360	69
Burnett, Burrum, Kolan	26 520	67
Mary	5 830	61

* Grazing land may include areas of State Forest and Timber Reserves.
Source: Queensland Department of Primary Industry, 1993.

Grazing occurs in all basins in the Great Barrier Reef Catchment Area to varying degrees (Table 21). The Burdekin-Haughton and Fitzroy are the two dominant basins in the Great Barrier Reef Catchment Area for land under grazing, with the proportions of grazed land in each basin at 88 % and 84 % respectively (Table 21).

The Fitzroy Statistical Division supports the highest number of meat cattle for Queensland, with 1 678 000 head in 1996 (Figure 15). Dairy cattle in the Fitzroy Statistical Division have declined from almost 200 000 animals in 1955 to 8 500 in 1996 (Figure 15). Historically, Rockhampton has dominated the livestock industry of the Great Barrier Reef Catchment Area with the Fitzroy Statistical Division showing a steady overall increase in beef cattle numbers and decline in dairy cattle and sheep. The latter decrease was most rapid between 1965 and 1980, reflecting a state-wide decline in the industry, including the Atherton Tableland dairy industry which had expanded after 1907. During the period from 1980 to 1996, all Statistical Divisions of the GBR region recorded slight decreases in cattle numbers. The exception was for the Northern Statistical Division, which recorded a sharp 23 % decrease in meat cattle numbers. Sheep numbers in the Fitzroy Statistical Division declined rapidly from 527 000 in 1980, 17 000 in 1996 and 43 000 in 1997. Pig numbers were 42 894 in 1996 and 42 369 in 1997 (Figure 15) (Queensland Year Book, 1998, 1999).

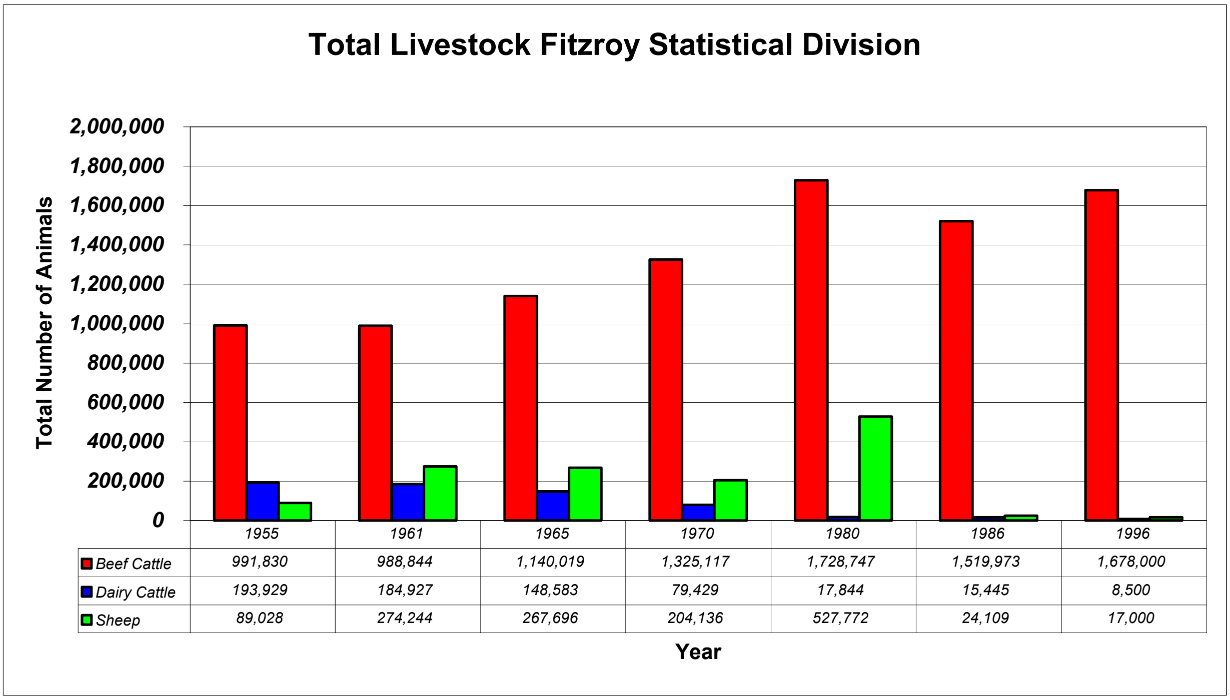


Figure 15. Total livestock in the Fitzroy Statistical Division 1955 - 1996.

7.4. Forestry

The development of the timber industry in Queensland was virtually unchecked for the first 100 years of settlement. Initial widespread clearing of timber resources for agricultural and denser settlement was closely followed by the exploitation of valued timber products such as native pines, cedar, walnut, maple, silkwood, and black bean by timber companies (see section 4.1 in this report). As a result of the extensive waste of timber resources, there were numerous calls during the first 100 years for the regulation of both land clearing and timber resource exploitation. The 1940 Queensland Year Book states that timber extraction had "*proceeded at a pace which threatens to exhaust accessible supplies long before the products of a still inadequate re-forestation can replace them*". Despite this, it was not until 1959 that a Forestry Act was implemented (Frawley, 1988).

The two main areas of early native timber extraction were the pine-hardwood forests near, and south of Maryborough, and the softwood timbers of the North Queensland rainforests (Figure 16). At 1938-9, Queensland had 449 sawmills and 15 plywood mills which were distributed between three Statistical Divisions (Table 22).

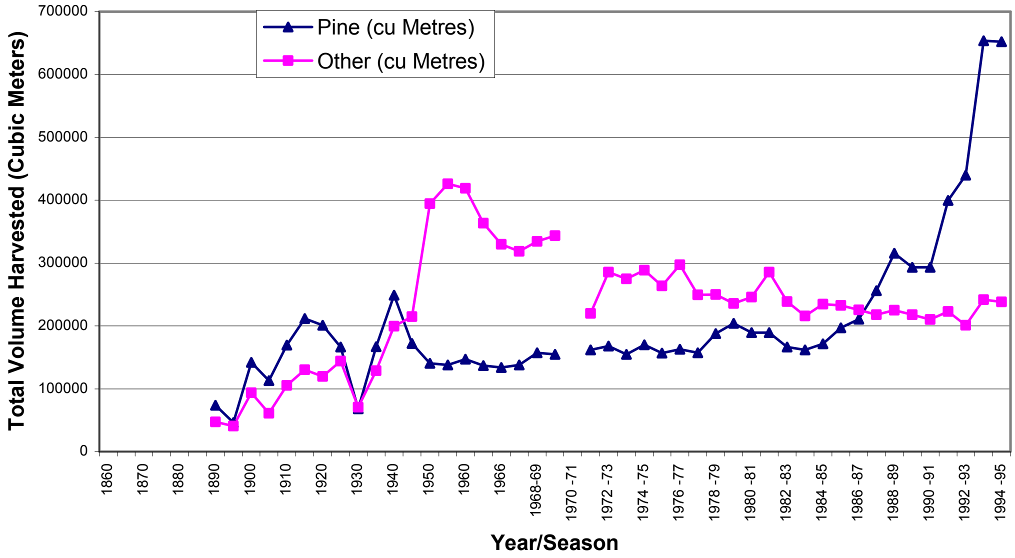


Figure 16. Historical sawn timber harvest for Queensland.
Source: Queensland Year Books, Australian Bureau of Statistics.

Table 22. Timber industry production for 1938-9.

Division	No. of Mills	Production 1938-9 (super feet)
Northern	74	27 487 087
Central	31	7 986 311
Southern	344	141 485 145

Source: Queensland Year Books, Australian Bureau of Statistics.

As timber was exhausted from private land, the Queensland Department of Lands came under increasing pressure to open Crown land to timber extraction. Since that time, the area of Permanent State Forests in Queensland has risen steadily while the area of Temporary Timber Reserves has declined.

The World Heritage listing of the Wet Tropic Rainforests of North Queensland has resulted in a dramatic decline in timber extraction from this area. Prior to listing, the Atherton Tablelands had an average annual timber extraction rate of 207 000 m^3 for the years between 1948 and 1978. In 1993-4, the Atherton District recorded 6 716 gross measure cubic metres of milling timber harvested from private land, and 19 366 gross measure cubic metres of milling timber from Crown lands Service (personal communication Queensland Forestry Service). An extensive tree-planting scheme and rainforest tourism has replaced the timber industry in this area.

7.5. Mining

Mineral production is the highest source of export revenue for the State of Queensland, totalling $4 612 million in 1988-89. Black coal productions represent 52 % of this total. The major source of this coal is from the Bowen Basin coal resources, which extend from Collinsville (west of Bowen) throughout the Burdekin and Fitzroy basins to Rolleston (the area currently exploited within the Great Barrier Reef Catchment Area). The Bowen Basin has dominated Queensland's coal production since the 1960s, with open cut mines at Moura-Kianga (1958), Blackwater (1966), Goonyella (1971), Peak Downs (1972), Saraji (1975) and Norwich Park (1979) (Wadley and King, 1993). Blair Athol is an example of a large open cut coalmine in the Great Barrier Reef Catchment Area, with an estimated 257 million tonnes of coal. Other open cut mines are at Gregory, German Creek, Oaky Creek and Riverside within the Fitzroy basin. Coal production in Queensland is a fairly recent phenomenon with 2.6 million tonnes mined in 1960 increasing rapidly to 99.4 million tonnes in 1996/97. The five Statistical Divisions of the Great Barrier Reef Catchment Area, produced approximately 96 % (95 351 488 tonnes) of Queensland's black coal production for 1996/97 (Government of Queensland, 1998).

Gold mining in Queensland began in 1857 with the discovery of gold near Rockhampton in the Fitzroy catchment. In the following decade, gold was discovered at Gladstone, Peak Downs and Gympie, beginning what was to become Queensland's gold era. Production peaked in 1900 when the Queensland gold fields produced 21 027 kg of gold (Figure 17). At this time, the principle gold fields were Charters Towers, Mount Morgan, Gympie and Croydon. At its peak, over 16 000 prospectors were working the Gympie fields. Following the depletion of alluvial gold, gold seams were mined for the next 50 years (Fitzgerald, 1982).

Improved mineral extraction technology has seen a renewed rapid increase in gold production since the 1980s. In 1980/81, 901kg of gold was produced with the 1994/95 production weight at 27 888 kg (Figure 17).

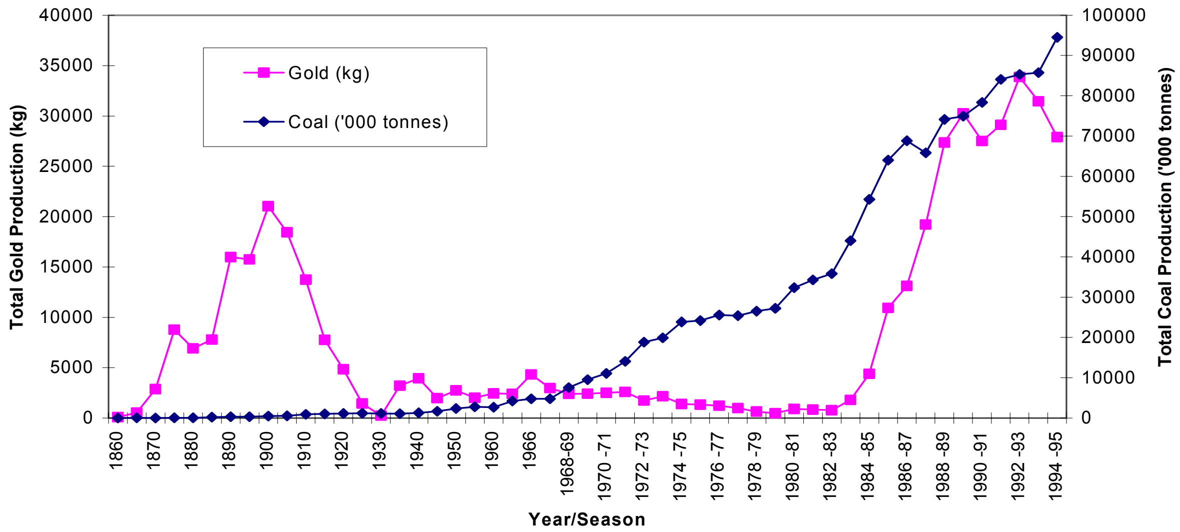


Figure 17. Historic gold and coal production for Queensland 1860-1995.
Source: Queensland Year Books, Australian Bureau of Statistics.

8. Water Resources

As the driest inhabited continent in the world with highly variable river flows, Australia has experienced a history of water development schemes of a scale rarely seen elsewhere. From settlement days, grandiose schemes such as the diversion of river systems to the centre of the continent to create a vast inland lake were typical of the scale of the Nation's water resource development vision in general (Powell, 1991). Powell (1991) chronicled the history of water development in both Victoria and Queensland and concluded that while most Australian states are now in a post-development phase, Queensland which owns 45 % of the nation's surface water supplies, remains strongly fixed within the developmental ethos.

