Australian Government

Great Barrier Reef
Marine Park Authority

Haughton Basin Assessment

Burdekin Dry Tropics NRM Region

Assessment of ecological functions within the Haughton basin focusing on understanding and improving the health and resilience of the Great Barrier Reef

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EXECUTIVE SUMMARY

Context

A healthy and resilient Great Barrier Reef World Heritage Area (the World Heritage Area) is reliant upon the ecological integrity of the adjacent Great Barrier Reef catchment and its coastal ecosystems.

The Haughton basin provides habitat for many important marine, estuarine, freshwater and terrestrial species with lifecycles that have connections to the World Heritage Area. The coastal ecosystems in the basin also provide a range of ecological functions that support the health and resilience of the marine environment.

Within the marine environment, coastal waters provide high value marine areas including around islands and inshore coral reefs. To protect representations of these areas, there are many coastal and inshore Marine National Park Zones adjacent to this basin.

This Report is part of a series of similar reports investigating the nature, condition, connectivity and management of coastal ecosystems within basins that form the catchment of the World Heritage Area. The purpose of this Report on the Haughton basin is to:

- Review coastal ecosystems in the basin, assess their state and consider the pressures that they are facing now, and into the future.
- Understand the connections between coastal ecosystems and the World Heritage Area, and how changes to these connections are impacting on the ecological functions they provide to the Great Barrier Reef.
- Provide information to support future planning and management decisions, including identifying areas important for protection or potential offsets.
- Empower communities and stakeholders by providing information that can support on-ground actions.

Maps shown in this basin assessment were derived from a range of data sources, and should only be used as a guide.

The Haughton basin

The Haughton basin has significant natural assets and is home to (and used by) many important marine, estuarine, freshwater and terrestrial species with connections to the World Heritage Area. The high levels of productivity generated from extensive wetland systems in this region support highly valuable commercial fisheries (trawl and inshore fin fish) and high value recreational fisheries (billfish, barramundi and mackerel).[1] The adjacent waters are also home to the world famous Yongala dive site. The Haughton basin estuaries make up eight per cent (33,112 hectares) of the extent of estuaries in the Great Barrier Reef catchment (the Catchment). This amounts to an estimated $6.3 million worth of annual recreational and commercial fisheries catch[1].

Figure 1: The Yongala shipwreck is a popular dive site and ranked as one of the worlds best wreck dives

Key issues

The Haughton basin was once dominated by extensive freshwater floodplain ecosystems. Wetlands, grass and sedgelands and forested floodplains once dominated the floodplain, providing substantial physical, biological and biogeochemical functions to the World Heritage Area. This highly productive low profile basin was noted by early settlers and as a result is now the largest sugar cane production area in Australia.[3]

The coastal ecosystems in the Haughton basin (and the ecological functions provided by them) have changed significantly over the last century. These changes include direct modifications to coastal ecosystems, significant changes to surface, groundwater and main river channel hydrology, bund walls and introductions of feral species. These changes are mostly irreversible and future management needs to be adaptive and innovative.

Land development for intensive irrigated sugar cane production has led to the reclamation of many of the wetlands of the lower floodplain. This has generated changes in overland and groundwater hydrology that are affecting both natural and modified ecosystems. As a consequence, extensive management of surface and groundwater resources is now needed to manage the modified hydrological regimes.

Ungrazed exotic pasture weeds in the basin have increased fuel loads and have changed the fire regimes in many of the riparian areas adjacent to cane farms. Hotter fires as a result of introduced grass species often kill all but the most fire resilient trees, reducing canopy cover in-stream riparian areas, promoting further weed infestation and habitat loss.

Floodwaters once meandered across the landscape, collecting organics that were transported into coastal waters, providing a cue for the reproduction in species such as barramundi and mangrove jack. These have been replaced with inorganic nutrient and chemical laden (and even anoxic) pulsed flows of water. Bund walls, created in the early 1900s across the saltmarsh/mangrove interface to increase the extent of grazing lands, now captures irrigation tailwater and support extensive, perennial, anoxic swamps of exotic and

[1] This figure was derived from the annual catch in the Great Barrier Reef of fish and invertebrate species that use estuaries for part or all of their life histories. This amounted to approximately $20,000 per square kilometre of estuary (assuming all estuaries are equally productive and using Gross Value of Production figures from the east coast inshore finfish fishery, mud crab fishery and otter trawl fishery).[2])

native emergent macrophytes that prevent migrations of aquatic species and reduce inshore productivity through limitations to the exchange of tidal water.

These changes in hydrology and in-stream ecology in the basin are leading to poor water quality and loss of ecosystem connectivity to the World Heritage Area. The nature of nutrients and agri-chemicals entering these coastal ecosystems has changed from slow release organic nutrients into rapidly assimilated inorganic nutrients. Pesticides and herbicides used on the land are now entering the sea. Inshore seagrass meadows are in decline, which affects seagrass dependant species such as dugong and tiger prawns. Coral health and recruitment has declined for inshore coral reefs. A constant flow of agri-chemical contaminated tailwater flowing into Barratta Creek is particularly concerning since it is one of the key watersheds that drain into the internationally listed Bowling Green Bay Ramsar wetland.[4]

Potential management actions

This report has been developed as a baseline for the Haughton basin, in order to ensure that the basin is best represented any available finer scale data, local knowledge and information would value add to this assessment.

Ensuring the long-term health of the Reef requires greater protection of, and restoration of important ecological processes and functions provided by Fitzroy basin coastal ecosystems. Restoration of the ecological functions in this basin is not simple. Land use change, artificial barriers and drainage channel construction is an issue in the Haughton basin and affects overland flow and groundwater. Actions that would increase protection and restore processes and function include:

1. Encourage strategic vegetation management, including planting climate change adapted species and plants designed to address the modified landscape (e.g. rainforest species in areas where water is perennial due to irrigation, deep rooted trees planted on the floodplain to assist in managing the rising groundwater and salinity).
2. A coordinated effort incorporating the vast array of data and reports and recognition that any planning for the area (in particular water use) should consider the Burdekin and Don basins. The Haughton basin itself was once part of the lower Burdekin delta and as such, is strongly influenced by the Burdekin River.
3. Public participation and engagement in the development of plans and prioritisation of works.
4. Incorporation of this basin assessment into regional and local planning documents.
5. Plan and manage new land use to have no net impact on the World Heritage Area.

A strategic study of groundwater engineering is needed to enable a balance between sustainable agriculture and functional coastal ecosystems. Significant changes to land management practices are needed, particularly changes in use of grazing on a broadscale and pasture management, and revegetation of critical coastal ecosystems. Low levels of grazing have been used successfully in weed infested riparian areas to improve riparian and wetland health. Any revegetation needs to involve landholders and consider the changed hydrology. In some areas, planting with modified hydrology adapted rainforest species may be more apt than re-establishing former vegetation communities, and Wet Tropics associated galley rainforest species may be more appropriate on the now perennial drainage channels. Despite major ecosystem disturbance, in general many freshwater ecosystems have shown recent improvements in health. This may be due to major investment in aquatic weed management and riparian vegetation planting, improved knowledge and management, or as a result of several years of flooding that have effectively 'reset the system'. Either way, the most opportune time to continue to improve coastal ecosystem health is now.

INTRODUCTION

Background

The Great Barrier Reef Marine Park (Marine Park) covers an area of approximately 348,000 km^2 and extends from Cape York in the north to Bundaberg in the south. The Great Barrier Reef World Heritage Area was accepted in 1981 for inclusion in the World Heritage List, meeting all four of the natural heritage criteria (aesthetics and natural phenomena; geological processes and significant geomorphic features representing major stages of earth's history; ecological and biological processes; and habitats for the conservation of biological diversity, including threatened species). The World Heritage Area includes additional areas outside of the Marine Park. The World Heritage Area extends from the low water mark on the Queensland coast to up to 250 km offshore past the edge of the continental shelf and includes coastal and island ecosystems, as well as some port and tidal areas, outside of the Marine Park.

The adjacent Great Barrier Reef catchment encompasses an area of 424,000 km^2 with all water flowing from the catchment into the World Heritage Area. The catchment contains a diverse range of terrestrial, freshwater and estuarine ecosystems. These coastal ecosystems include rainforests, forests, woodlands, forested floodplains, freshwater wetlands, heath and shrublands, grass and sedgelands, and estuaries.

Coastal ecosystems support the health and resilience of the World Heritage Area. The ecological functions provided by coastal ecosystems include physical processes (such as sediment and water distribution and cycling), biogeochemical processes (such as nutrient and chemical cycling) and biological processes (such as habitat and food provisioning).

This report looks beyond boundaries and assesses the Haughton basin's current land use, remaining extent and pressures on coastal ecosystems, and how this basin supports and maintains the health and resilience of the World Heritage Area.

Purpose

The purpose of a basin assessment is to assess at the landscape scale ecological functions, the risks to these functions and the cumulative impacts that are affecting the long-term health of the World Heritage Area. The focus area for this Report is the Haughton basin, which includes ecosystems extending from the inshore areas of the Marine Park to the upper extent of the Haughton basin. The information collected, collated and analysed provides a rapid summary of the state of the basin's ecological assets and highlights pressures and threats, ecological condition and the social response to threats and pressures that are influencing the health of the World Heritage Area. More influencing factors – and consequently more pressures – are at work at finer scales of analysis and should be considered when planning or managing these areas.

The Great Barrier Reef catchment is made up of thirty-five basins draining directly into the World Heritage Area, as shown in Table 1.

Table 1: Basins in the Great Barrier Reef catchment

Great Barrier Reef catchment	NRM regions	Basins	Coastal zone as defined by Queensland State Coastal Management Plan 2011
	Cape York NRM region (managed by Cape York NRM)	Jacky Jacky	
		Olive-Pascoe	
		Lockhart	
		Stewart	
		Normanby	
		Jeanie	
		Endeavour	
	Wet Tropics NRM region (managed by Terrain)	Daintree	
		Mossman	
		Barron	
		Mulgrave-Russell	
		Johnstone	
		Tully	
		Murray	
		Herbert	
	Burdekin Dry Tropics NRM region (managed by NQ Dry Tropics)	Black	
		Ross	
		Haughton	
		Burdekin	
		Don	
	Mackay Whitsunday NRM region (managed by Reef Catchments)	Proserpine	
		O'Connell	
		Pioneer	
		Plane	
	Fitzroy NRM region (managed by Fitzroy Basin Association)	Styx	
		Shoalwater	
		Waterpark	
		Fitzroy	
		Calliope	
		Boyne	
	Burnett-Mary NRM region (managed by Burnett Mary Regional Group)	Baffle	
		Kolan	
		Burnett	
		Burrum	
		Mary	

Methodology

The methods underpinning this basin assessment are detailed in the Coastal Ecosystems Assessment Framework[5], a tool developed in partnership with the Queensland Government (available at www.gbrmpa.gov.au). The Coastal Ecosystems Assessment Framework was developed and used as the basis of the *Informing the Outlook for Great Barrier Reef coastal ecosystems*[6] report, and provides a holistic approach to assessing and understanding ecological functions provided by coastal ecosystems and the pressures affecting them.

The catchment in its current state is a mosaic of natural and modified ecosystems with a suite of values and functions of importance to the World Heritage Area. The methodology used to understand the values and functions provided by natural and modified coastal ecosystems are outlined in the Coastal Ecosystem Assessment Framework[5] and have been used as a basis to assess the Haughton basin assessment. Figure 2 below describes the methodology used to rapidly assess the ecological functions and values to conduct the Haughton basin assessment.

Figure 2: Summary of the methodology for conducting a rapid basin scale assessment

Stakeholder engagement and verification of assessment information has been crucial to the development of this basin assessment. Building on the information collected and collated for the *Informing the Outlook for coastal ecosystems*[6] report, the methodology for preparing this Report incorporated the following steps:

1. Local experts were consulted to identify areas of interest to visit in the field as part of a 'rapid assessment'.
2. Research was conducted on the basin using available information.
3. Sites of interest were identified using coastal ecosystem maps and Google earth (GPS identification for sites to be visited for field work).
4. Collaboration with local stakeholders (i.e. consultants, natural resource management bodies, local land owners) helped to verify the issues affecting the basin, as well as additional field sites.
5. Field investigations were conducted using the field site assessment template forms (Appendix A) to capture site locations and reference photos at basin sites (Figure 3).
6. GPS coordinates from field assessments were imported into Google earth to assist with report preparation.
7. Preliminary basin assessments were compiled to facilitate stakeholder input.
8. Workshops were conducted to bring stakeholders together to present information and incorporate feedback into the basin assessment.
9. Draft basin assessments were prepared as a basis to further stakeholder input.
10. Basin assessments finalised and published.