Pre-European Aboriginal populations were concentrated in coastal areas where water was readily accessible. Aboriginal water management practices included knowledge of the behaviour and distribution of water bodies under seasonal changes, some collection in small natural and constructed reservoirs (up to 3 500 litre capacity), and construction of weirs and dams to regulate water for fishing purposes (Powell, 1991; Fitzgerald, 1982). By the 1880s, settlers were discovering the availability of artesian water to alleviate drought conditions. While groundwater use was concentrated mostly in the area west of the Great Barrier Reef catchments, there were some coastal settlements which relied on groundwater supplements. That reliance on groundwater supplements is still true to the present day. The Burdekin Delta was first drilled for water in 1884, and later the Bundaberg supplies were also drawn from the ground for agriculture (Powell, 1991) (See Section 8.2 in this report).

8.1. Dams and Weirs

Within the Great Barrier Reef Catchment Area, 123 official dams and weirs have a total potential capacity of approximately 7 298 143 mega litres (Table 23). The Burdekin Falls Dam is currently the largest dam in the Great Barrier Reef Catchment Area (Table 24). The dam design makes allowance to increase this capacity to 8 Million mega litres in the future, an equivalent capacity to the total volume currently dammed in the Great Barrier Reef Catchment Area (MAP 15).

Apart from the major dams noted in Table 23, instream regulation occurs in the form of barriers for water storage throughout the Great Barrier Reef Catchment Area. The construction of dams has continued to increase during this century (Figure 18). The sharpest increase in the dammed capacity over time occurred in 1958 with the construction of the Koombooloomba Dam and Tinaroo Falls Dam; in 1973 with the Ross River Dam and Fred Haig Dam; and, in 1987 with the construction of the State's largest dam, the Burdekin Dam.

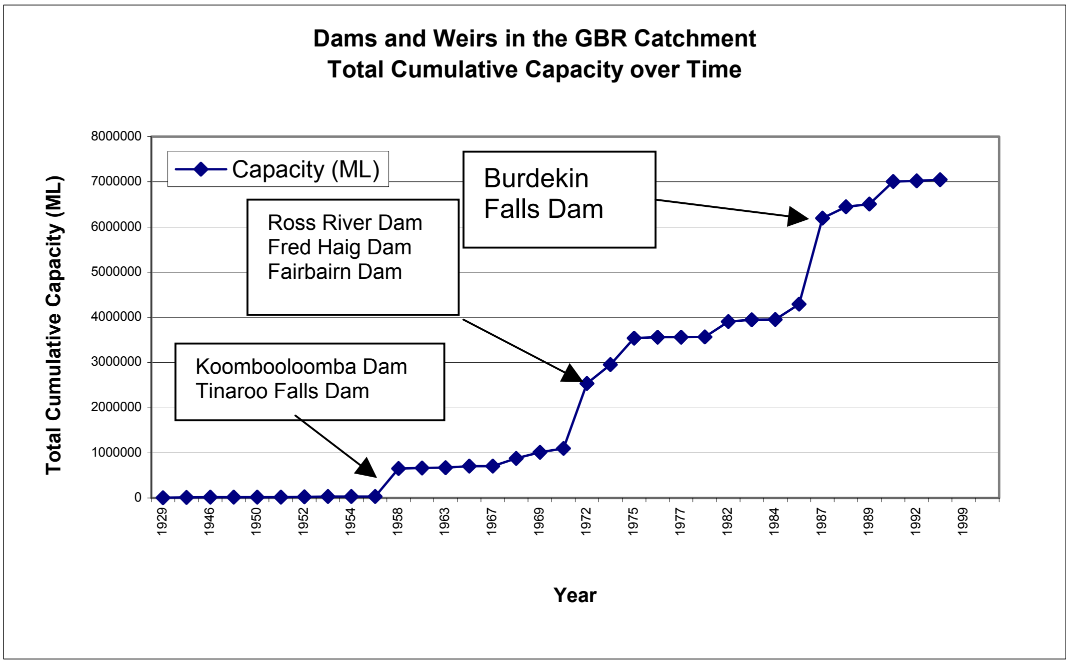
Table 23. Total capacity of dams and weirs within each basin in the Great Barrier Reef Catchment Area in 1997.

Basin Name	Dams Total Capacity (mega litres	Basin Name	Dams Total Capacity (mega litres)
Burdekin	2 032 910	Plane	64 084
Fitzroy	1 826 105	Burrum	18 510
Burnett	700 030	Pioneer	15 720
Kolan	599 780	Black	10 000
Proserpine	498 000	Haughton	3 088
Barron	453 129	Johnstone	1 500
Ross	422 060	Calliope	435
Boyne	315 000	Herbert	260
Tully	212 000	Styx	152
Mary	125 245	Endeavour	135
		GBRCA Total	7 298 143

Table 24. Major dams in the Great Barrier Reef Catchment Area – location by stream and basin, and total capacity.

Dam Name	Stream	Basin Name	Total Capacity (mega litres)
Burdekin Falls Dam *	Burdekin R.	Burdekin	1860000
Fairbairn Dam – Lake Maraboon	Nogoa R.	Fitzroy	1440000
Fred Haigh Dam	Kolan R.	Kolan	586000
Peter Faust Dam	Proserpine R.	Proserpine	498000
Ross River Dam	Ross R.	Ross	417000
Tinaroo Falls Dam	Barron R.	Barron	407000
Awoonga High Dam	Boyne R.	Boyne	250000
Koombooloomba Dam	Tully R.	Tully	212000
Boondooma Dam	Boyne R.	Burnett	212000
Wuruma Dam	Nogo R.	Burnett	165411
Eungella Dam	Broken R.	Burdekin	131000
Callide Dam	Callide Ck.	Fitzroy	127000
Bjelke-Petersen Dam	Barker Ck.	Burnett	125000

*This total does not include the potential future increase to 8 Million mega litres that was built into the design of the Burdekin Falls Dam (QDPI 1993).



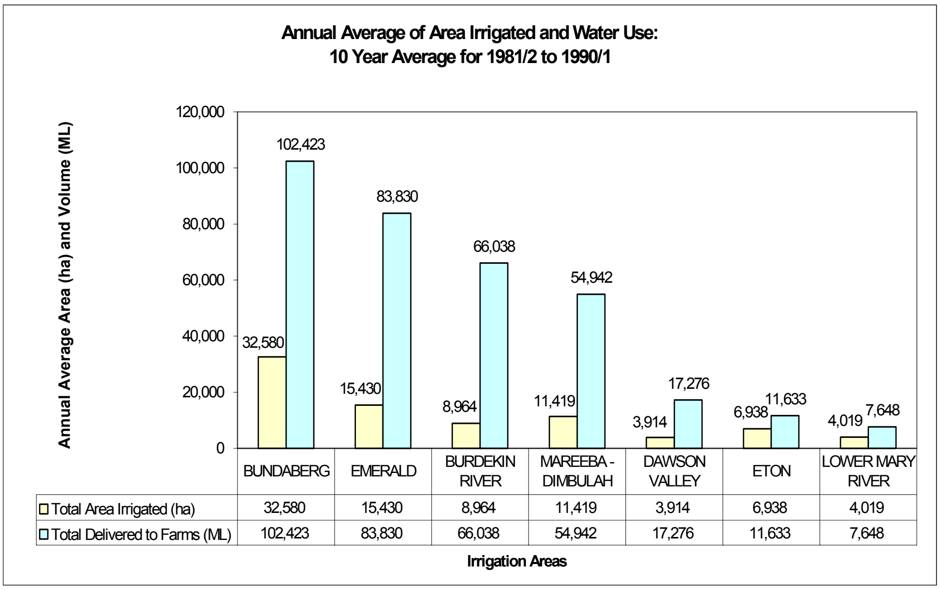
Source: Queensland Department of Natural Resources, 1997.

Figure 18. Dams and weirs in the Great Barrier Reef Catchment Area – total cumulative potential capacity over time.

8.2 Irrigation

The high level of variability in Queensland's rainfall and the resulting widespread implementation of water regulation schemes has produced a number of irrigation areas for agriculture within the Great Barrier Reef Catchment Area (MAP 16). The total average annual area irrigated and volume of water supplied for each irrigation area is shown in Figure 19 and 20 (Queensland Agriculture Statistics; ABS). Sugarcane is currently the most irrigated crop, particularly in the Wide Bay/Burnett and Northern Statistical Divisions (Queensland Year Book, 1998; ABS Agricultural Statistics, 1998).

Since 1991 there has been a large increase in the irrigation for sugar cultivation in the Burdekin associated with the Burdekin River Irrigation Area. It is estimated that the area of cane under the Burdekin River Irrigation Area is approximately 15-20 % of the total area (450 km^2) (personal communication with CANEGROWERS 1998).



	BUNDABERG	EMERALD	BURDEKIN RIVER	MAREEBA - DIMBULAH	DAWSON VALLEY	ETON	LOWER MARY RIVER
Total Area Irrigated (ha)	32,580	15,430	8,964	11,419	3,914	6,938	4,019
Total Delivered to Farms (ML)	102,423	83,830	66,038	54,942	17,276	11,633	7,648

Figure 19. Annual average area irrigated and total water usage for the major irrigation areas within the Great Barrier Reef Catchment Area (1981/2 to 1990/1).

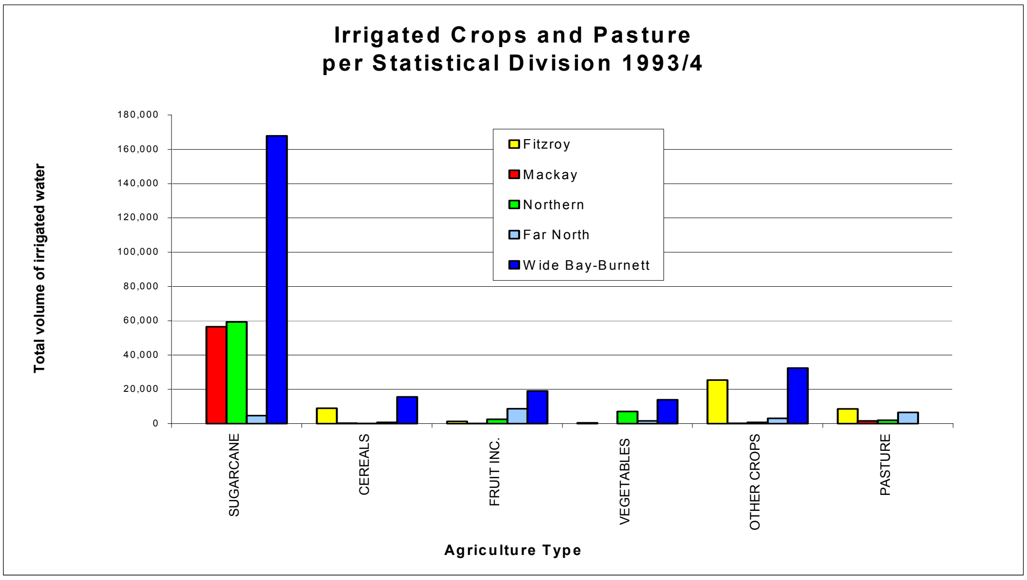


Figure 20. Irrigation water volumes (mega litres) on various crop types per Statistical Division 1993/4.

9. Discussion

Landuse modification associated with increased population and agricultural expansion has transformed the Great Barrier Reef Catchment Area since European settlement 200 years ago (MAP 17). Land clearing, predominantly for pastoral development, has dramatically accelerated during the last 50 years and continues at rates far higher than that of other Australian states. Increases in the area of cropping lands, particularly sugarcane, has reduced the area of valuable wetland habitat, particularly Melaleuca forests, while impacting on the marine environment through higher sediment and nutrient run-off levels.

Soil erosion, fertiliser and pesticide applications, disturbance to acid sulphate soils and alteration to natural drainage systems are some of the impacts on marine ecosystems, resulting from post-settlement landuse modification which have caused a decline in water quality within the Great Barrier Reef lagoon. Monitoring of water quality within the Great Barrier Reef lagoon is relatively recent in the history of settlement of the catchment area with some major land disturbance events occurring prior to long-term monitoring.

Land use change within the Great Barrier Reef Catchment Area is gaining increasing attention from researchers and managers of the Great Barrier Reef World Heritage Area as the pervasive nature of the downstream effects of catchment modification on the marine ecosystems becomes increasingly evident.