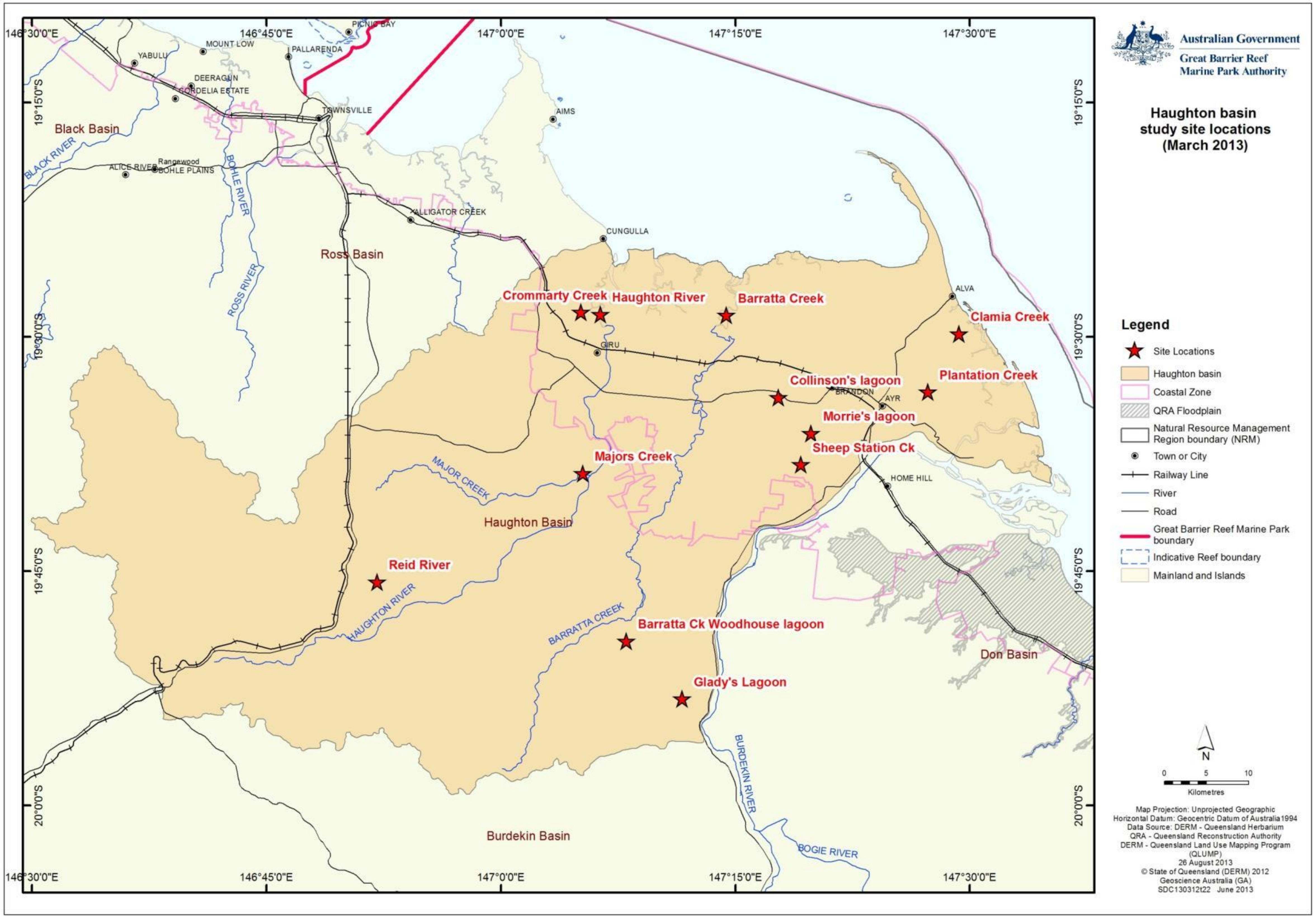

Figure 3: Study sites for the Haughton basin assessment

PART A: VALUES OF THE GREAT BARRIER REEF REGION – HAUGHTON BASIN

Chapter 1: Haughton basin – background to changes affecting matters of national environmental significance

1.1 Background and history of the Haughton basin

The boundary used in this report for the Haughton basin is that used by the Queensland Government. The Haughton basin itself was once part of the lower Burdekin delta and as such is strongly influenced by the Burdekin River. The influences of development in the lower Burdekin floodplain (the Haughton, Burdekin and Don basins) also transcend these boundaries. Consequently, in this report references are often made to either or both the Haughton basin and the lower Burdekin floodplain.

The Haughton basin is located south of Townsville and flows from Mingela in the west and enters the World Heritage Area between Townsville and Ayr (Figure 1.1.1).

Figure 1.1.1: Haughton basin and proximity to the Great Barrier Reef

The Haughton River in the north of the Haughton basin runs from the hill slopes in the upper basin across an extensive floodplain landscape into wide tidal delta made up of extensive areas of saltmarsh, saltpan and mangrove forests. This delta flows into Bowling Green Bay. Two relatively natural tributaries – Reid River and Major Creek flow into the Haughton River in the upper part of the basin (Figure 1.1.2).

The south of the Haughton basin is actually part of the Burdekin River delta (the Burdekin River is located south of the Haughton basin). Overbank flows during peak flood events in the Burdekin River would once fan out across the Haughton basin floodplain and into Barratta, Kalamia, Barramundi, Sheep Station and other smaller creeks. These flows would replenish and renourish the extensive wetland systems that were once widespread across the floodplain. Water would be filtered in these systems before flowing on into the coastal waters of the World Heritage Area. The construction of a levee bank along parts of the Burdekin River now prevents all but the largest of overbank flows of the Burdekin River.

To the west, the Haughton basin is elevated land with relatively intact vegetation. To the east, the Haughton basin is an old alluvial floodplain with river systems flowing into coastal estuaries.

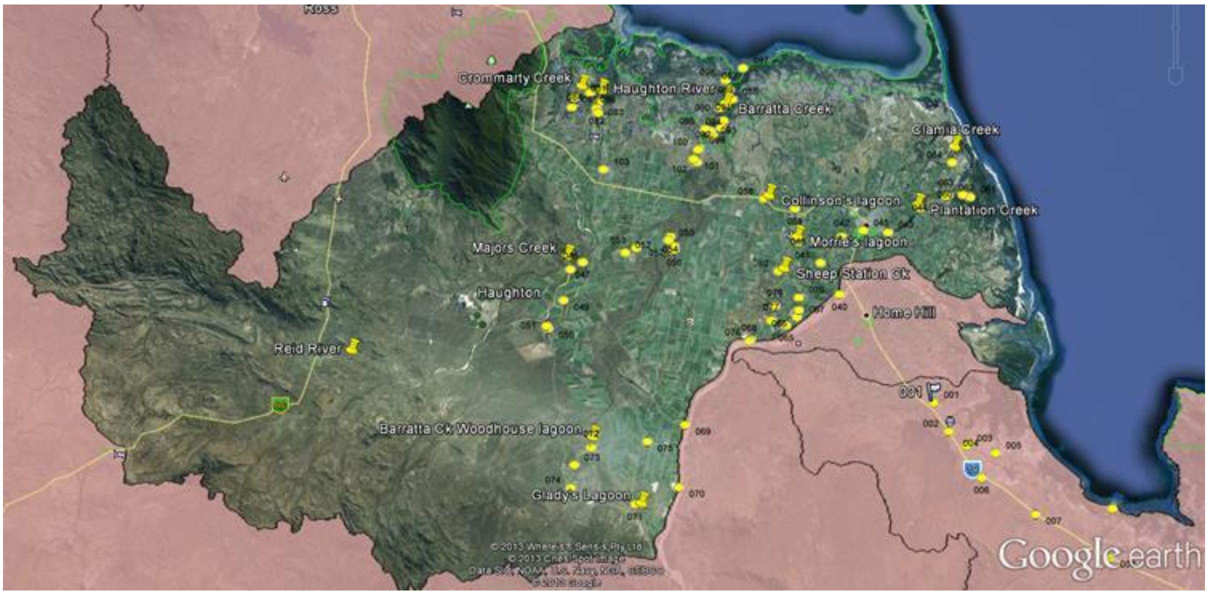

Figure 1.1.2: A map showing the Haughton basin, with yellow dots indicating assessment sites

Social and economic values of the Haughton basin include recreation (boating, swimming and tourism), irrigation, stock watering, human consumption of aquatic food, and the cultural and spiritual values of Bindal and Jiru Traditional Owners.[2] The adjacent waters are also home to the Yongala shipwreck, an important dive site for local tourism and home to bountiful marine flora and fauna.

Over 700,000 people visit the Great Barrier Reef in the Townsville/Whitsunday region annually. These visitors contribute financially to the local communities and the tourism industry. There were 3420 recreational vessels (motorboats, speedboat, personal watercraft and sailboats) registered in the Burdekin Shire council as of December 2012.

The inshore coastal receiving waters adjacent to the Haughton basin are influenced by the flows from the river and estuary systems in the basin and also from the Burdekin River. Discharges from the Burdekin River are mostly carried northwards by the prevailing trade winds and it is thus difficult to attribute inshore coastal water quality measurements to specific Haughton basin waterways, except where monitoring has occurred at the river mouths.

The mean annual rainfall for the catchment for the 50 year period 1920 to 1969 varies between 750 mm and 1300 mm across the basin. The area experiences occasional cyclones and highly variable rainfall predominantly in summer. This rainfall occurs mostly in coastal areas delivering sediments, nutrients and pesticides to the inshore and sometimes offshore parts of the Great Barrier Reef in pulsed flows.

The Haughton basin has a long history of agricultural development, including cane, rice and horticulture (Table 1.1.1). The dominant land use in the Haughton basin today is grazing (in the upper catchment), followed by irrigated agriculture (sugar) in the lower basin. There is 64,576 hectares of protected areas, mostly within the Bowling Green Bay Ramsar wetlands. The main settlements in this basin are Ayr, Giru, Brandon, Alva beach and Cungulla. Because of the intensive land, fishing and water resource development, many of the creeks and wetlands have been highly modified from their original state.

Historically, land clearing was promoted by the Commonwealth and Queensland governments as part of promoting productivity and national economic prosperity. Incentives for agricultural development (such as post war settlement schemes) increased the rate of land clearing, with offerings of cheap land, loans or tax concessions.[7]

The Haughton River basin contains the largest area of irrigated cane land and high nitrogen fertiliser application rates. The Haughton basin forms part of the Burdekin delta that overlies a shallow groundwater aquifer which is hydrogeologically linked to wetlands, waterways, estuaries and the World Heritage Area. Consequently, agricultural expansions have had detrimental impacts on the function of coastal wetlands. Excessive water extraction has been occurring for almost a century and saltwater intrusion is a concern in the region. During low flow conditions and flood events, over 20 different herbicides have been detected, the majority of which are associated with the sugar cane industry. The dominant herbicides in the Haughton River basin are diuron, atrazine, hexazinone and ametryn. Monitoring of coastal waters within the Great Barrier Reef lagoon has shown that 80 per cent of the time more than one herbicide was present. Diuron samples from the Haughton River basin have been found to exceed the Great Barrier Reef water quality guidelines (Appendix G).

Table 1.1.1: Historical timeline for the Haughton basin[4, 7]

Year	Event
1870	Pastoral land resumed for sugar in the region.
1882	Town of Brandon established.
1882	Town of Ayr established.
1883	First crushing mills, discovery of bore water in Ayr.
1884	Kalamia and Pioneer Mills (Sheep Station Creek) open.
1886	Sugar industry held back by annual droughts and dry spells until irrigation advances through development of 'Haughton tube'.
1901	Tramway opened to Townsville from Ayr.
1903	Cyclone Leonta (9/3/1903) destroyed most of Ayr.
1904	Small dairy opened in Ayr.
1906	Cane first harvested in Giru.
1913	Ayr connected by railway to Bowen.
1920s	Expansion of the sugar industry.
1921	Town of Giru established.
1950s	Bore water used to supply homes but purity endangered by household pollution.
1950s	Widespread clearing of parts of the basin promoted by the government of the time.
1960s	The Brigalow scheme introduced by the state government to give returning soldiers land to clear and establish farms on.
1960s	New water supply pumped from Racecourse Reserve and reticulated.
1960s	Rice and mangoes introduced. Home Hill rice mill opened in 1968.
1965	Northern Burdekin Water Board established to address groundwater salinity problems caused by over extraction of groundwater.
1970s	Giru Weir built in the Haughton River.
1978	Claire Weir constructed on the Burdekin River.
1980	Queensland Parliament authorised the establishment of the Burdekin River Project to supply and irrigate the lower Burdekin floodplain.
1983	Val Bird Weir constructed across the Haughton River near Giru, causing the watertable in Giru to rise by 7-8m to 2-3m below ground level.
1987	Burdekin Dam started filling driving expansion of sugar. Dam opened in 1988.
1988	Burdekin Dam opened, allowing great expansion of the sugar industry, mitigating flooding and provided controlled refilling of the watertable for irrigation.
1988	Townsville/Thuringowa Water Supply Board (NQ Water) completed construction of a pumping station and pipeline from the Haughton balancing Storage to the headwaters of Ross River Dam near Townsville.
1980s -90s	Burdekin Haughton Water Supply Scheme created to drive irrigated production in the region.

Chapter 2: Values and their current condition and trend

The values that are considered in this report include:

- Inshore marine ecosystems that underpin the outstanding universal value of the World Heritage Area (such as coral reefs, seagrasses and associated species).
- Terrestrial, freshwater and estuarine coastal ecosystems that provide ecological functions to the World Heritage Area and other matters of national environmental significance.

A conceptual model of these ecosystems and the functions they provide is shown in Figure 2.1.

The ecosystems examined in this report also provide habitat for a range of other matters of national environmental significance.The matters of national environmental significance in the Haughton basin are outlined in Section 2.1 below and the values and their elements that underpin matters of national environmental significance for the Haughton basin and adjacent waters are shown in Appendix C.

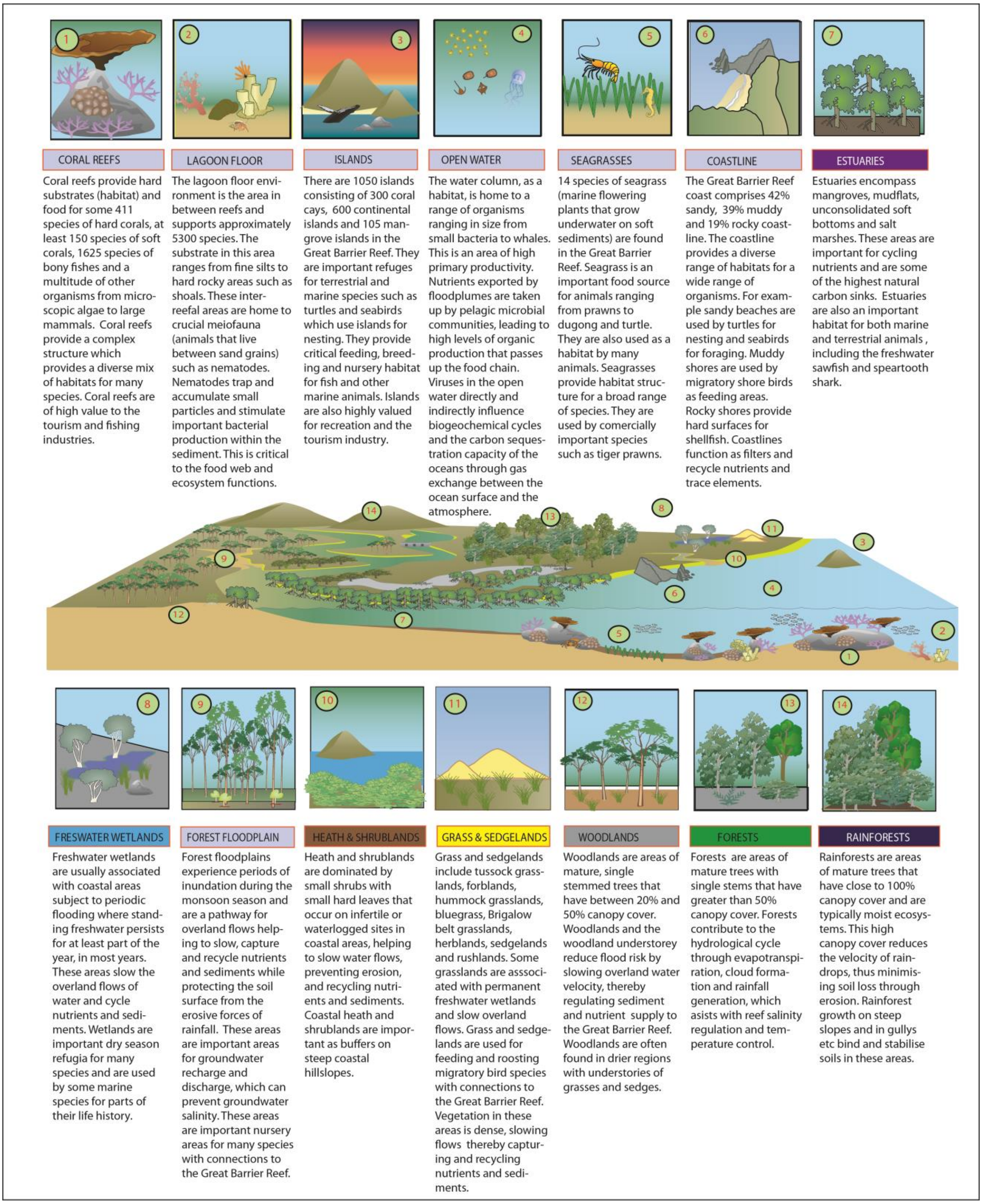

Figure 2.1: Conceptual model for categorizing the Great Barrier Reef coastal, catchment and inshore ecosystems and assessing the ecological functions and functions of those ecosystems to the cumulative impacts of development

2.1 Matters of National Environmental Significance in the basin

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), actions that have, or are likely to have, a significant impact on a matter of national environmental significance require referral to the Australian Government Environment Minister. The Minister will decide whether assessment and approval may be required under the EPBC Act. There are eight matters of national environmental significance protected under the EPBC Act. These are:

- World heritage properties
- National heritage places
- Wetlands of international importance (listed under the Ramsar Convention)
- Listed threatened species and ecological communities
- Migratory species protected under international agreements
- Commonwealth marine areas
- The Marine Park
- Nuclear actions (including uranium mines).