Some major trends in land use change can be identified for the Great Barrier Reef Catchment Area:

• Approximately one-third of the Queensland population of 3.3 million persons resides in the Great Barrier Reef Catchment Area. Population growth rates have seen the State's population increase from 1 million in 1938, to 3 million in 1992, with 6 million predicted by the middle of this century. Pollution from urban runoff and discharge from sewage treatment facilities are regarded as the major point source of pollution entering the Great Barrier Reef lagoon. The urban sprawl is placing pressure on adjacent habitat, such as wetlands, particularly in the coastal zone.

• A post-settlement tradition of land clearing, predominantly for pastoral development, has sharply accelerated since the 1950s and continues at rates far higher than that of other Australian states. Over 6 million hectares of *Acacia* woodlands alone were cleared during the brigalow development scheme since the 1950's.

• Soil erosion is widespread and is estimated to be affecting up to 80 % of croplands and 50 % of rangelands within the Great Barrier Reef Catchment Area. Soil loss is considered to significantly greater than pre-settlement sediment loads to waterways and ultimately the Great Barrier Reef lagoon.

• A total annual volume (1995/96) of 300 000 tonnes of fertiliser was applied to land with the Great Barrier Reef Catchment Area. An estimated 50 % of this is lost from the agricultural system and may enter the Great Barrier Reef lagoon via the hydrological system. This volume represents a 3-4 fold increase in fertiliser usage since the 1960s.

• A rapid mineral boom since the 1960s has seen the State's coal production increase from 2.5 million tonnes to just under 100 million tonnes per year. Ninety-six percent of this coal is mined from reserves within the Great Barrier Reef Catchment Area. Rapid port development associated with the mineral boom has created higher shipping traffic within the lagoon, with a greater potential for shipping accidents and oil spills.

• Increased population and agricultural expansion has driven a simultaneous increase in the total number of dams and weirs within the streams and rivers of the Great Barrier Reef Catchment Area. There is currently a potential impunded capacity of over 7 million mega litres of water.

• The loss and degradation of wetlands vital to the long-term integrity of the Great Barrier Reef ecosystem continues as a result of urban and agricultural expansion. In the few instances where data is available, wetland area losses in excess of 60 % have been reported. Melaleuca wetlands have been most severely reduced in extent, as expansion of the sugar industry continues. More recent threats to wetlands are occurring with the widespread adoption of ponded pasture systems for grazing.

- Most catchments have experienced extensive modification except on Cape York Peninsula.

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References for Spatial Data

MAP 1. THE DRAINAGE BASINS OF THE GREAT BARRIER REEF WORLD HERITAGE AREA.
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MAP 2. GEOLOGY OF QUEENSLAND AND THE GREAT BARRIER REEF CATCHMENT AREA.
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MAP 4. EXTENT OF LANDCOVER CLEARANCE ADJACENT TO THE GREAT BARRIER REEF WORLD HERITAGE AREA.
Graetz, RD, Wilson, MA & Campbell, SK (1995). Landcover disturbance over the Australian Continent. Resource Future Program CSIRO Wildlife and Ecology, Canberra. Biodiversity Unit, DEST Canberra. Compiled 1997.

MAP 5. LAND TENURE OF THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND – 1994.
Land tenure data reproduced courtesy of Geoscience Australia. Compiled 1998.

MAP 6. NATIONAL ESTATE WITHIN THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND -1996.
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MAP 7. STATE FORESTS AND TIMBER RESERVES OF THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND -1996.
State forest data reproduced with permission of Queensland Environmental Protection Authority. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

MAP 8. QUEENSLAND GEOGRAPHIC AREAS.
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MAP 9. TOTAL POPULATION PER CENSUS COLLECTION DISTRICT IN THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND -1996.
Census boundaries reproduced courtesy of the Australian Bureau of Statistics. Compiled 1998.

MAP 10. MAJOR URBAN CENTRES AND LOCALITIES IN THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND -1996.
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MAP 11. MARITIME INCIDENTS REPORTED IN THE GREAT BARRIER REEF WORLD HERITAGE AREA - 1987 TO 1997.
Australian Maritime Safety Authority, 1987-1997.

MAP 12. MAJOR PORTS, SHIPPING ROUTES AND ARRIVALS IN THE GREAT BARRIER REEF WORLD HERITAGE AREA – 1994 TO 1995.
Queensland Department of Transport, 1994-1995.

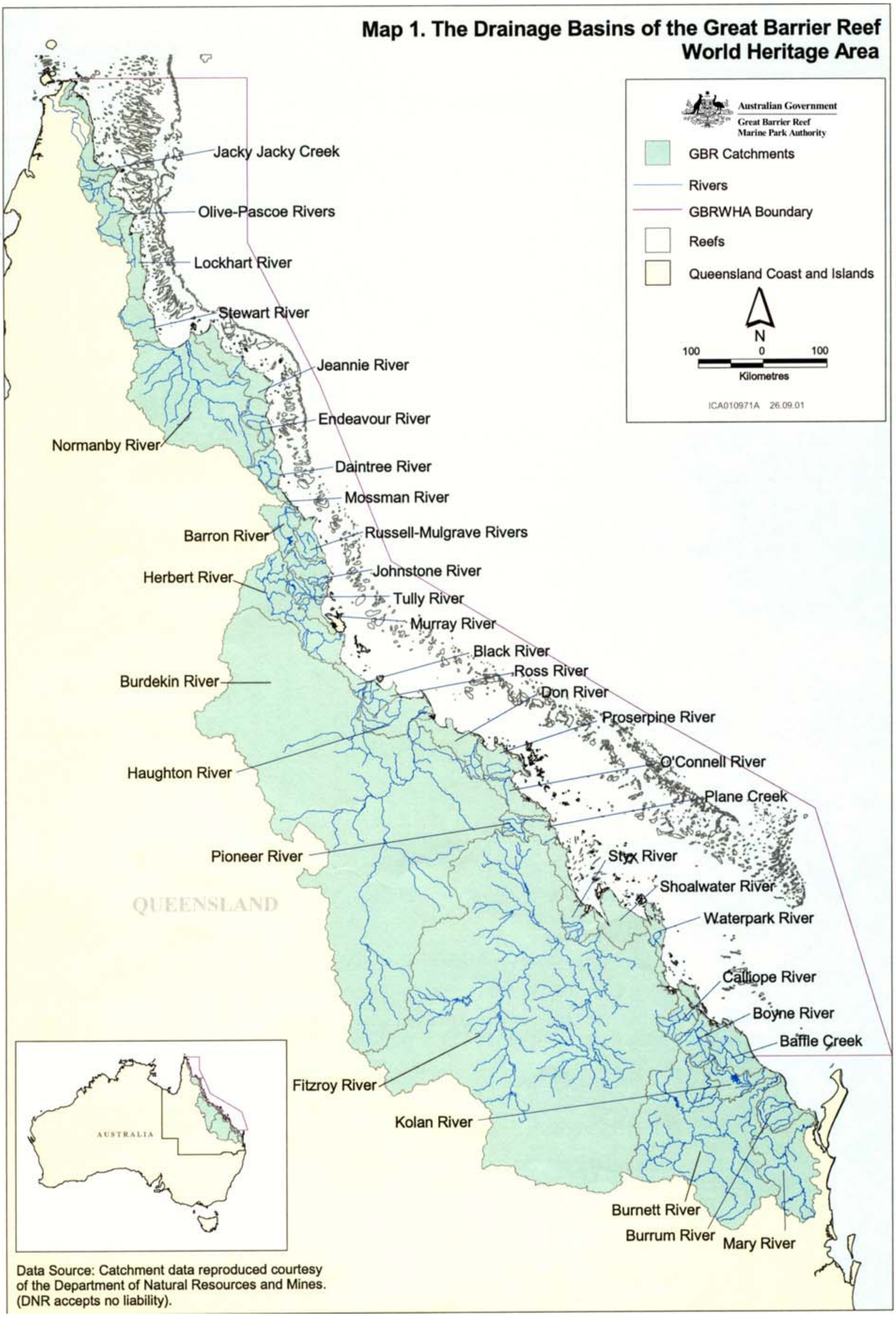
MAP 13. MAJOR SUGAR LANDS IN THE GREAT BARRIER REEF CATCHMENT AREA 1991-1994.
Crop data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability). Derived from visual interpretation of Landsat TM imagery and field validation. Imagery ranging from 1991-1994.

MAP 14. LIVESTOCK NUMBERS PER STATISTICAL DIVISION IN THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND -1996.
Agriculture data reproduced courtesy of the Australian Bureau of Statistics. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

MAP 15. DAMS AND WEIRS IN THE GREAT BARRIER REEF CATCHMENT AREA AND QUEENSLAND - 1997.
Dams and weirs and catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

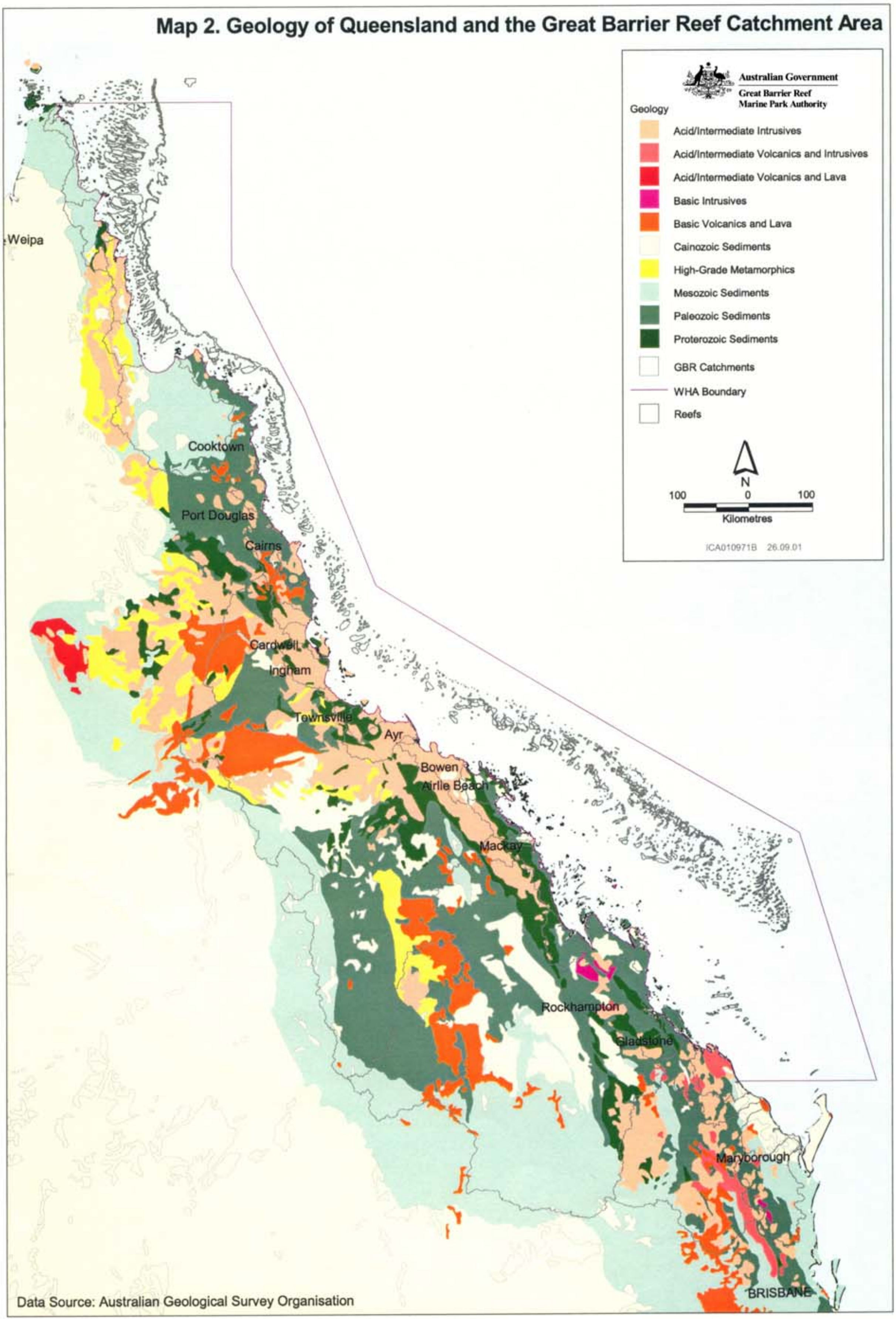
MAP 16. MAJOR IRRIGATION AREAS OF THE GREAT BARRIER REEF CATCHMENT AREA.
Crop and irrigation area data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability). Derived from visual interpretation of Landsat TM satellite imagery and field validation. Imagery ranging from 1991-1994. Statistical boundary reproduced courtesy of the Australian Bureau of Statistics.

MAP 17. MAJOR LAND USE OF THE GREAT BARRIER REEF CATCHMENT AREA.
Sugar and Crop data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability). Derived from visual interpretation of Landsat TM imagery and field validation 1991-1994. Australian Land Information Group, Wet Tropics Management Authority, Queensland Department of Environment.

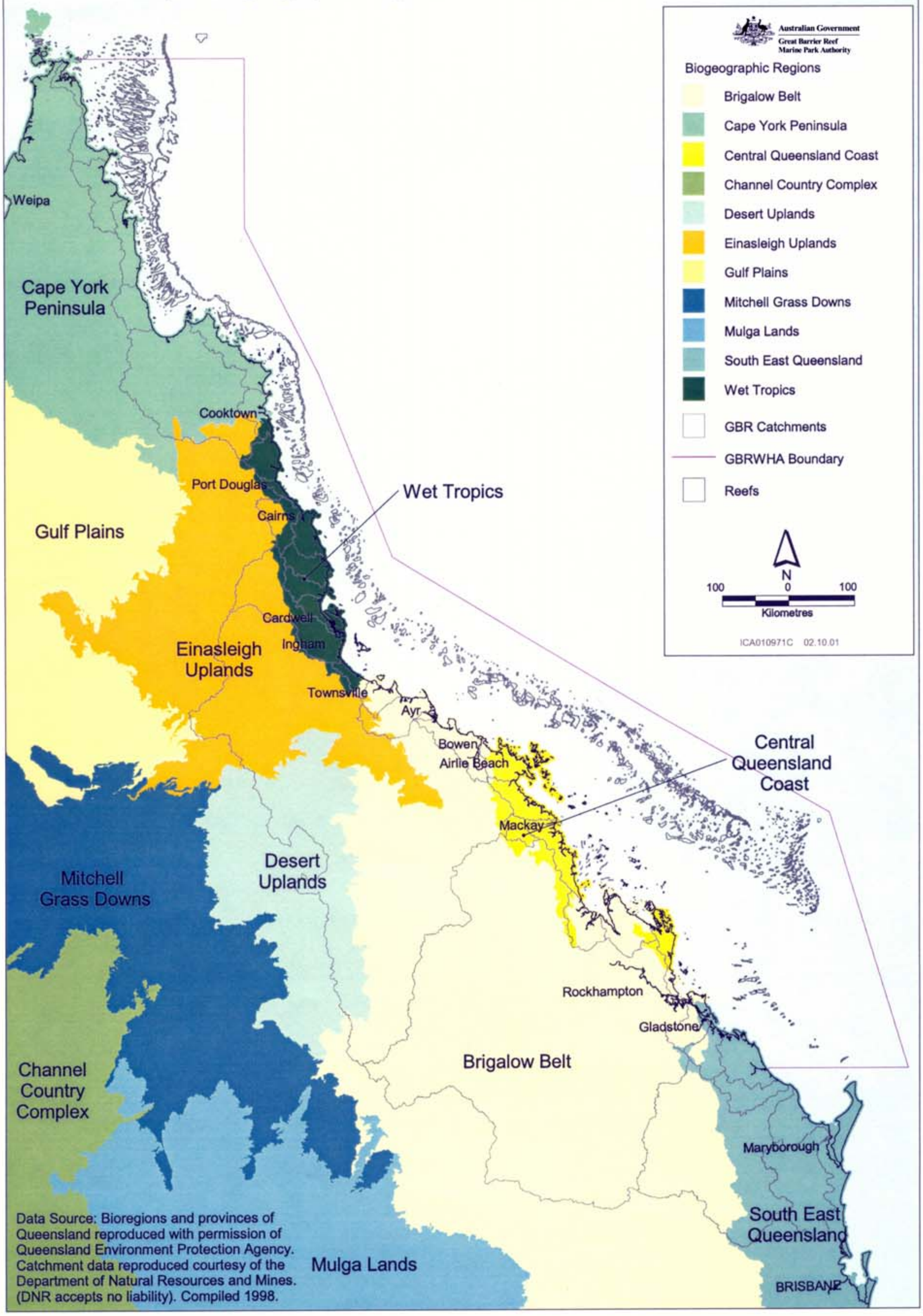


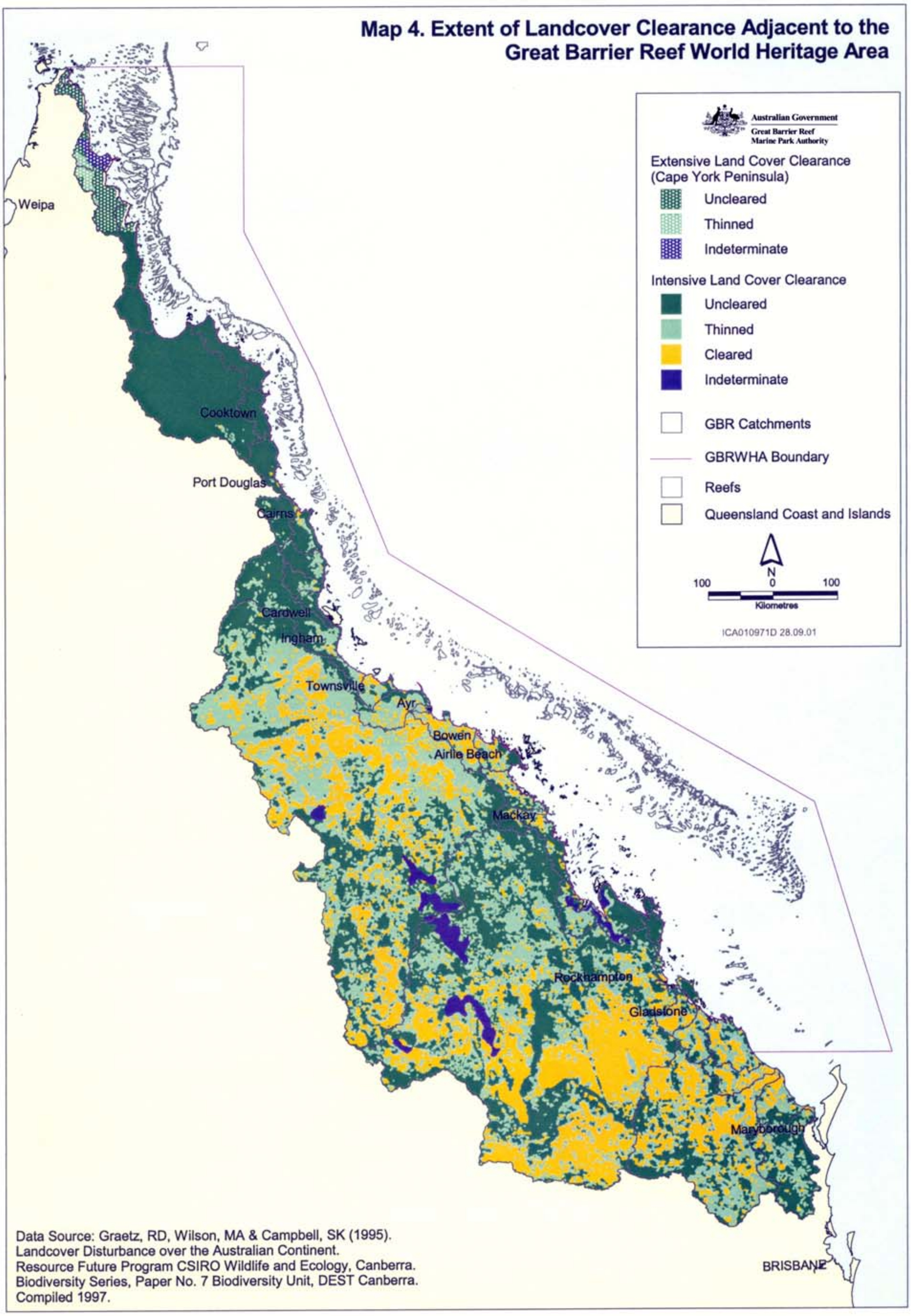
Map 1. The Drainage Basins of the Great Barrier Reef World Heritage Area

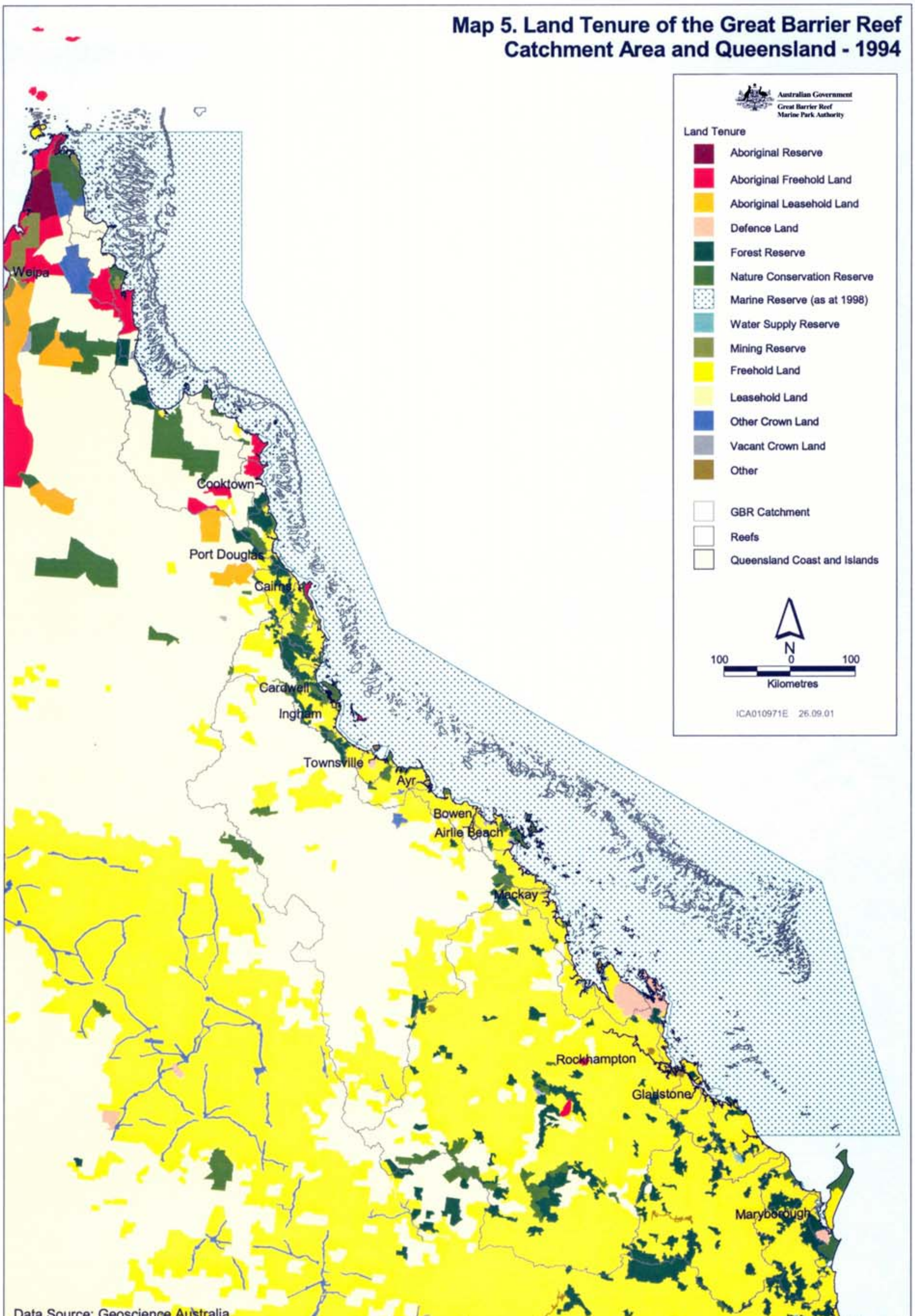
Data Source: Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).