There are also a number of species that are not listed under the EPBC Act, including the snubfin dolphin, which is of concern because of its limited home range.

World heritage properties

The Great Barrier Reef was inscribed in the World Heritage List in 1981 and meets all four natural criteria. Parts of the Haughton basin to mean low water and all of the adjacent marine areas fall within the World Heritage Area.

National heritage properties

The EPBC Act provides for the listing of natural, historic or Indigenous places that are of outstanding national heritage value. Within the Haughton basin only the Great Barrier Reef is listed as a National Heritage Property (for its natural values).

Wetlands of international importance (declared Ramsar wetlands)

The Haughton basin contains part of the Bowling Green Bay Ramsar site which was listed on the Wetlands of International Importance (Ramsar sites) in 1993. Bowling Green Bay contains examples of the richest coastal habitats typical of north-east Australia's coastal wet-dry tropics.[3] The key biodiversity and conservation values of Bowling Green Bay include:

- 25 threatened species
- One threatened community
- 26 migratory species
- Very high species richness
- Very high endemism
- Bowling Green Bay Ramsar wetland
- Seven nationally important aquatic ecosystems
- Native vegetation present.[3]

The Bowling Green Bay Ramsar site is a diverse complex of coastal wetland systems formed on four broad physiographic types, those being:

- Mountainous areas of Cape Cleveland and Feltham Cone
- The elevated parallel dune systems
- The lower lying parts of the coastal plain
- The actively prograding sand spit of Cape Bowling Green.[1]

Over most of the site, coastal mangrove communities give way inland to the highly saline communities of the salt pans which in turn lead to the brackish and freshwater communities of the lower lying coastal plain further inland. These lowland areas are typified by communities whose dominant ecological characteristic is a tolerance of saline conditions. Extensive areas of forest and woodland, and some closed forest, occur on the mountainous areas, riverine galley forests and the coastal dune system.

Around 75 per cent seafood production is linked to the ecological functions provided by estuaries.[8] The Haughton basin is the fifth largest estuary in the Great Barrier Reef catchment making up eight per cent of the extent of estuaries. The estuaries in the Haughton basin support a large commercial and recreational fishery in addition to food resources for listed threatened species, such as the Australian snubfin dolphin.

Listed threatened species

Seven species of birds, one species of frog, eight species of mammal, nine species of plant and seven species of reptiles have been identified as listed threatened species within the Haughton basin and adjacent waters. A list of these can be found in Appendix D.

Ecological communities

Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions communities have a status of Endangered, and are considered likely to occur within the Haughton basin.

Listed migratory species

The EPBC Act lists migratory species which includes those species listed in the:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- China-Australia Migratory Bird Agreement (CAMBA)
- Japan-Australia Migratory Bird Agreement (JAMBA).

The wetlands in this region represent important habitat for some 50 per cent of the species listed in the Japan-Australia Migratory Bird Agreement (JAMBA), Chinese-Australian Migratory Bird Agreement (CAMBA) conventions and the Bonn Convention.[9] The shallow sedge swamps and salt pan areas are used for breeding and foraging by large populations of brolga and magpie geese. Thirty-five species of bird, two species of mammal and seven species of reptile are listed migratory species found in the Haughton basin. These are listed in Appendix E.

The Great Barrier Reef Marine Park

The Marine Park is recognised as a matter of national environmental significance under the EPBC Act to enhance the management and protection of the ecosystems in the Great Barrier Reef Region. The *Great Barrier Reef Marine Park Zoning Plan 2003* (the Zoning Plan) is the overarching plan that provides for a range of ecologically sustainable recreational, commercial, and research opportunities and for the continuation of traditional activities. Each zone has different rules for the activities that are allowed (as of right), prohibited, and those that require permission. Zones may also place restrictions on how some activities are conducted.

2.2 Other protected areas and values in the basin

Although not matters of national environmental significance, there are other areas within the Haughton basin that have intrinsic values and may also have significance for the long-term health and resilience of the World Heritage Area as detailed below.

Dugong Protection Areas

Dugong Protection Areas A and B occur in the coastal waters of the Haughton basin (Figure 2.2.1). Zone 'A' Dugong Protection Areas include significant dugong habitats in the southern Great Barrier Reef (consistently contains over 50 per cent of dugong numbers). In these areas, the use of offshore set, foreshore set and drift nets are prohibited. The use of river set nets is allowed with modifications in Zone 'A' Dugong Protection Areas. Other netting practices such as ring, seine, tunnel and set pocket netting which are not considered to pose a serious threat to dugong are unaffected.

In Zone ‘B' Dugong Protection Areas mesh netting practices are allowed to continue, but with more rigorous safeguards and restrictions than before. Zone ‘B’ Dugong Protection Areas have been shown to contain about 22 per cent of dugongs in the southern Great Barrier Reef. These measures are being kept under review to ensure protection of dugongs in these areas. These are mapped, along with Nationally Important Wetlands, Conservation Parks, National Parks, Forest Reserves, Nature Reserves and Fish Habitat Protection areas in Figure 2.2.1.

Nationally important wetlands (Directory of Important Wetlands in Australia)

Nationally important wetlands in the Haughton basin include:

- Barratta Channels Aggregation
- Bowling Green Bay
- Burdekin - Townsville Coastal Aggregation
- Burdekin Delta
- Great Barrier Reef Marine Park
- Haughton Balancing Storage Aggregation
- Jerona Aggregation
- The Serpentine Aggregation
- Wongaloo Fans Aggregation (Cromarty wetlands)
- Wongaloo Swamps Aggregation.

These are mapped, along with Conservation Parks, National Parks, Forest Reserves, Nature Reserves and Fish Habitat Protection areas in Figure 2.2.1.

Conservation parks, national parks and forest reserves

There are 5 protected areas within the Haughton basin:

- Bowling Green Bay Conservation Park
- Bowling Green Bay National Park
- Horseshoe Lagoon Conservation Park
- Mingela State Forest
- Mount Flagstone Forest Reserve.

These are shown in Figure 2.2.1.

Fish Habitat Areas

Declared fish habitat areas (FHA) are areas protected under the *Fisheries Act 1994* (Qld) against physical disturbance associated with coastal development and are selected on the basis of their respective values. There are two fish habitat areas in this area – Bowling Green Bay and Burdekin (Table 2.2.1, Figure 2.2.1).[5]

Table 2.2.1: Fish Habitat Areas located in the Haughton basin

FHA	Location	Habitat Values	Fisheries Value	Unique Values
Burdekin (declared in 1999)	Ten kilometres east of Ayr and Home Hill and is approximately 92,000 hectares in size	Extensive mangrove communities containing approximately 20 mangrove species, dominated by *Rhizophora*, *Avicennia* and *Ceriops* species and *Xylocarpus mekongensis*; dense seagrass meadows – at least eight species of seagrass recorded; extensive saltpans.	Commercial and recreational fishing grounds for barramundi, grunter, flathead, mullet, mackerel, shark, whiting, mangrove jack, queenfish, bream, dart, trevally and jewfish. Prawns and mud crabs.	
Bowling Green Bay (declared in 1989)	Bowling Green Bay south of Townsville and is approximately 68,600 hectares in size.	Closed *Rhizophora* and *Ceriops* dominated mangrove stands with extensive areas of salt marsh, sparse seagrass beds within the bay, exposed banks and freshwater lagoons.	Major barramundi nursery habitat; area identified as important to the food chain of offshore billfish fishery; barramundi, blue salmon, bream, estuary cod, flathead, grey mackerel, grunter, mangrove jack, queenfish, school mackerel, whiting, tiger and banana prawns.	Declared to conserve commercial and recreational fishing grounds and resources and as important dugong and loggerhead turtle habitat. Adjacent to Bowling Green Bay RAMSAR wetlands, freshwater lagoons immediately upstream.

Nature refuges

A nature refuge is a class of protected area under the *Nature Conservation Act 1992* that acknowledges a commitment to manage and preserve land with significant conservation values while allowing compatible and sustainable land uses to continue. Although a nature refuge agreement may be entered into voluntarily, a nature refuge agreement is legally binding. There are two nature refuges in the Haughton basin, the Corrick Plains Nature Refuge and Serpentine Nature Refuge. These are shown in Figure 2.2.1

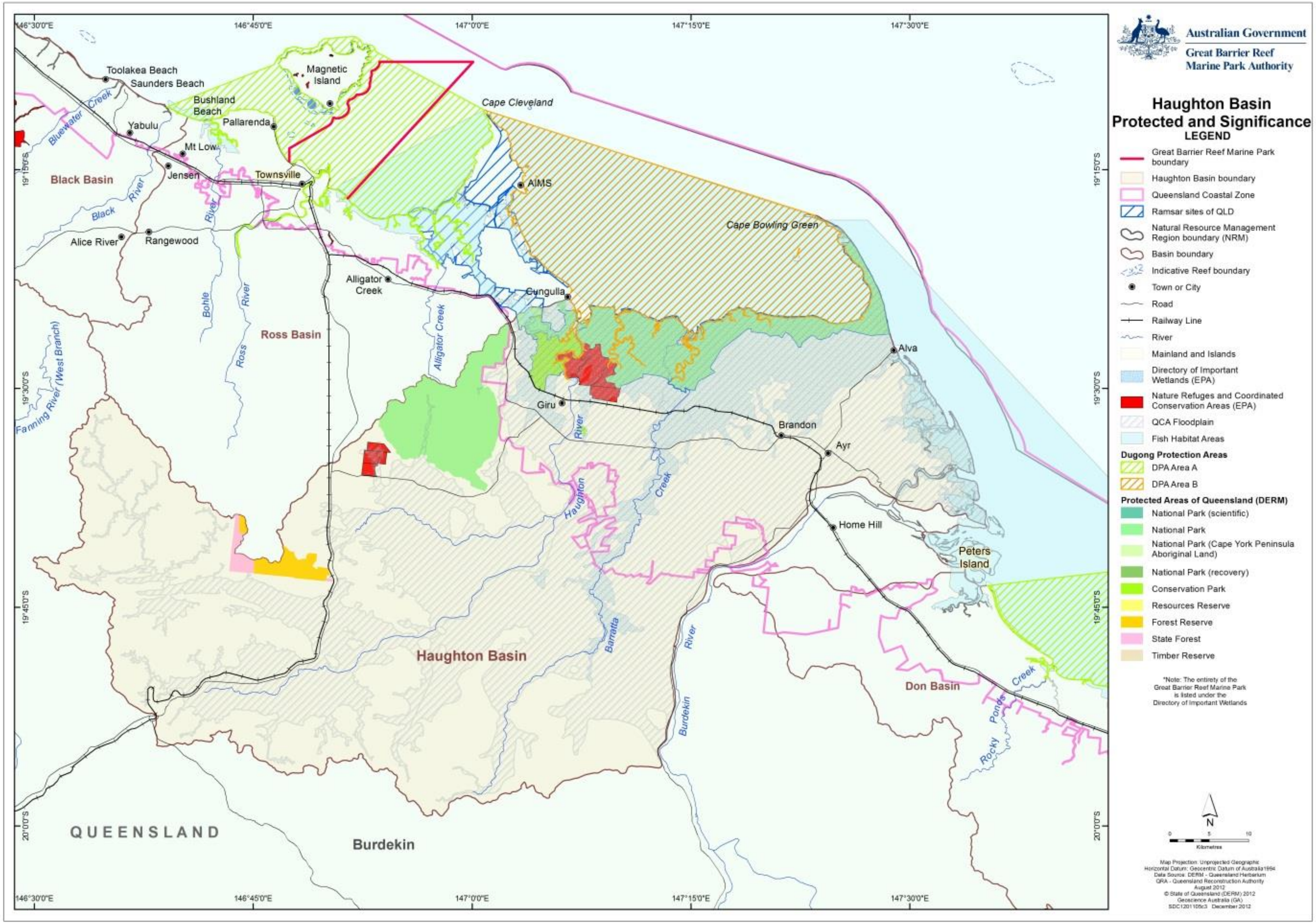

Figure 2.2.1: This map shows the spatial extent of some values in the Haughton basin that may underpin matters of national environmental significance, including World Heritage Properties, National Heritage Properties, Ramsar wetlands, Nationally Important wetlands, National Parks, Conservation Parks, forest reserves, Fish Habitat Areas and Nature Refuges

2.3 Coastal ecosystems

The Great Barrier Reef inshore ecosystems are made up of many complex components, including estuarine and marine ecosystems such as mangroves, seagrasses and inshore coral reefs, which are closely linked to adjacent coastal ecosystems. These include coastal freshwater wetlands, coastlines and forested floodplains (Figure 2.3.1). These coastal ecosystems are interconnected and reliant on one another for their ongoing health and resilience. Species that form part of the amazing biodiversity of the Marine Park live in and move between these ecosystems throughout their life cycles.