Map 2. Geology of Queensland and the Great Barrier Reef Catchment Area
Australian Government
Great Barrier Reef Marine Park Authority
Geology
Acid/Intermediate Intrusives
Acid/Intermediate Volcanics and Intrusives
Acid/Intermediate Volcanics and Lava
Basic Intrusives
Basic Volcanics and Lava
Cainozoic Sediments
High-Grade Metamorphics
Mesozoic Sediments
Paleozoic Sediments
Proterozoic Sediments
GBR Catchments
WHA Boundary
Reefs
N
100
0
100
Kilometres
ICA010971B 26.09.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
BRISBANE
Data Source: Australian Geological Survey Organisation

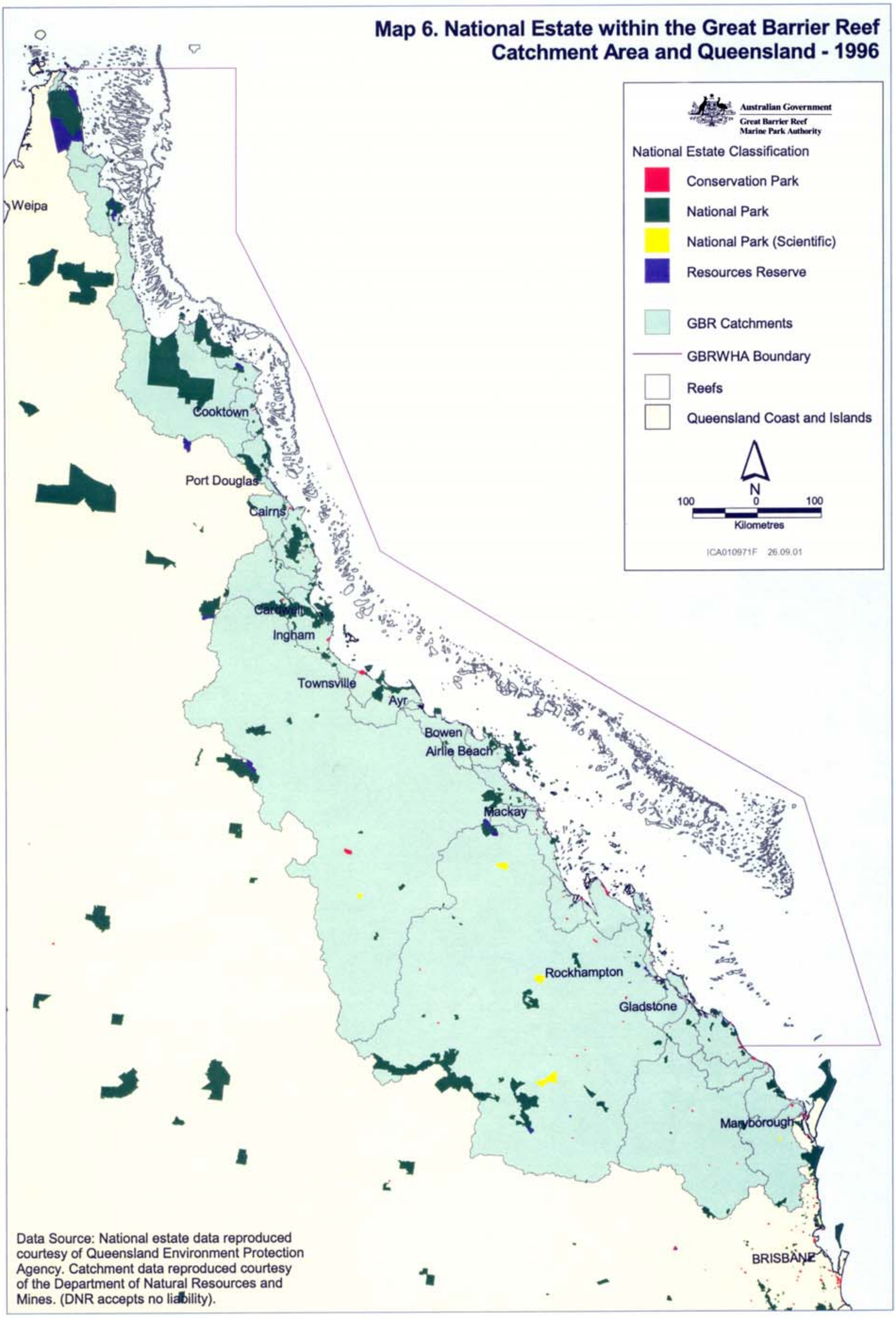
Map 3. Biogeographic Regions within the Great Barrier Reef Catchment Area



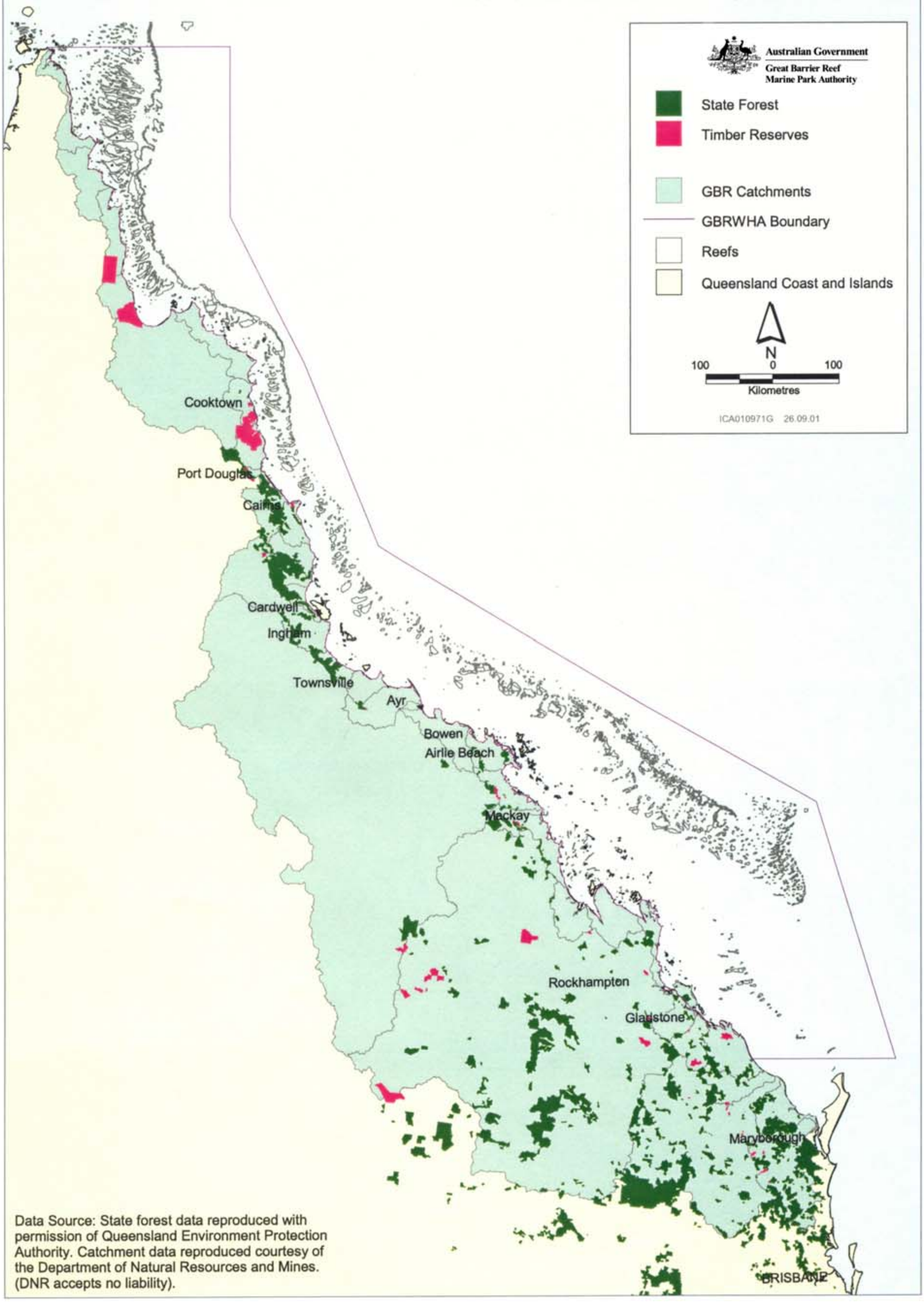

Map 4. Extent of Landcover Clearance Adjacent to the Great Barrier Reef World Heritage Area
Australian Government
Great Barrier Reef Marine Park Authority
Extensive Land Cover Clearance (Cape York Peninsula)
Uncleared
Thinned
Indeterminate
Intensive Land Cover Clearance
Uncleared
Thinned
Cleared
Indeterminate
GBR Catchments
GBRWHA Boundary
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971D 28.09.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
BRISBANE
Data Source: Graetz, RD, Wilson, MA & Campbell, SK (1995).
Landcover Disturbance over the Australian Continent.
Resource Future Program CSIRO Wildlife and Ecology, Canberra.
Biodiversity Series, Paper No. 7 Biodiversity Unit, DEST Canberra.
Compiled 1997.