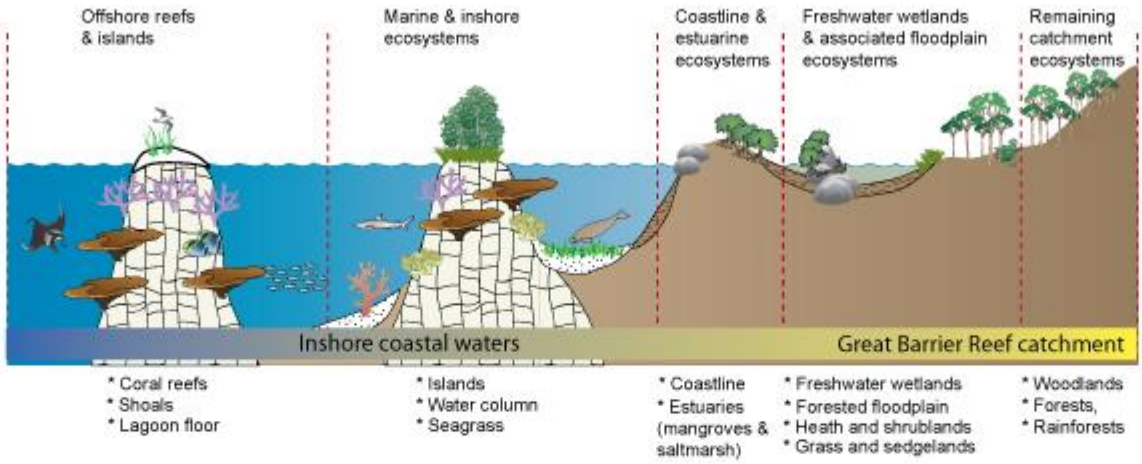

Figure 2.3.1: Broad groupings of coastal ecosystems illustrating the general level of importance for the ongoing health and resilience of the Great Barrier Reef

Coastal ecosystems are not easily separated and defined, as functionally they are all connected one way or another. Each component provides specific ecological functions that together make up and support the health and resilience of the ecosystem as a whole.

Inshore marine coastal ecosystems

The inshore coastal waters adjacent to the Haughton basin are home to a range of marine flora and fauna, many of which are matters of national environmental significance. These include marine turtles, migratory marine mammals and whale sharks, which have been recorded at the Yongala shipwreck dive site. Figure 2.3.2 shows the bioregions in the area that were used as the basis for the Great Barrier Reef Marine Park Authority Zoning Plan. Figure 2.3.3 shows the Marine Park Zoning Plan.

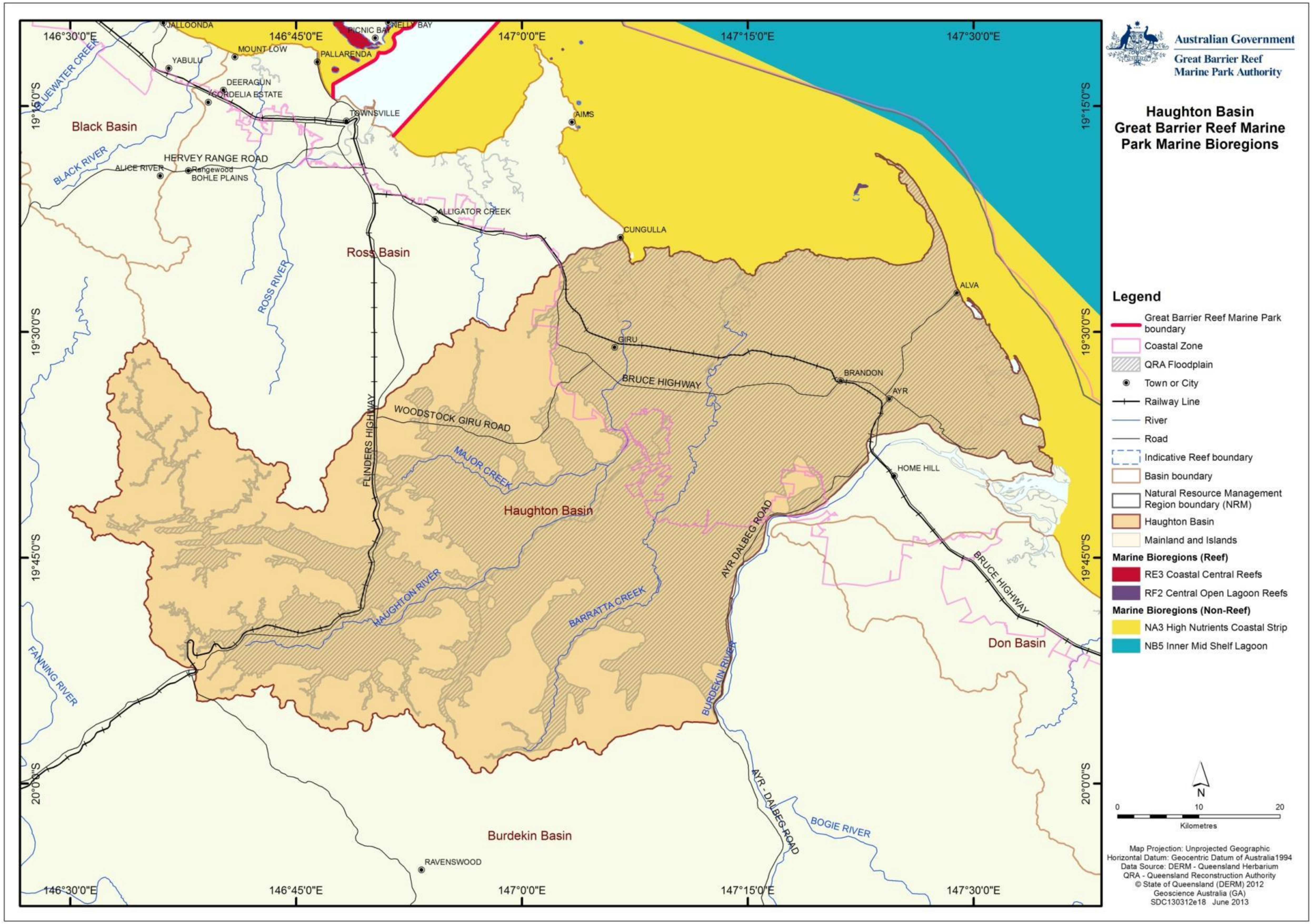

Figure 2.3.2: Marine bioregions adjacent to the Haughton basin

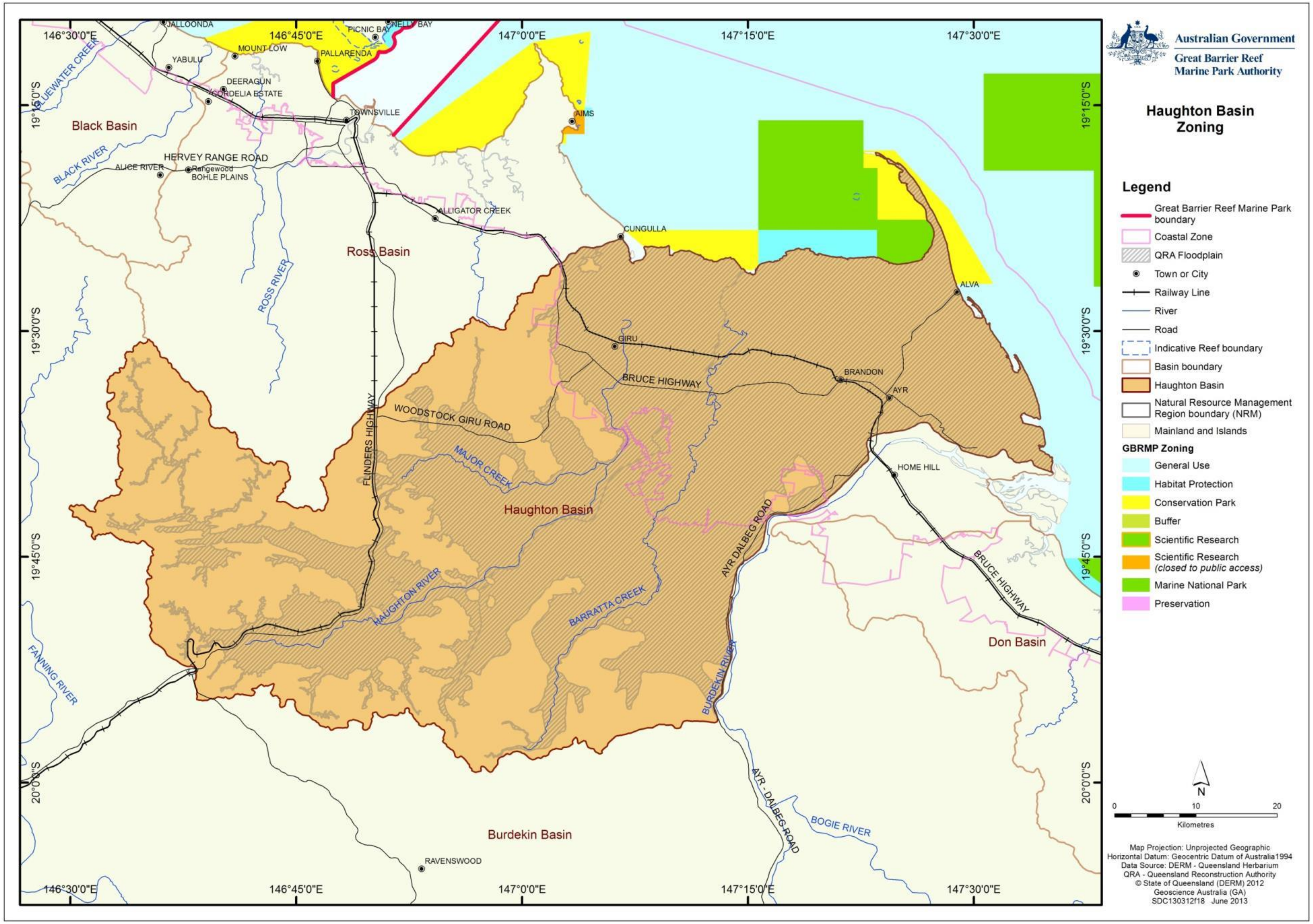

Figure 2.3.3: Zoning within the Marine Park adjacent to the Haughton basin

Flood plumes from the Haughton and adjacent basins in this region have been shown to reach beyond the Great Barrier Reef. At risk of exposure to one or more water quality concerns (sediments, nutrients or pesticides) is 207,982 hectares of coral reefs, 58,605 hectares of seagrass beds and extensive areas of seabed.[10]

Flood plumes have been extensively studied within the lower Burdekin region; however emphasis has been placed on discharge from the Burdekin River.[11] Monitoring of the extreme wet season floods from December 24, 2010 – January 18, 2011, resulted in highly elevated discharge from the Burdekin River into the World Heritage Area for more than 200 days. Prior to the extreme flood event smaller plumes were already observed off the Haughton River and Barratta Creek mouths, which were still present on the 4th of January, 2011 (Figure 2.3.4).[11]

During peak conditions the Burdekin River extended more than 50 kilometres offshore and spread 100 kilometres north of the river mouth.

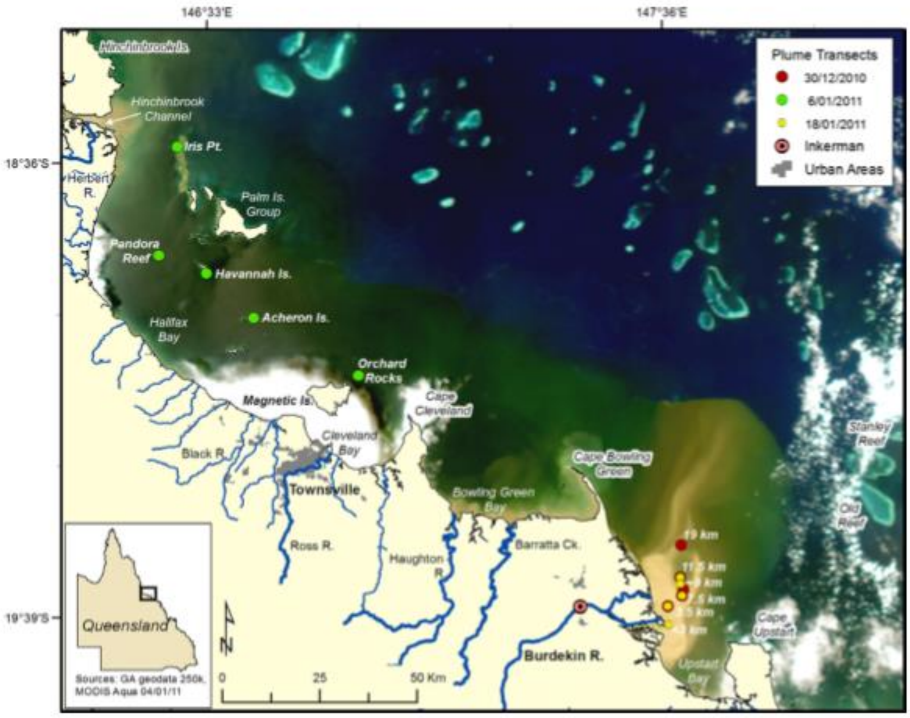

Figure 2.3.4: Flood plume sampling map superimposed on a MODIS satellite image of the Burdekin River flood plume captured on the 4th January, 2011. The turbid inner plumes from the Haughton River, Barratta Creek and the Burdekin River are clearly visible along the coast adjacent to the river mouths

Output from the rivers of the lower Burdekin region is the largest contributor of sediments to the Great Barrier Reef and a large portion of this output is trapped in the eastern portion of Bowling Green Bay.[12] The dry season dynamics of the shallow coastal waters in Bowling Green Bay were modelled by Wolanski and Ridd (1990) and revealed that the tidal dynamics in the shallow waters of the bay generate coastal trapping and waters are poorly flushed during the dry season.[13] The estuaries in Bowling Green Bay have a water residence time in the order of several weeks,[14] making Bowling Green Bay a pollutant trap that could potentially impact ecosystem function and services.[15]

Seagrass meadows occur in the waters adjacent to the Haughton basin. Due to the poor water clarity of coastal waters in this region, seagrass monitoring is limited. Intertidal seagrass mapping is conducted under the Reef Plan Marine Monitoring Program (MMP) and also by the Queensland Government (ad hoc).

Seagrass monitored under the MMP further north showed seagrass has declined at coastal locations and is variable at reef locations. Seagrass extent, health (reproductive effort) has been in decline over the last five years and results showed low numbers of reproductive structures indicating reduced resilience to disturbance.[16,17]

Intermittent seagrass mapping undertaken by the Queensland Government over a thirty year period is shown in Figure 2.3.5. Both Cleveland Bay to the north and Edgecombe Bay to the south (with comparable conditions to Bowling Green Bay) interestingly have more extensive seagrass meadows.

Figure 2.3.5: Cumulative seagrass mapping conducted by the Queensland Government

In 2009, the Reef Water Quality Protection Plan baseline report stated that the inshore reefs in the Burdekin region were in poor condition. There was concern about the lack of recovery of these reefs as there had been no obvious natural disturbances since they were impacted by coral bleaching in 2002. Settlement of coral larvae had been very poor and the numbers of juvenile corals were also poor, which may have been due to low coral cover limiting the availability of coral larvae.[8] Since then these reefs have been impacted by Tropical Cyclones Hamish (March 2009) and Yasi (February 2011). Tropical Cyclone Yasi also removed much of the coral off the Yongala shipwreck.

Dugong numbers for Bowling Green Bay have declined in recent times. Table 2.3.1 shows dugong numbers in two adjacent comparable bays - Bowling Green Bay and Cleveland Bay to the north.[18] There has been a significant decline in dugongs in Bowling Green Bay since 1999.

Table 2.3.1: Dugong numbers for Bowling Green and Cleveland Bays. TFE= too few to estimate

Site	1987	1992	1994	1999	2005	2011
Bowling Green Bay	136	58	54	270	TFE	TFE
Cleveland Bay	360	106	183	361	211	TFE

Changes to coastal ecosystems

Much of species and ecosystem diversity has been reduced in the Haughton basin, due to development of land and water resources which modify or remove ecosystems, and the introduction of monoculture. Significant changes include:

- Broadscale clearing of forests, forested floodplains, grass and sedgelands and infilling of freshwater wetlands.
- Intensive development of irrigated agriculture, with perennial water supplies drawn from the adjoining Burdekin River and supplied to the Haughton basin floodplain via large constructed channels supplementing flows and groundwater recharge within the floodplain distributary channel systems.
- Introduction of pasture grasses that have changed the flora biodiversity and the fire regime. These African and South American grasses burn hotter causing significant changes to ecological processes including habitat loss and erosion of soils. The risks to biodiversity can be reduced through introduction of controlled grazing.
- Aquatic biodiversity has declined in some parts of the basin as a result of landscape changes and land use. Irrigated cropping is the dominant land use on the floodplain which has also had the greatest impact on aquatic biodiversity.
- Broadscale changes to overland and underground hydrology through river straightening and groundwater management for irrigation. These have reduced habitat for terrestrial and in-stream biodiversity. Changes to the seasonality of water flows are further impacting on both aquatic and terrestrial biodiversity.
- Introduced fauna – feral pigs, tilapia and other introduced fish species and introduced flora – hyacinth, hymenachne and other aquatic and terrestrial weeds.

Changes in land use have left ongoing legacy issues (such as ponded pastures), which continue to impact on the life history of local aquatic and terrestrial species with connections to the Reef (such as migratory fish and migratory birds), leading to an ongoing decline in species diversity due to reduced resilience.

In pre-European times, the Haughton basin was dominated by forests and woodlands (Figure 2.3.6). Since European settlement, these forested areas were thinned for grazing and later cleared for irrigated intensive agriculture (in some areas) (Figure 2.3.7).

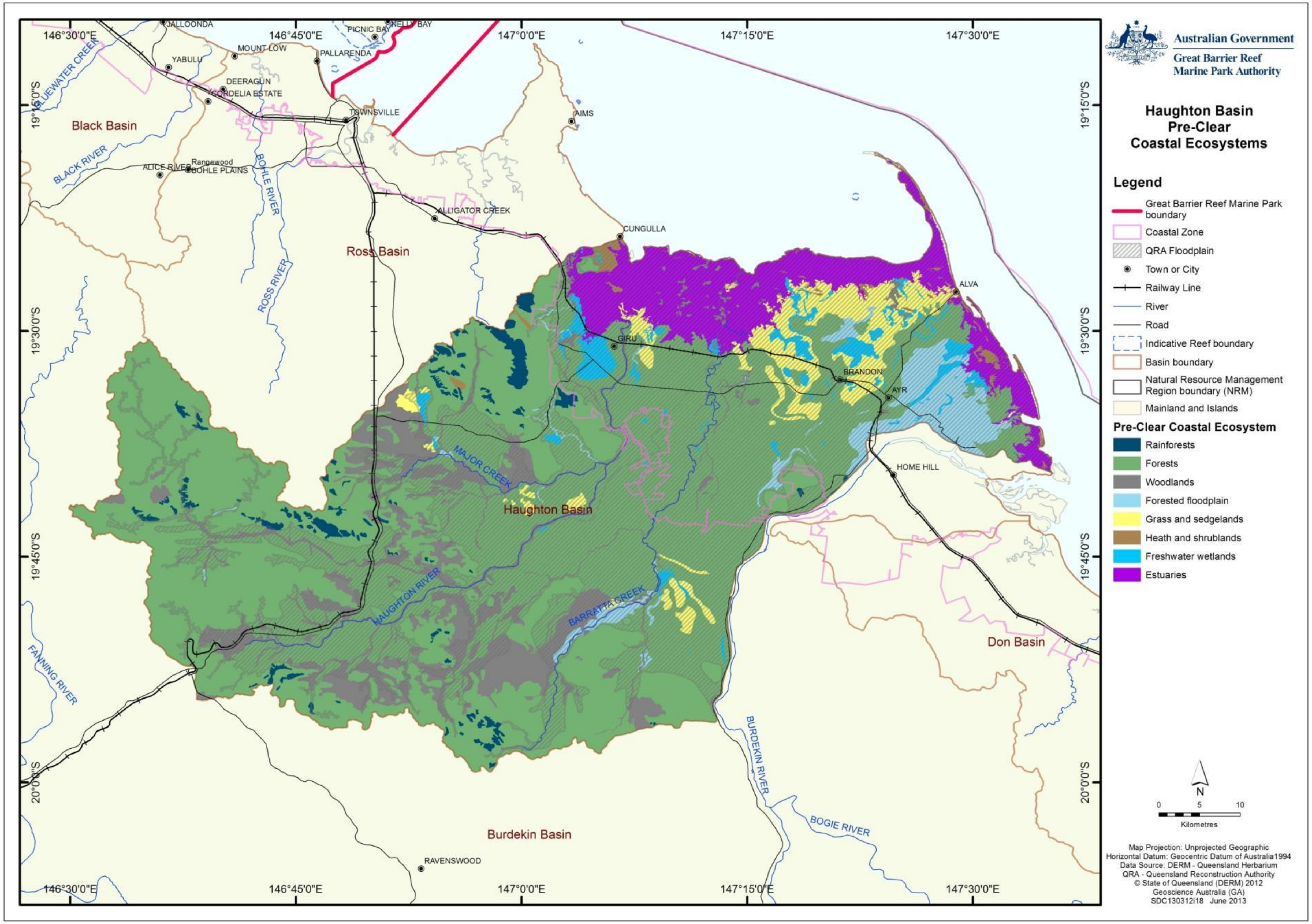

Figure 2.3.6: This map shows the pre-clear coastal ecosystems in the Haughton basin

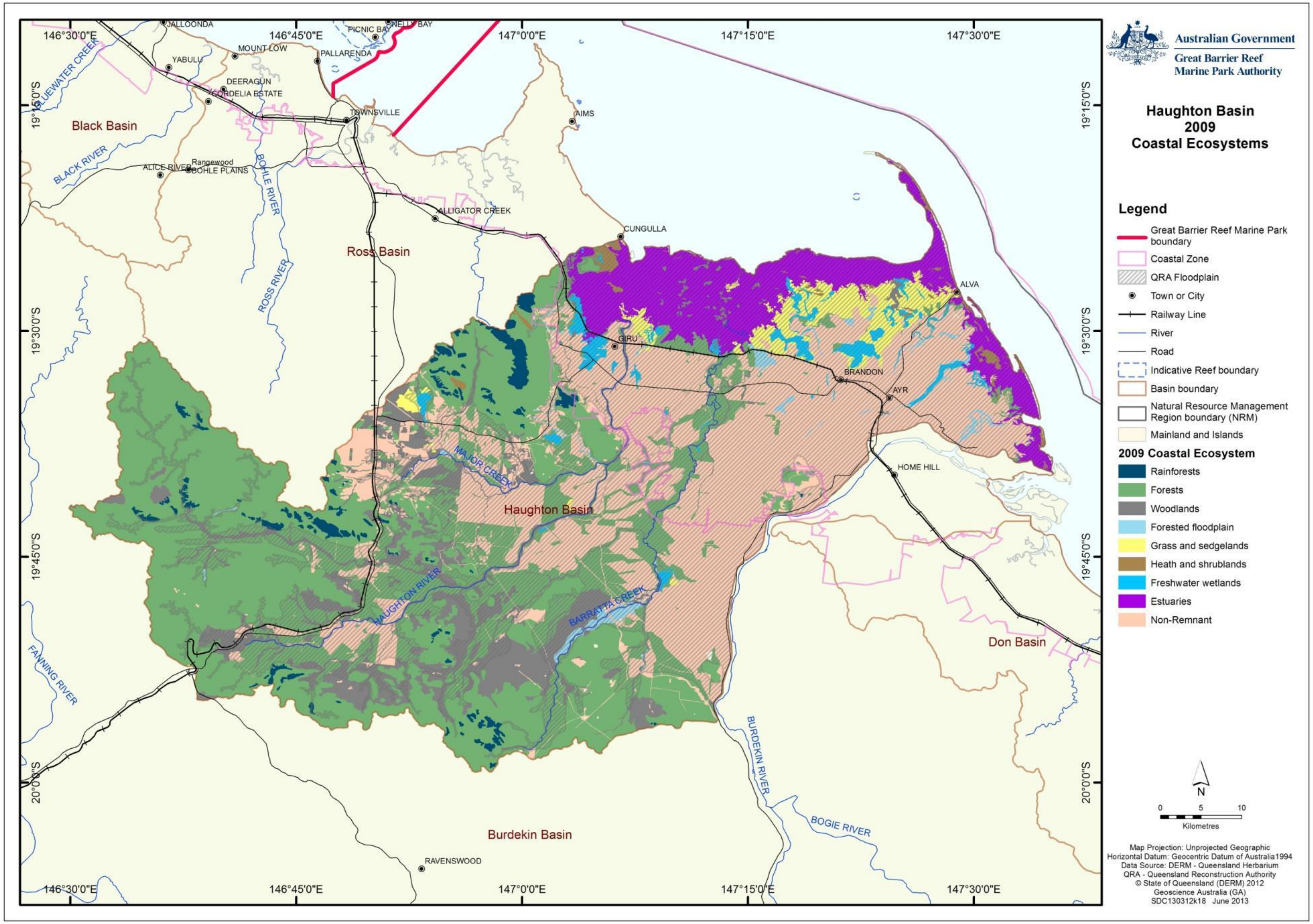

Figure 2.3.7: This map shows the post-clear coastal ecosystem assemblages in the Haughton basin (derived from 2009 Queensland Government Regional Ecosystem data)

The changes to coastal ecosystems (Table 2.3.2) show that the greatest proportion of modification in terrestrial coastal ecosystems has occurred to forested floodplains (loss of 75 per cent), grass and sedgelands (loss of 43 per cent), forests (loss of 36 per cent) and freshwater wetlands (loss of 32 per cent).

Table 2.3.2: Area (ha) of pre-clear and post-clear coastal ecosystems based upon Queensland Government Regional Ecosystem mapping

	Ecosystem	Pre-clear	2006	2009	% remaining
	Rainforests	7,077	6,924	6,924	98
	Forests	271,805	173,427	173,109	64
	Woodlands	47,322	40,621	40,592	86
	Forested floodplain	14,254	3,494	3,494	25
	Grass and sedgelands	18,537	10,647	10,647	57
	Heath and shrublands	2,478	2,383	2,374	96
	Freshwater wetlands	9,348	6,359	6,359	68
	Estuaries	33,266	33,112	33,112	100
	Non Remnant	0	126,950	127,307	N/A
	Not Mapped	700	870	870	N/A

Coastline and estuarine coastal ecosystems

Estuaries are highly productive fish nursery areas providing a range of ecological functions for species with connections to the Reef. Animals such as prawns, crabs and many popular commercially and recreationally fished species (such as barramundi and mangrove jack) use estuaries for part of their life history. The coastline of the Haughton basin consists of low profile estuarine deltas (made up of mangroves and mudflats) interspersed with lengths of sandy beaches, dunes and nearshore sand bars. There are two coastal settlements – Cungulla and Alva Beach within the Haughton basin. The settlement of Jerona sits within the Barratta Creek estuary.

On the northern side of the Haughton River mouth is Cungulla, a small low lying coastal settlement on the river delta. The river delta flows behind Cungulla, on the south west side of the settlement and to the west. On the north east of the town is a sandy beach that is currently accreting to the north and south and eroding in the central area. The residents with beach front properties in this area have installed illegal groynes constructed from old tyres and concrete.

The coastline south of the Haughton basin remains relatively unmodified (Figure 2.3.8). The coastal settlement of Alva resides behind coastal dunes with walking paths leading to the beach. There are no impediments to natural coastal processes in this part of the basin.

Figure 2.3.8: Bowling Green Bay looking northwards towards Cape Cleveland showing the extensive tidal flats that are important to many aquatic estuarine species

The coastline and estuarine coastal ecosystems of the Haughton basin are significant habitats for matters of national environmental significance including threatened and migratory species.

The extent of estuaries in the Haughton basin has remained relatively unchanged according to Queensland Government Regional Ecosystem mapping (Table 2.3.2). There are six estuarine ecosystems in the Haughton basin (Table 2.3.3) that experience a tidal range of around four metres. These estuaries represent areas of high terrestrial and aquatic biodiversity as shown by their listing as part of a Ramsar wetland.