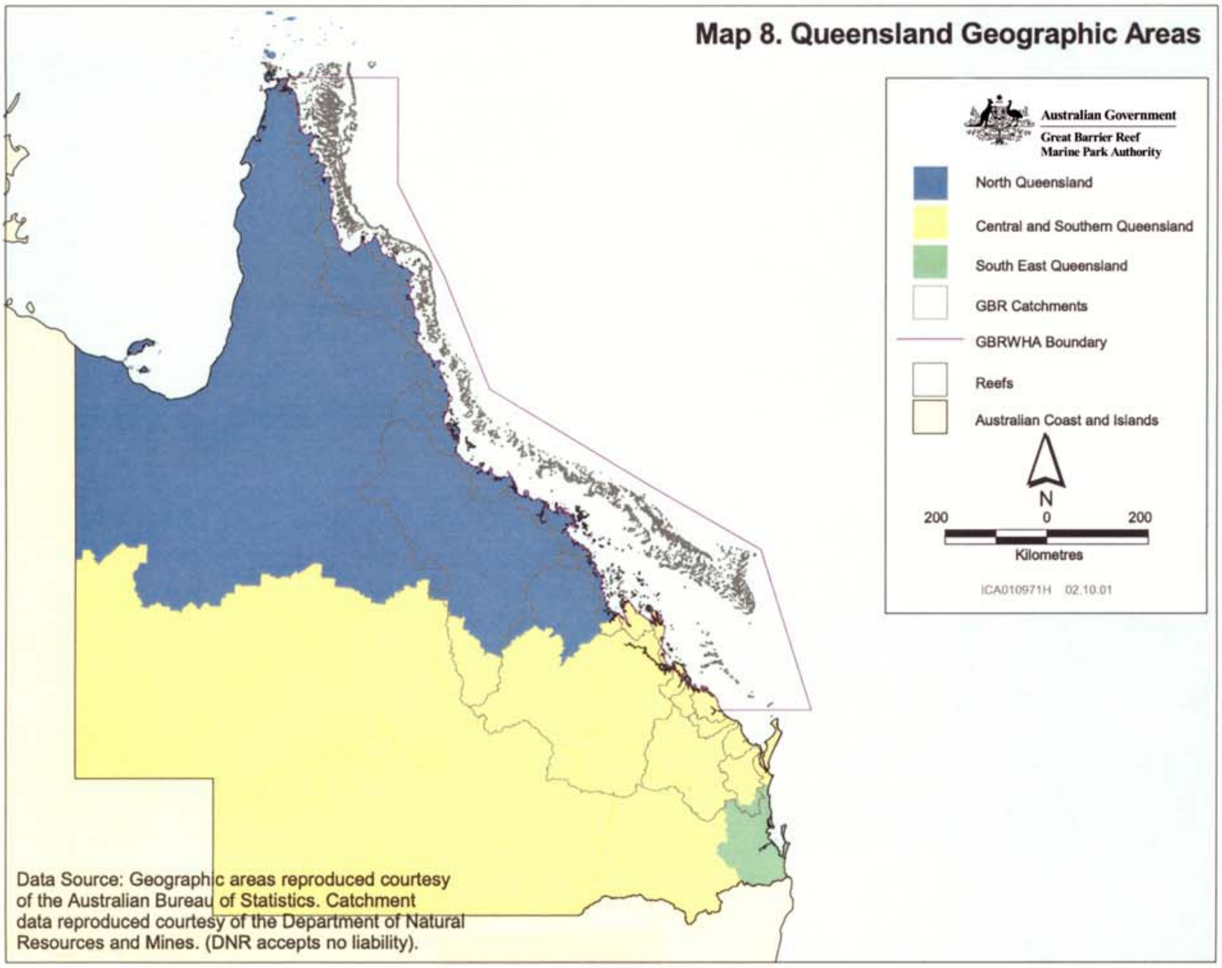


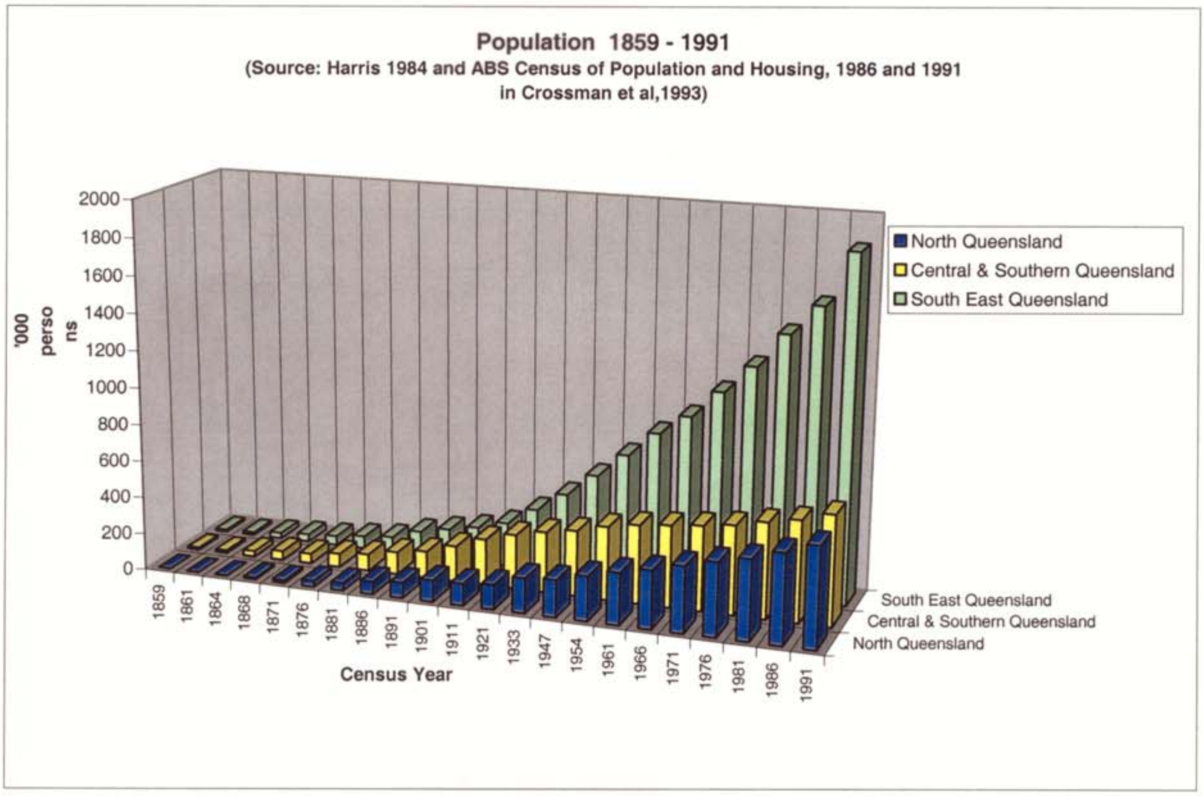
Map 5. Land Tenure of the Great Barrier Reef Catchment Area and Queensland - 1994
Australian Government
Great Barrier Reef Marine Park Authority
Land Tenure
Aboriginal Reserve
Aboriginal Freehold Land
Aboriginal Leasehold Land
Defence Land
Forest Reserve
Nature Conservation Reserve
Marine Reserve (as at 1998)
Water Supply Reserve
Mining Reserve
Freehold Land
Leasehold Land
Other Crown Land
Vacant Crown Land
Other
GBR Catchment
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971E 26.09.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
Data Source: Geoscience Australia.
Compiled 1998.

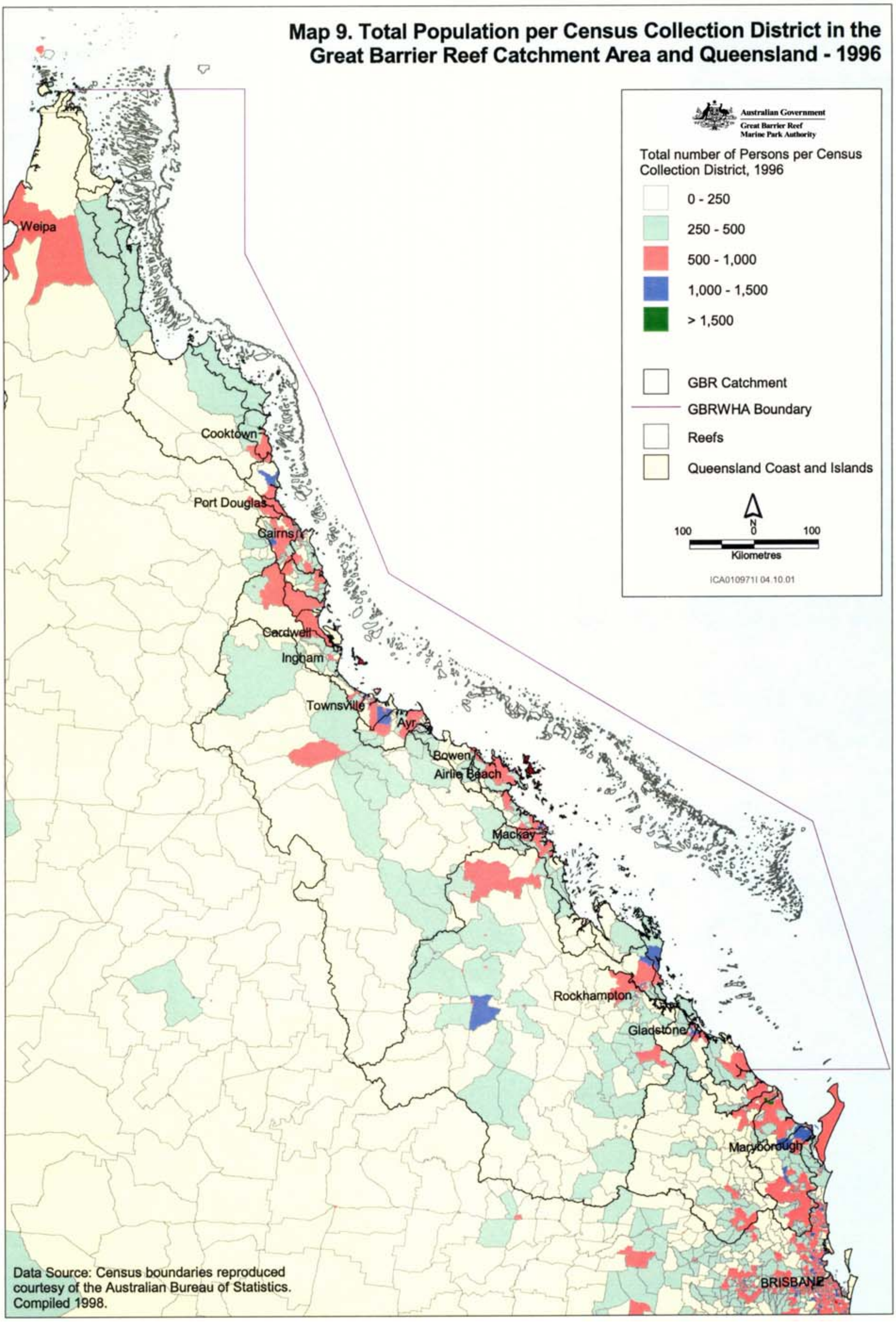

Map 6. National Estate within the Great Barrier Reef Catchment Area and Queensland - 1996
Australian Government
Great Barrier Reef Marine Park Authority
National Estate Classification
Conservation Park
National Park
National Park (Scientific)
Resources Reserve
GBR Catchments
GBRWHA Boundary
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971F 26.09.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
BRISBANE
Data Source: National estate data reproduced courtesy of Queensland Environment Protection Agency. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

Map 7. State Forests and Timber Reserves of the Great Barrier Reef Catchment Area and Queensland - 1996

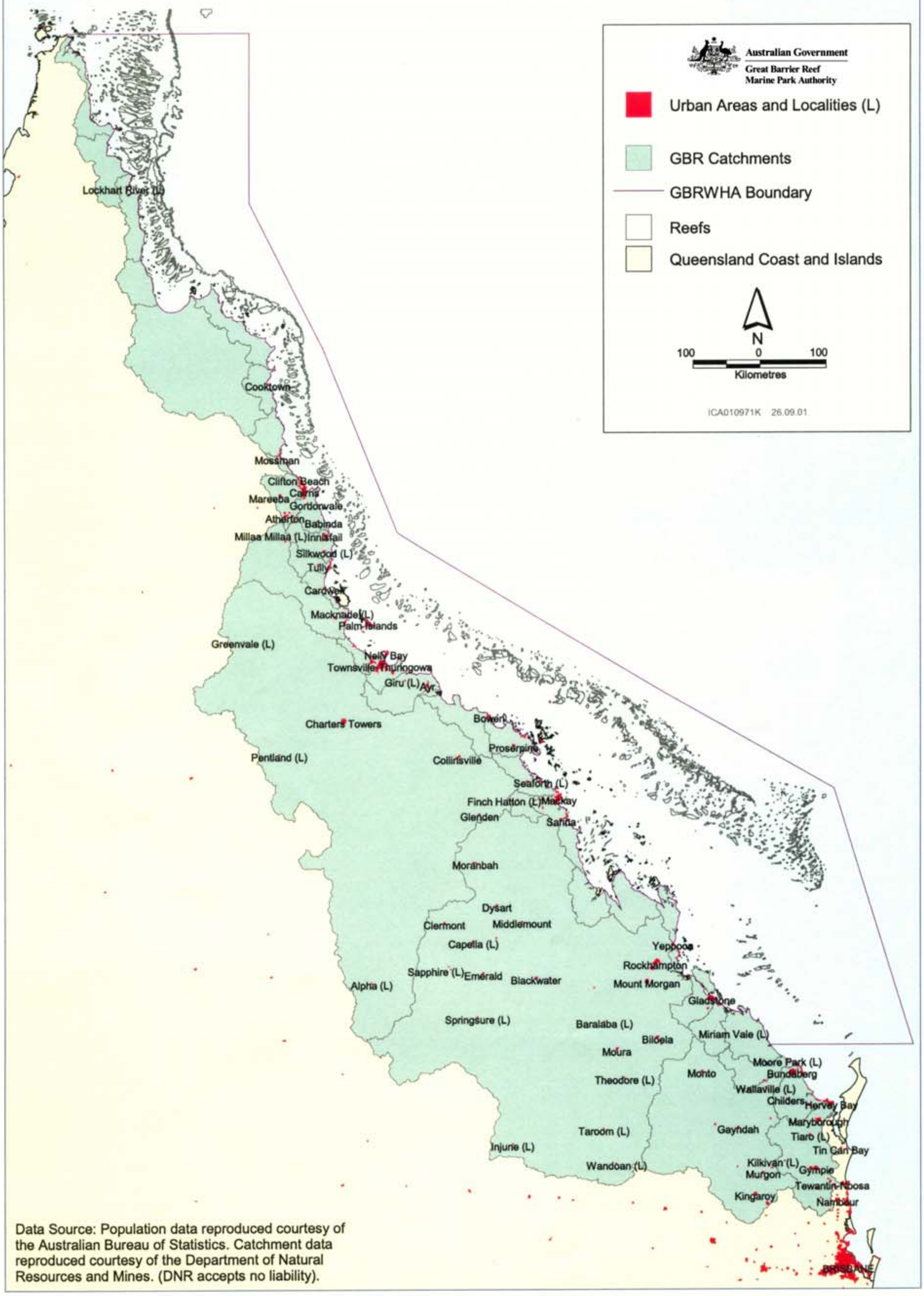



Map 8. Queensland Geographic Areas
Australian Government
Great Barrier Reef
Marine Park Authority
North Queensland
Central and Southern Queensland
South East Queensland
GBR Catchments
GBRWHA Boundary
Reefs
Australian Coast and Islands
N
200
0
200
Kilometres
ICA010971H 02.10.01
Data Source: Geographic areas reproduced courtesy of the Australian Bureau of Statistics. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