Table 2.3.3: Australian Natural Resource Atlas (ANRA) classification of estuaries for the Haughton basin

Name of estuary	Class	Sub-class	Condition
Barramundi Creek	River Dominated	Tide-Dominated Delta	Largely Unmodified
Haughton River	River Dominated	Tide-Dominated Delta	Modified
Estuary Q195	Tide Dominated	Tidal Flat/Creek	Largely Unmodified
Barratta Creek	River Dominated	Tide-Dominated Delta	Modified
Mud Creek	Wave Dominated	Strandplain	Largely Unmodified
Plantation Creek	Wave Dominated	Strandplain	Largely Unmodified

The condition of the six estuaries in the Haughton basin was assessed by the Australian Natural Resources Atlas in 2000.[19] None of these estuaries were identified as being in pristine condition. The Haughton River and Barratta Creek (Figure 2.3.9) were found to be modified (indicating modification of coastal ecosystems in the vicinity of the system) while the remainder were found to be largely unmodified.[6]

Figure 2.3.9: Photos of the Barratta Creek estuary taken in October 2012. The Barratta Creek distributary network is a great example of a healthy estuarine coastal ecosystem with a mix of mangrove species (left) and healthy functional saltmarshes (centre). Natural eroding and accreting banks (right) provide good examples of the dynamic nature of this type of system

Although the estuaries in the Haughton basin are reported to be largely unmodified,[19] barriers (bund walls) to encourage pasture grasses for grazing have been installed in the saltmarsh/saltpan areas (including 18 barriers in the Bowling Green Bay Ramsar wetlands) and in the transitional areas between the estuaries and former freshwater wetlands.[7]

Freshwater wetlands and associated floodplain coastal ecosystems

Wetland form and health is variable between the wetlands of the Haughton basin and they show high variability in biodiversity. The wetlands change in physical form and vegetation assemblage according to their proximity to the coast, landform and dominant hydrological regime. They range from shallow depressions to oxbows or channels. Some are in near natural condition, others have become part of the irrigation distribution network.[9]

The upper Haughton River is a seasonally dry, sandy watercourse with few permanent waterholes. Its major tributaries contain several significant waterholes and wetlands. The Haughton River floodplain also contains one of the greatest concentrations of wetland habitat in the entire Burdekin region.[2] Several areas of the Haughton basin have been identified as containing High Ecological Value (HEV) waters including the upper section of the Reid River, the southern and western slopes of the Mount Elliott section of Bowling Green Bay National Park and the coastal freshwater and estuarine wetlands contained within Bowling Green Bay National Park.[20]

Bowling Green Bay National Park lies within in the Haughton basin floodplain. Bowling Green Bay National Park is a 57,900 hectare national park that is recognised internationally as a Ramsar wetland (one of only two Ramsar listed wetlands in the World Heritage Area).[21] It forms one of tropical Australia's largest and most diverse coastal wetlands. Many rare and threatened species live in or visit the wetlands. The bay has many wetland types and is an important home for fish, dugongs, crocodiles, green turtles and migratory birds.[2]

The high rates of productivity in these wetlands in turn support productive inshore marine ecosystems. Extensive baitfish breeding occurs within Bowling Green Bay and this supports important bill (black marlin and sail fish), pelagic fisheries (Spanish mackerel and other predatory species) and coastal inshore fisheries (barramundi and mangrove jack).[3] The intertidal and subtidal seagrass beds of both Bowling Green and Cleveland Bays provide feeding habitat for the threatened herbivores dugong, *Dugong dugon* and green turtle, *Chelonia mydas* and are nursery areas for prawns and mudcrabs. Commercial and recreational harvesting of prawns and mud crab, *Scylla serrata* within Bowling Green Bay and adjacent marine areas is based on the productivity of the local wetland communities. The importance of the Bowling Green Bay wetlands as a fish habitat has been recognised with the protection of the entire bay as a declared Fish Habitat Area.[3]

The Queensland and Australian governments, through the Queensland Wetlands program, has mapped wetlands within the Haughton basin at a finer scale than the current Regional Ecosystems mapping (Table 2.3.4).[22] Through this mapping, approximately 694 lacustrine/palustrine wetlands were identified in this basin.

Table 2.3.4: Queensland Wetlands Program data for the freshwater and estuarine wetlands of the Haughton basin

System as defined by Queensland Wetlands Program	Area (km^2)	Wetlands area (%)	Total area of basin (%)
Artificial and highly modified	14.42	2.5	0.4
Estuarine	315.98	54.1	7.8
Lacustrine	2.51	0.4	0.1
Palustrine	116.86	20.0	2.9
Riverine	134.82	23.1	3.3
Total	584.58	100.0	14.4

In a historically seasonal landscape, the wetlands within floodplain distributary channels used for irrigation water distribution or drainage are now permanently wet, are often the most modified, and in the absence of management interventions can develop high levels of ecosystem stress.[23,24] These occur mostly on Land zone 3 - alluvium (river and creek flats) and coincide with areas used heavily for irrigated agriculture.[9]

Other wetlands retain some degree of seasonal variability (despite some supplementation from irrigation tail water) allowing waters to recede during the dry season. These occur primarily on Land zone 5 (old loamy and sandy plains) occurring as old oxbows and depressions. The presence and abundance of weeds in these wetlands is dependent on a number of factors including the level of soil salinity, the degree of supplementation, connections to sources of weed propagules and the surrounding land use practices.[9]

Wetlands on Land zone 1 (tidal flats and beaches) are naturally resilient to weed infestation mainly due to tidal salt water intrusion suppressing weed growth. They are however vulnerable to excess native sedge (*Typha* sp.) growth when supplemented with nutrient rich freshwater from irrigation tail waters which prevents the salt water intrusions.[9]

Forested coastal ecosystems

Of terrestrial ecosystems, forests and woodlands have been subjected to the greatest losses within the Haughton basin (36 and 14 per cent respectively (2.3.5). Only one per cent of rainforests have been lost (of an initial area of 7077 hectares). The impacts that the loss of these forested ecosystems on the World Heritage Area are reflected in section 2.4 – Processes.

The Queensland Government has assigned regional ecosystems a conservation status which is based on its current remnant extent (how much of it remains) in a bioregion. Regional ecosystems were originally defined by Sattler and Williams (1999)[25] as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.[25] Vegetation that is classified as endangered is afforded most protection in Queensland; however some industries such as mining, transport, electricity and community infrastructure may be exempt. Lesser protection is afforded by the other categories. These have been mapped for the Haughton basin (Figure 2.3.10).

Regional ecosystem information provides the basis for the development of coastal ecosystem functional groups identified in the Coastal Ecosystem Assessment Framework.[5] However regional ecosystem conservation classification is based on terrestrial distribution, and do not assess their functional linkage to the World Heritage Area. Regional ecosystem conservation classifications most likely do not protect coastal ecosystems most important to maintaining the health and resilience of the World Heritage Area.

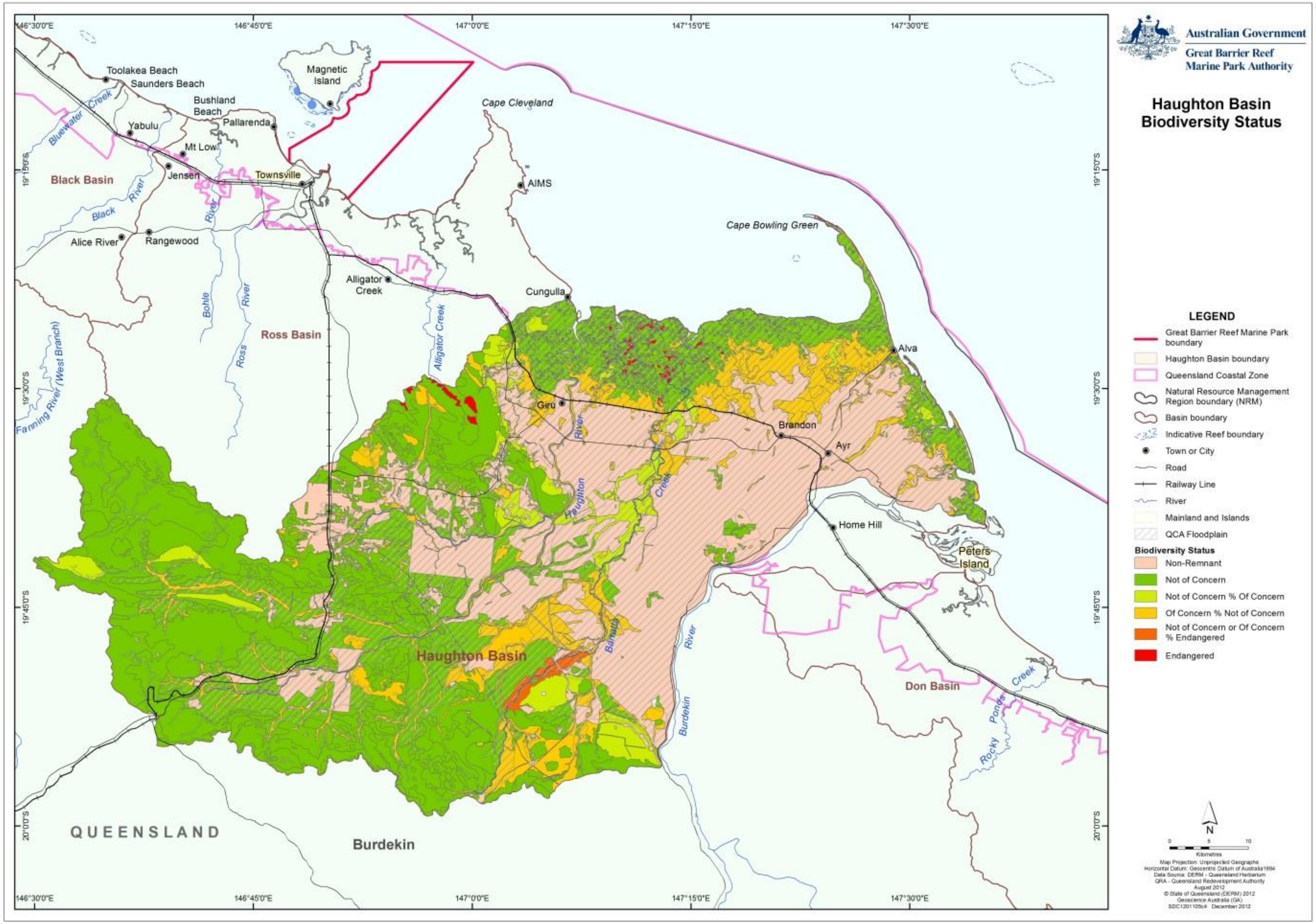

Figure 2.3.10: Regional ecosystem conservation status for the Haughton basin

The extent of riparian vegetation in the Haughton basin is approximately 92,000 hectares. Of this, 65,200 hectares is forested, 23,500 hectares is non-forested with high ground cover and 1300 hectares is non-forested with low groundcover.[17]

Summary

The coastal ecosystems of the Haughton basin have changed significantly and are unlikely to ever return to their former state and condition. Table 2.3.5 summarises the condition and trend of coastal ecosystems in this basin assessed by GBRMPA field work supported with referenced materials and expert opinion.[1,17,19,26,27]

Table 2.3.5: Values – Biodiversity habitats and species assessment for the Haughton Basin (Australian SoE, adapted from Outlook Report 2009) showing percentage of remaining coastal ecosystems in the basin. Orange cells indicate areas with 10-30 per cent remaining and green greater than 50 per cent. Note these figures provide no information about ecosystem condition or functionality

Rainforests	Forests	Woodlands	Forested floodplain	Grass and sedgelands	Heath and shrublands	Freshwater wetlands	Estuaries
98	64	86	25	57	96	68	100

2.4 Ecosystem processes

The condition of ecosystem processes in the Haughton basin varies both spatially and temporally. Areas that have been highly modified from the natural coastal ecosystems that were once there show the greatest degree of change in processes. For example, rivers that have been modified into water distribution channels offer limited capacity for biological processes for fish species such as reproduction, dispersal recruitment and migration and are often nutrient enriched.

Appendix F contains a list of coastal ecosystems and some of the ecological processes they deliver for the health and resilience of the World Heritage Area. The Haughton basin has some of the most diverse and extensive freshwater and estuarine wetlands in the Great Barrier Reef catchment. With an area covering approximately 32,541 hectares, the Bowling Green Bay wetlands constitute one of the largest coastal wetland complexes along the east coast of Australia,[28] which play an important role in nutrient assimilation and sediment stabilisation.[29] These areas provide for important biological processes such as the recruitment of animals like prawns, barramundi, mangrove jack, mullet and crabs. This area is an important habitat for protection, foraging and breeding for a large number of waterbirds, marine reptiles and large mammal species.[15] At least four species of turtles (loggerhead, *Caretta caretta*; green turtle, *Chelonia mydas;* hawksbill turtle*, Eretmochelys imbricata*; and flatback turtle, *Natator depressus*) that are considered as “vulnerable” under the EPBC Act feed in this area. The Ramsar site is one of four areas along the Queensland coast that is considered of “high” conservation value to dugong.[15]

The condition of processes in the Haughton basin varies across the basin both spatially and temporally. Areas that have been highly modified from the natural coastal ecosystems that were once there show the greatest degree of change in processes. For example historically seasonal streams and river systems used for irrigation water distribution exhibit some of the highest levels of modification, including nutrient enrichment, and their often degraded condition inhibits their capacity for biological processes such as reproduction, dispersal recruitment and migration. Seasonality in flows has also been lost in some systems (such as the Barratta Creek system – Figure 2.4.1) which have implications for ecological processes.

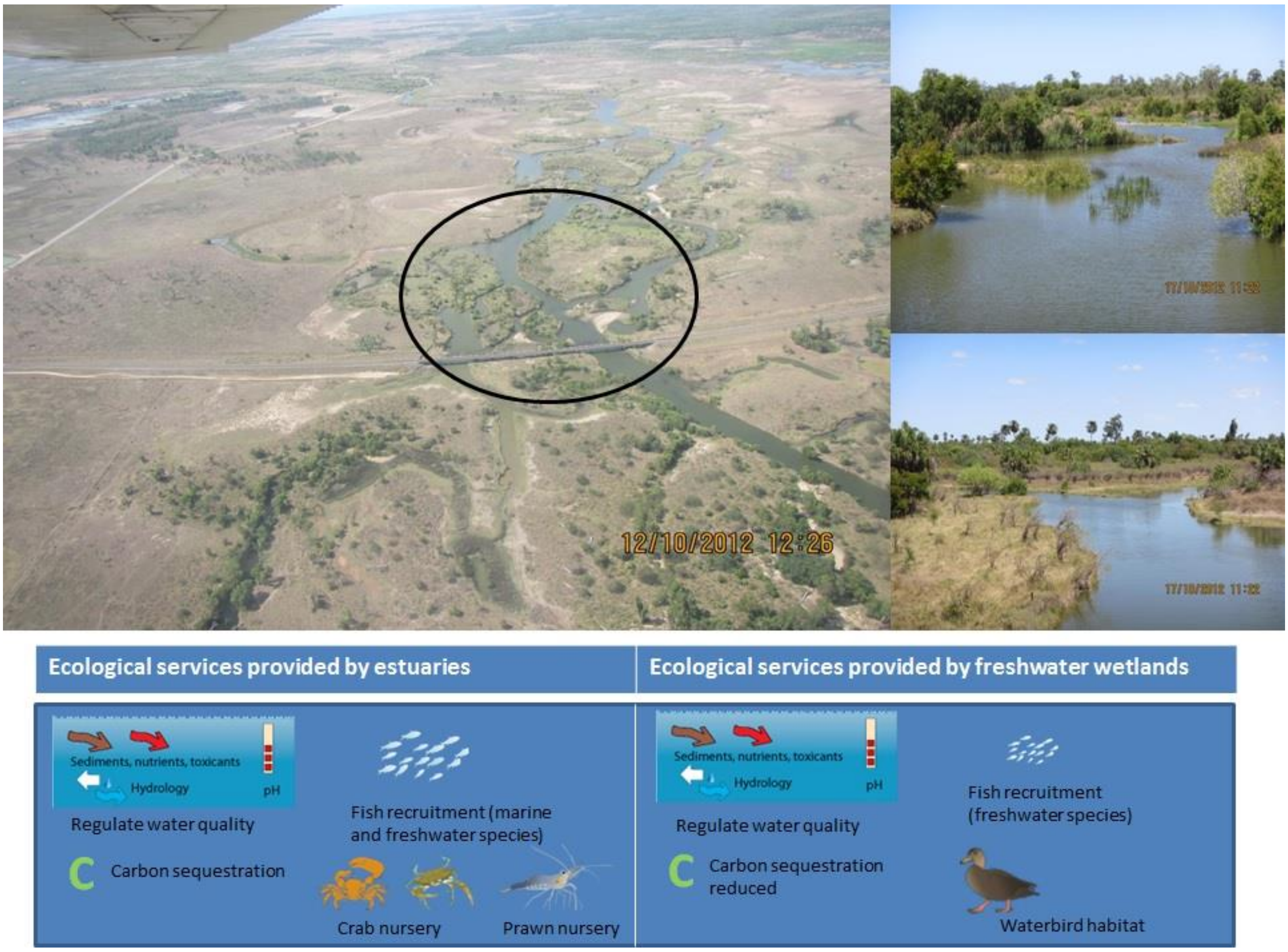

Figure 2.4.1: Barratta Creek estuary - changes to ecological functions caused by a phase shift from estuarine ecosystem to freshwater wetland. Increases in freshwater delivery to the Barratta Creek estuary is reducing the extent of the saltmarsh which is being replaced by *Melaleuca* sp. dominated freshwater wetlands (circled). This phase shift will alter the ecological functions delivered by these ecosystems to the Great Barrier Reef

Physical processes

Physical processes are the processes that transport and mobilise elements such as water, sediments and minerals. They include groundwater recharge/discharge, sedimentation/erosion of soils and deposition and mobilisation processes. All coastal ecosystems provide these functions, some more than others.

Historic land clearing has resulted in greater levels of sediment transport in the Haughton basin. Whilst the majority of finer sediments are transported through the basin and into coastal waters, the coarser sands have been building up in some of the waterways in the Haughton basin. The Haughton River in particular (Figure 2.4.2) has a build-up of sand in its upper reaches (in some locations sand in the riverbed is higher than the bank) and below the weir. Reduced water velocity below the weir has resulted in deposition of sand which is not being transported to the coast. The coastal settlement of Cungulla, on the north of the mouth of the Haughton River, is experiencing sand loss through erosion which may be attributed to reduced sand delivery from the Haughton River.

Figure 2.4.2: Weirs and erosion from grazing of natural areas is causing the Haughton River to fill with sand, both above (inset) and below the weirs (main picture). The weir traps heavier sediments above the weir and the reduced water velocity below the weir fails to move the coarser sand to the coastline. Interestingly the beach at the coastal settlement of Cungulla is eroding

Since the commencement of irrigation in the Burdekin Haughton Water Supply Scheme, turbid water has been constantly trapped and released from the Burdekin Falls Dam before being transported through the lower Burdekin floodplain systems (which includes the lower catchment of the mapped Haughton catchment: Haughton River, Barratta Creek, Sheep Station Creek and Plantation Creek) for irrigation water delivery.[15] As a result of supplemental water flows the water clarity and hydrological regime of the Haughton River, Barratta Creek, Sheep Station Creek and Plantation Creek have been greatly altered.[15] Alterations include loss of seasonality, increased nutrient and pesticide loads, loss of fish passage connectivity, altered sedimentation patterns, riparian tree death due to water logging, vegetation clearing and species invasions by introduced plants and animals.[15,30] Consequently, the underlying function of most wetland environments across the floodplain has been altered.[15]

The effects of chronic turbidity on floodplain ecosystems is not yet certain, however, it has been speculated that as a response to perennial turbidity, aquatic plant beds have become increasingly sparse, scattered and dominated by emergents.[28] For example, fringing water lilies and submerged aquatic plants are now largely absent from the lower East Barratta Creek system.[15]

Biogeochemical processes

Biogeochemical processes revolve around energy and nutrient dynamics. Biogeochemical processes include production, nutrient cycling, carbon cycling, decomposition, oxidation-reduction, regulation processes and chemical/heavy metal modification. Wetland and associated floodplain ecosystems offer the greatest capacity for maintaining biogeochemical processes as these ecosystems slow the flow of water and allow the processes to occur. During large flood events biogeochemical processes in coastal ecosystems often do not occur as water flows at high speed directly into inshore coastal waters. In more developed basins, the volume of nutrients is often higher as a result of fertiliser use and point source discharges. These processes then generally occur in the inshore coastal waters. Table 2.4.1 outlines the nutrient forms and their availability for biogeochemical processes.

Table 2.4.1: Forms of nutrients and their impact on the aquatic environment

Term	Description/source	Impact on aquatic environment
Particulate organic matter	Large particles of organic matter (e.g. dead plants and animals) that get broken down by decomposers into smaller dissolved organic matter.	Not available for uptake by plants and animals.
Dissolved organic matter (DOM)	Large molecules of organic matter (nitrogen, carbon, phosphorus etc.) produced as a result of decomposition.	Not biologically available until broken down by bacteria.
Dissolved inorganic matter	By-product of bacterial decomposition of DOM or applied in this form as fertilisers.	Nutrients such as nitrogen and phosphorus are freely available in this form for uptake by cyanobacteria, plants and animals.

The channelisation of the Haughton basin for the purposes of water transport has in effect reduced the residence time of water in waterways. This in turn reduces the capacity of coastal ecosystems to cycle nutrients. Additional stress has been placed on coastal ecosystems with the addition of rapid release fertilisers. These are leading to eutrophication of aquatic ecosystems in some areas.

Saltmarshes have one of the highest capacities to sequester carbon and the interaction with tidal salt water in effect permanently locks away carbon.[31] The placement of bund walls across the mangrove/saltmarsh interface to allow the retention of freshwater for the purpose of growing pasture grasses for cattle (see Section 3.3.9) has effectively reduced the area of carbon sequestration by as much as 23,000TCha-1yr-1.[32,33]

Biological processes

Biological processes are the processes that maintain animal and plant populations. These include survival/reproduction mechanisms, dispersal/migration/regeneration, pollination and recruitment. Wetland and associated floodplain ecosystems offer the greatest capacity for maintaining biological processes.

In-stream habitat has been reduced in the Haughton floodplain through the channelisation of waterways, loss of riparian vegetation and weed infestations which denude waterways of oxygen making the habitat unsuitable for fish (Figure 2.4.3).

Figure 2.4.3: Sheep Station Creek has a number of issues affecting its biodiversity

The change from natural conditions consisting of a low flow dry season, to a perennial system with sustained inflows of turbid, nutrient rich water has resulted in the modification of the floodplain and lower catchment wetlands, as the environmental conditions now favour exotic pasture species such as Olive hymenachne (*Hymenachne amplexicaulis*) and Para grass (*Urochloa mutica*), as well as floating exotic weeds such as salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*).[15,23,30] Where these species have been left unmanaged, extensive floating multi-species weed mats have resulted.[24] Ecological and limnological surveys of these areas have revealed a host of impacts, including anoxia within underlying water bodies; significant reduction in native fish and submerged macrophyte diversity and the promotion of exotic fish populations; the creation of water quality fish passage barriers; and enhanced liberation of phosphorus from bottom sediments (Figure 2.4.4 and Figure 2.4.5).[23,24,34] This shift from native species to exotic species is resulting in low oxygen environments that are in effect reducing the extent of habitat for most native fish species, whilst allowing some low oxygen tolerant introduced fish species (tilapia and blue gourami) to proliferate.

Figure 2.4.4: Some of the barriers to fish passage present in the Haughton basin. Dams, weirs and water regulation infrastructure are all barriers to fish migration (left). Native and introduced sedges and aquatic plants grow across the water's surface removing oxygen from the water preventing in-stream photosynthesis and oxygenation of the water and contribute large loads of organic material. This oxygen poor blackwater area serves as an impassable barrier to most fish (except surface breathers such as tarpon) (right)

Figure 2.4.5: In Kalamia Creek, $1 million was invested in the creation of a fish ladder (top). Although the ladder may allow passage for smaller fish, larger species (including the freshwater turtle pictured) have difficulty navigating the structure

Summary

Many ecosystem processes have been compromised in this basin. Around 68 per cent of wetlands (predominantly small ephemeral wetlands) have been lost in this basin and many of the remaining ones have been affected as a result of land use modifications such as altered flow regimes from irrigation. Weirs installed in some river systems have severely affected the physical processes that would normally occur, with repercussions for downstream ecosystems. Nutrient enrichment, loss of riparian processes and weed infestations has forever altered the landscape in this basin. Development of adaptive and intervening management (such as managed grazing, weed control and environmental flows) is now needed to maintain the health of coastal ecosystem processes in this basin.

2.5 Connectivity

Aquatic ecosystem connectivity refers to how ecosystem components are linked, whether through air, water or by land. Disruptions to connectivity between different areas where fish breed and grow can lead to a reduction in population resilience, or even localised extinctions.

Figure 2.5.1 shows the sub-basin waterways that were considered by this assessment. Figure 2.5.2 shows the stream orders (classification system where waterways are given an 'order' according to the number of additional tributaries associated with each waterway) combined with land zones and elevation. These tools were used to assess connectivity.

The major waterways in the Haughton basin are the Haughton River (with Majors Creek and Reid River tributaries) and Barratta Creek. Barratta Creek (and many other smaller waterways such as Kalamia Creek, Plantation Creek, Sheep Station Creek and Barramundi Creek) are actually part of the distributary network of the Burdekin River but are mapped as part of the Haughton basin by the Queensland Government.

The Haughton basin is a low profile floodplain dominated basin (Figure 2.5.2).[9] Historically, overbank floods from the Burdekin River once contributed to peak flow events within floodplain distributary creeks systems that supply wetlands within the Haughton basin and recharged groundwater. Levee banks and weirs built for flood protection purposes now prevent these overland flows except during one-in-twenty-year flood events. Much of the water from this basin discharges northwards into Bowling Green Bay with some smaller creeks discharging to the waters north of Edgecumbe Bay. Flows in many systems are now supplemented from irrigation supply and pumping from the Burdekin River, and irrigation tailwater contributions.

These changes impact upon four Groundwater Dependent Ecosystems present:

- Shallow, non-permanent palustrine wetlands
- Non-permanent riverine wetlands
- Permanent riverine wetlands
- Shallow estuarine wetlands.[35]

Two weirs are in place in the Haughton River – the Val Bird Weir and Giru Weir. The Val Bird Weir was constructed in 1983 as part of the Burdekin Haughton Water Supply Scheme.[36] This has led to a rise in groundwater levels and created the potential threat of salinisation of the surrounding properties in the region.[36] These weirs also reduce biological connectivity (such as fish passage) and may also be the cause of sand build up in the lower reaches of the Haughton. The reduction in sand delivery to the coast may also be affecting the beachside settlement of Cungulla, which is in need of beach renourishment works.

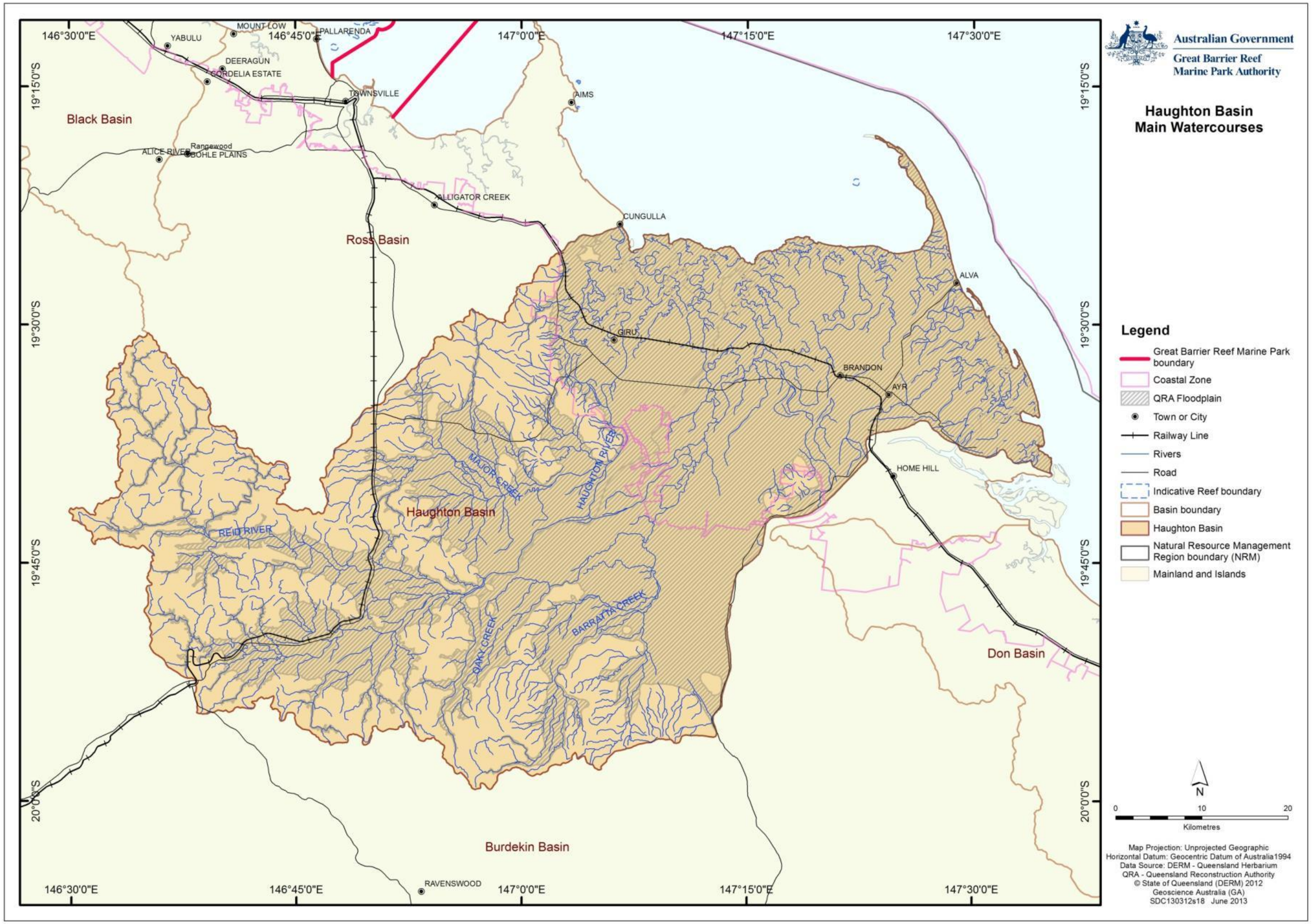

Figure 2.5.1: Major streams in the Haughton basin that were considered in this assessment