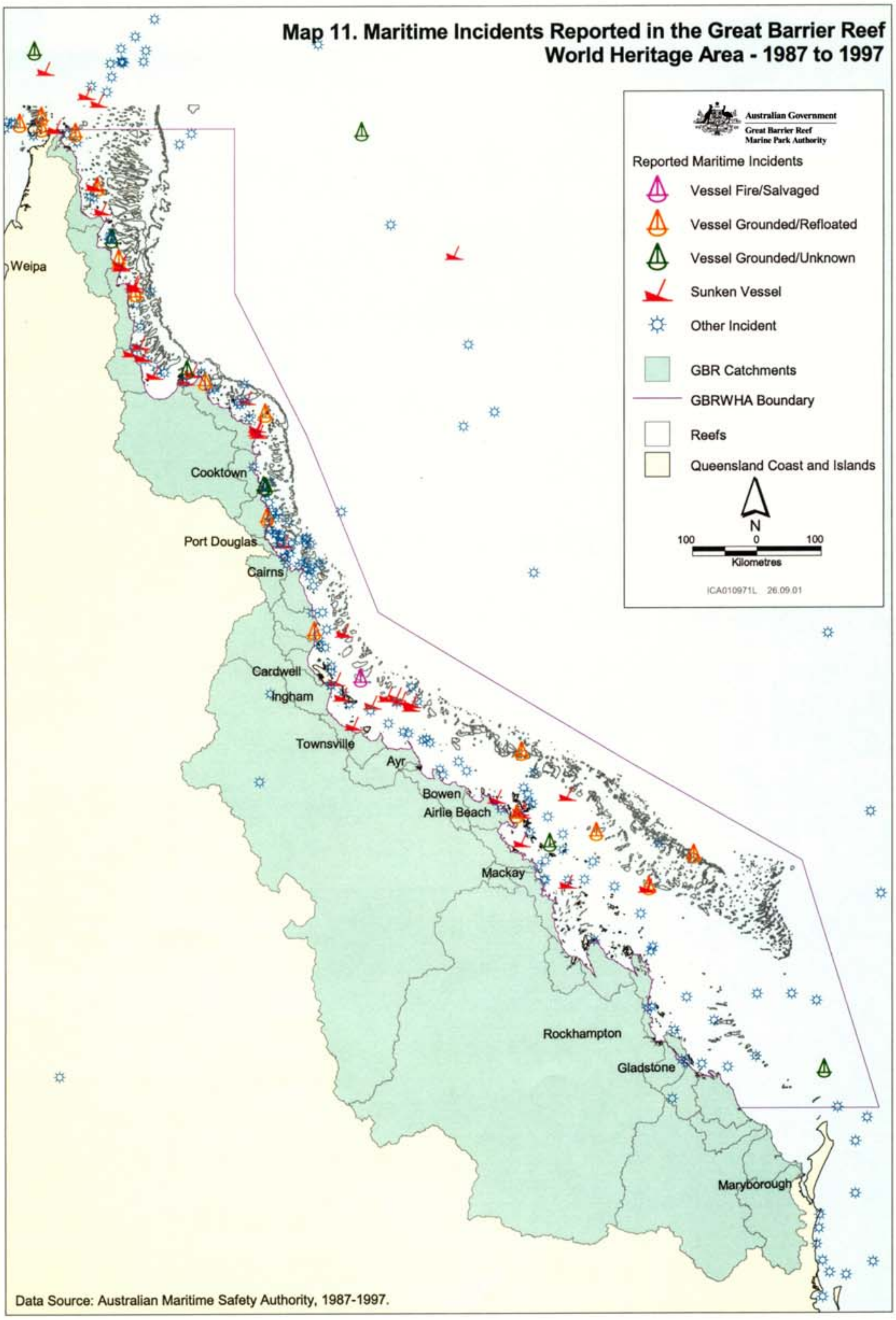

Population 1859 - 1991
(Source: Harris 1984 and ABS Census of Population and Housing, 1986 and 1991
in Crossman et al,1993)
'000 perso ns
2000
1800
1600
1400
1200
1000
800
600
400
200
0
North Queensland
Central & Southern Queensland
South East Queensland
1859
1861
1864
1868
1871
1876
1881
1886
1891
1901
1911
1921
1933
1947
1954
1961
1966
1971
1976
1981
1986
1991
Census Year
South East Queensland
Central & Southern Queensland
North Queensland


Map 9. Total Population per Census Collection District in the Great Barrier Reef Catchment Area and Queensland - 1996
Australian Government
Great Barrier Reef Marine Park Authority
Total number of Persons per Census Collection District, 1996
0 - 250
250 - 500
500 - 1,000
1,000 - 1,500
> 1,500
GBR Catchment
GBRWHA Boundary
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971I 04.10.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
BRISBANE
Data Source: Census boundaries reproduced courtesy of the Australian Bureau of Statistics. Compiled 1998.

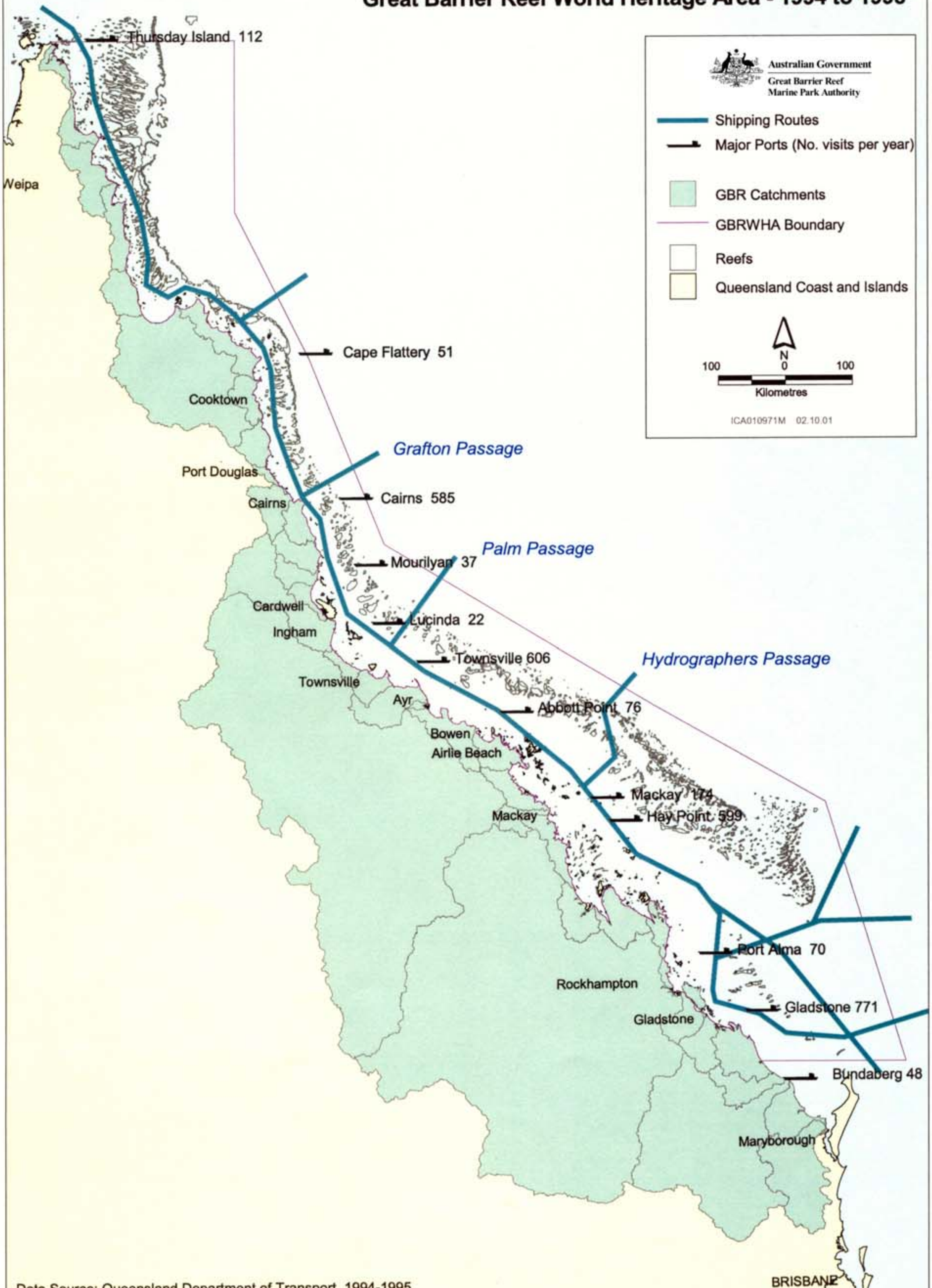
Map 10. Major Urban Centres and Localities in the Great Barrier Reef Catchment Area and Queensland - 1996



Data Source: Population data reproduced courtesy of the Australian Bureau of Statistics. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).

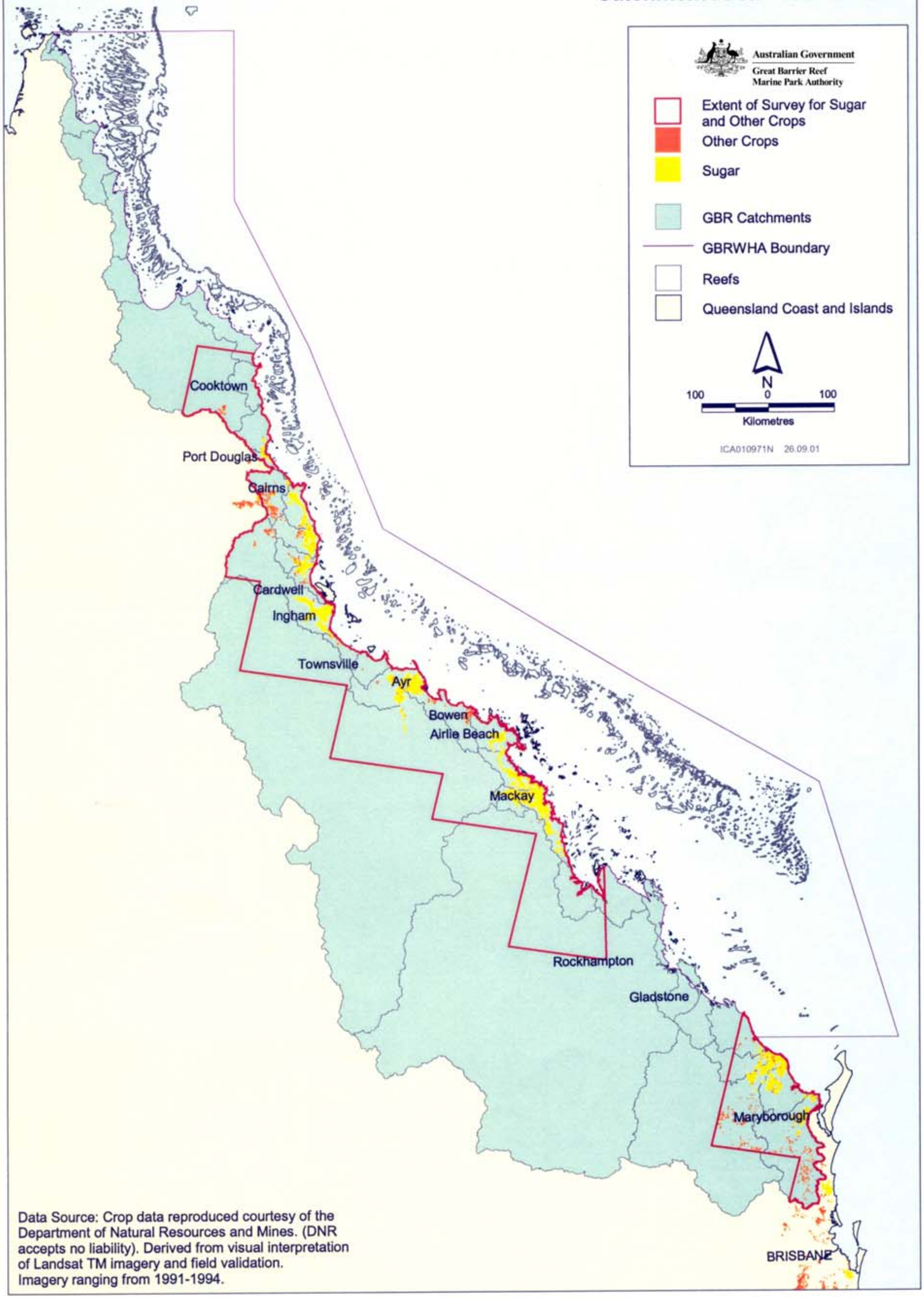

Map 11. Maritime Incidents Reported in the Great Barrier Reef
World Heritage Area - 1987 to 1997
Australian Government
Great Barrier Reef Marine Park Authority
Reported Maritime Incidents
Vessel Fire/Salvaged
Vessel Grounded/Refloated
Vessel Grounded/Unknown
Sunken Vessel
Other Incident
GBR Catchments
GBRWHA Boundary
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971L 26.09.01
Weipa
Cooktown
Port Douglas
Cairns
Cardwell
Ingham
Townsville
Ayr
Bowen
Airlie Beach
Mackay
Rockhampton
Gladstone
Maryborough
Data Source: Australian Maritime Safety Authority, 1987-1997.

Map 12. Major Ports, Shipping Routes and Arrivals in the Great Barrier Reef World Heritage Area - 1994 to 1995

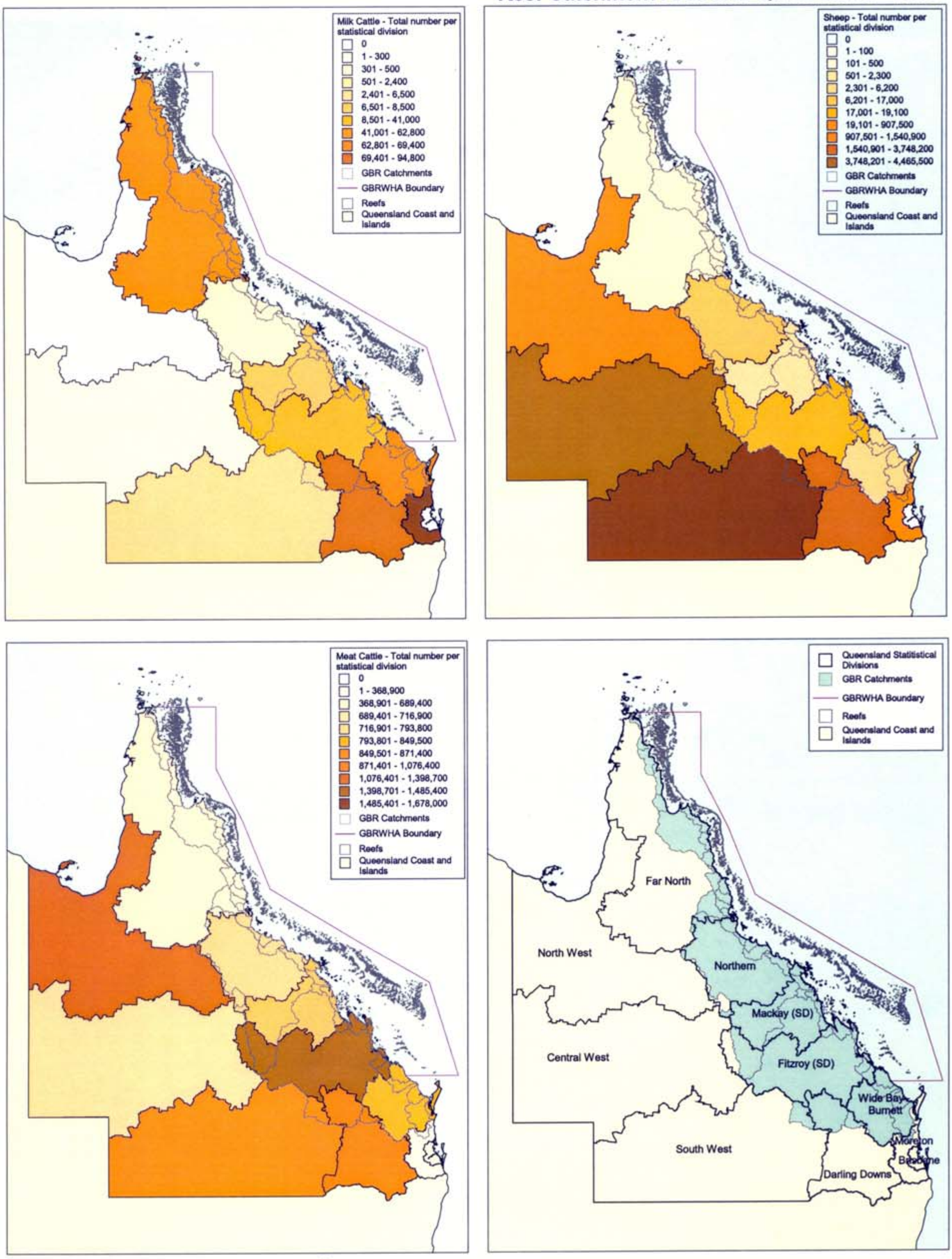


Data Source: Queensland Department of Transport, 1994-1995.

Map 13. Major Sugar Lands in the Great Barrier Reef Catchment Area - 1991 to 1994



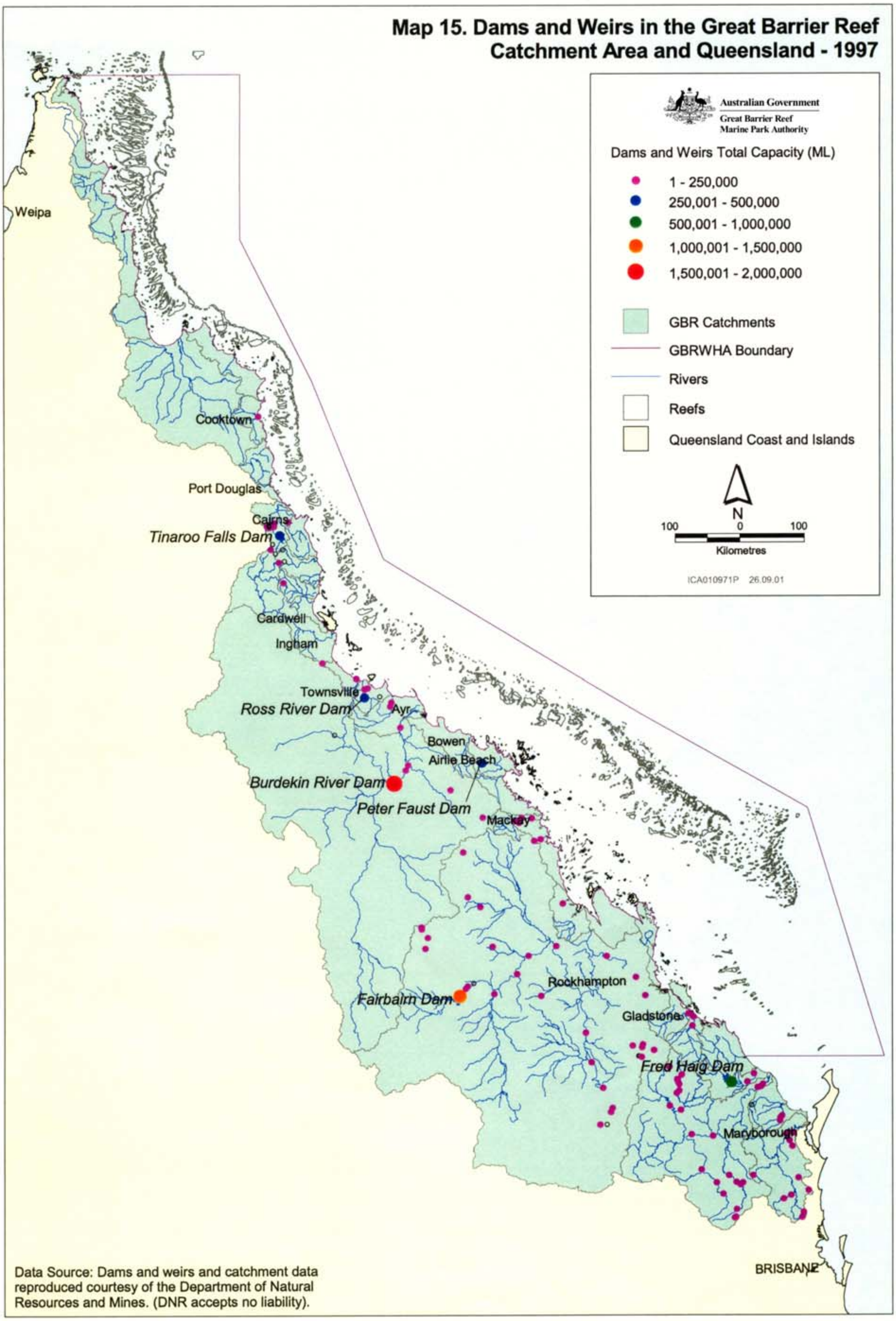
Map 14. Livestock Numbers per Statistical Division in the Great Barrier Reef Catchment Area and Queensland - 1996



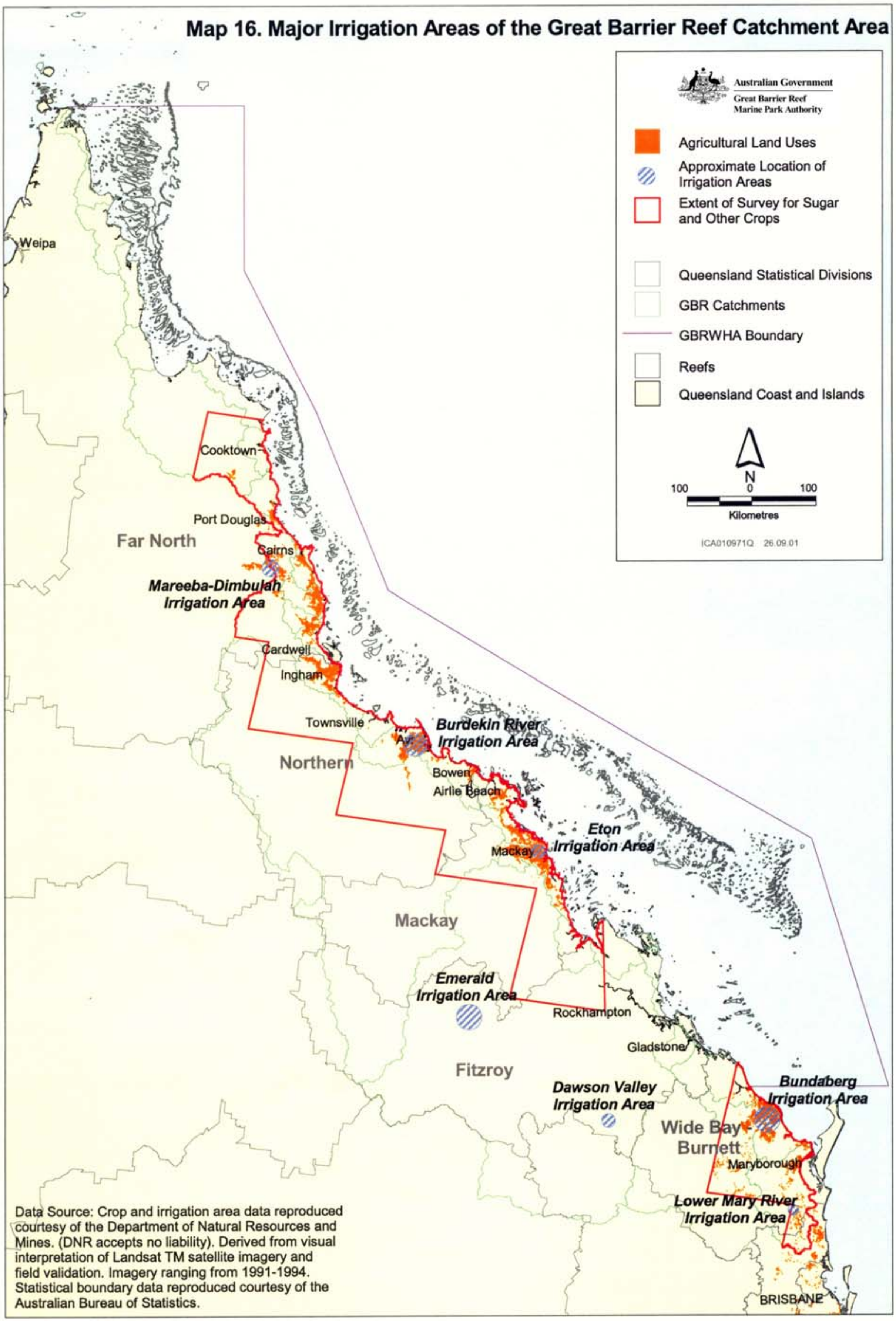
Australian Government
Great Barrier Reef Marine Park Authority

N
200 0 200
Kilometres

Data Source: Agriculture data reproduced courtesy of the Australian Bureau of Statistics. Catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).



Map 15. Dams and Weirs in the Great Barrier Reef Catchment Area and Queensland - 1997
Australian Government
Great Barrier Reef Marine Park Authority
Dams and Weirs Total Capacity (ML)
1 - 250,000
250,001 - 500,000
500,001 - 1,000,000
1,000,001 - 1,500,000
1,500,001 - 2,000,000
GBR Catchments
GBRWHA Boundary
Rivers
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971P 26.09.01
Weipa
Cooktown
Port Douglas
Cairns
Tinaroo Falls Dam
Cardwell
Ingham
Townsville
Ross River Dam
Ayr
Bowen
Airlie Beach
Burdekin River Dam
Peter Faust Dam
Mackay
Rockhampton
Fairbairn Dam
Gladstone
Fred Haig Dam
Maryborough
BRISBANE
Data Source: Dams and weirs and catchment data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability).



Map 16. Major Irrigation Areas of the Great Barrier Reef Catchment Area
Australian Government
Great Barrier Reef Marine Park Authority
Agricultural Land Uses
Approximate Location of Irrigation Areas
Extent of Survey for Sugar and Other Crops
Queensland Statistical Divisions
GBR Catchments
GBRWHA Boundary
Reefs
Queensland Coast and Islands
N
100
0
100
Kilometres
ICA010971Q 26.09.01
Weipa
Cooktown
Port Douglas
Far North
Cairns
Mareeba-Dimbulah Irrigation Area
Cardwell
Ingham
Townsville
Burdekin River Irrigation Area
Ayr
Northern
Bowen
Airlie Beach
Eton Irrigation Area
Mackay
Mackay
Emerald Irrigation Area
Rockhampton
Gladstone
Fitzroy
Dawson Valley Irrigation Area
Bundaberg Irrigation Area
Wide Bay-Burnett
Maryborough
Lower Mary River Irrigation Area
BRISBANE
Data Source: Crop and irrigation area data reproduced courtesy of the Department of Natural Resources and Mines. (DNR accepts no liability). Derived from visual interpretation of Landsat TM satellite imagery and field validation. Imagery ranging from 1991-1994. Statistical boundary data reproduced courtesy of the Australian Bureau of Statistics.

Map 17. Major Land Use Types in the Great Barrier Reef Catchment Area