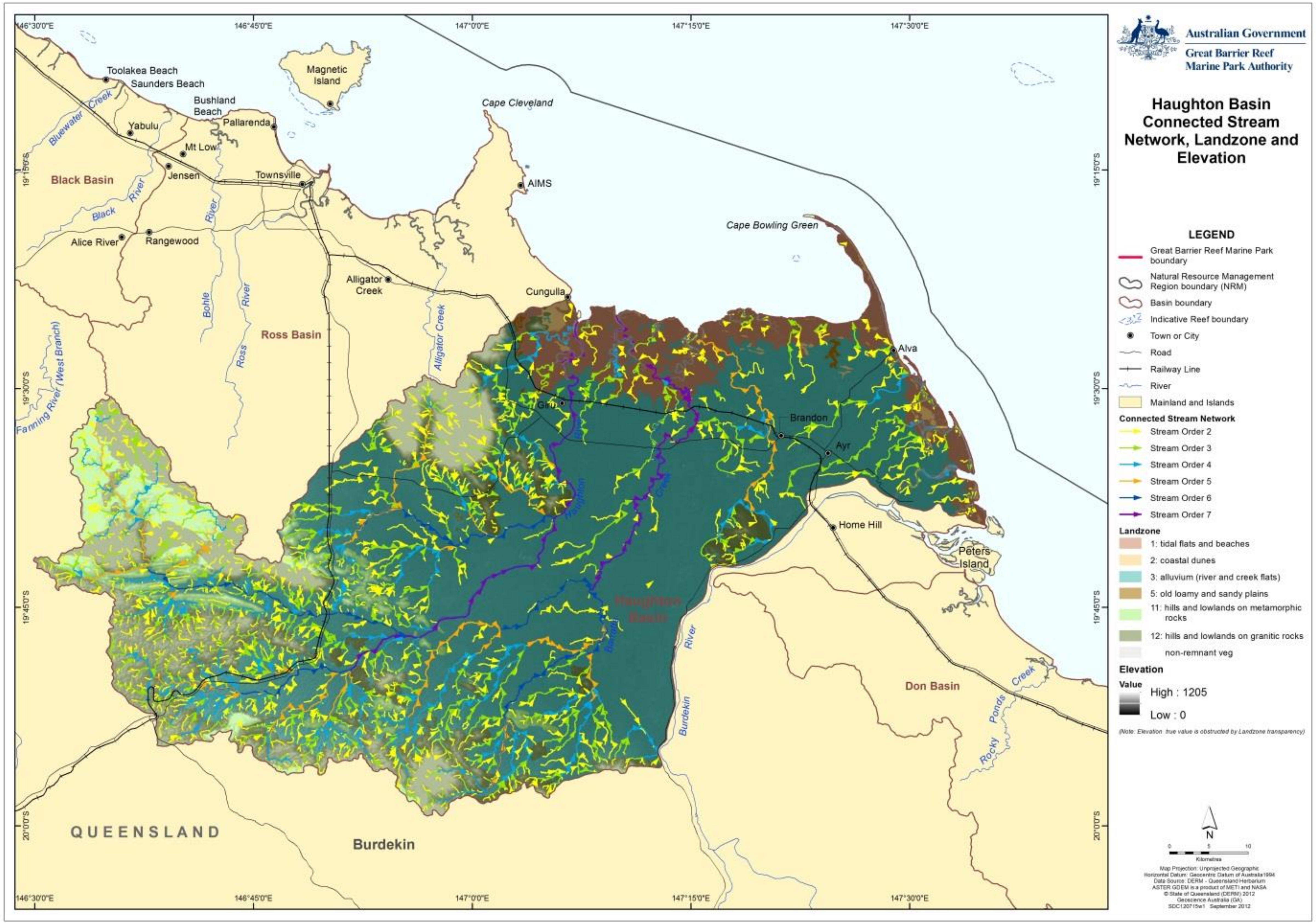

Figure 2.5.2: Stream order and elevation map showing the floodplain in the Haughton Basin

In 1965 the North Burdekin Water Board came into existence in response to declining water levels brought about by a combination of drought conditions and increased demand for irrigated sugar cane cropping. As a result, the North Burdekin Water Board artificially manages the groundwater system through the use of water from the Burdekin River in the lower Haughton basin (Figure 2.5.3).[37]

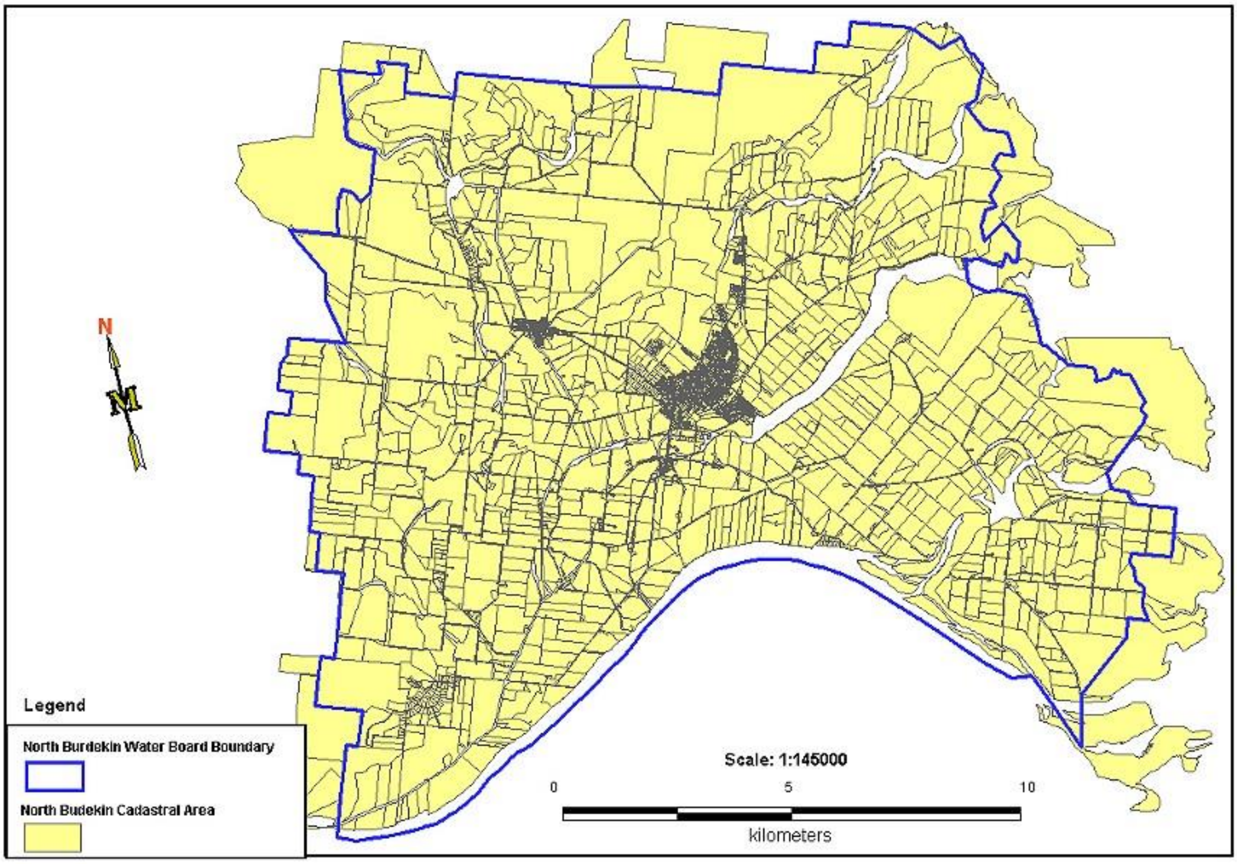

Figure 2.5.3: Area of the Haughton basin managed for groundwater by the North Burdekin Water Board

In 1980, the Queensland Government authorised the establishment of the Burdekin River Project. This project supplies water for the irrigation of new and existing farms in the Haughton basin floodplain and supplements Townsville's water supply. Balancing storages and irrigation channels (Figure 2.5.4) have been constructed throughout the lower Haughton basin to direct water to areas of irrigated cropping and other channels (and streams) are used to direct irrigation tailwater away from cropping lands into downstream coastal ecosystems and groundwater recharge ponds (including the North Burdekin Water Board area).

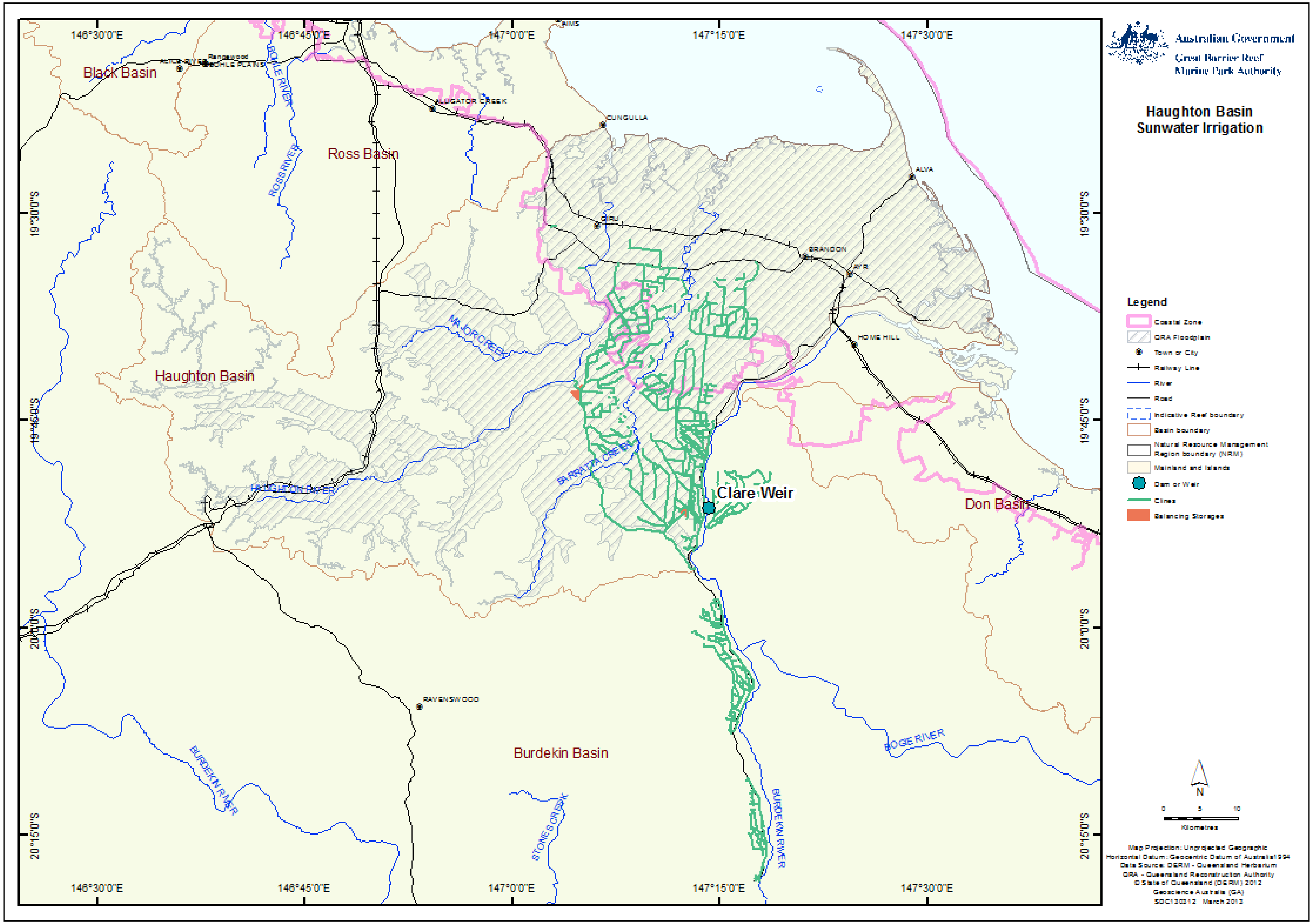

Figure 2.5.4: Network of irrigation channels (modified river systems and new channels) constructed by SunWater for the purposes of irrigating the Haughton basin

In 1987 the Burdekin Falls Dam was completed, creating the Burdekin River Irrigation Area (BRIA – now the Burdekin-Haughton Water Supply Scheme (BHWSS)).[15] The dam is located approximately 80 km from the river mouth and is the largest water reservoir in Queensland (1,860,000 ML). Expansion of cane agriculture followed in 1988, which has also contributed to the detrimental impacts on the function of local coastal wetlands.[15] The Haughton River and lower Burdekin allocate water (150,000 ML per annum) for crop irrigation through the BHWSS. The establishment of the BHWSS led to an increased diversity of irrigated horticultural and tree crop areas that are situated upstream of coastal zone wetland complexes.[15] Both the Haughton River and Barratta Creek have been modified hydrologically as a result of the BHWSS. The BHWSS has also impacted on the North Burdekin Water Board operations perennial supply and water quality.

Additionally, after the completion of the Burdekin Falls Dam and the introduction of surface water for irrigation, ground and surface water flows have been impacted and watertable levels across the BHWSS have shown significant changes.[15] The watertable has risen from 10 m to 2 m below ground level upstream of the BHWSS site since 1987[38,39] and is expected to continue rising.[40] Groundwater is rising because the BHWSS aquifer is receiving an increased average of 67,576 ML/year compared to pre-development conditions[41], and there is a lack of deep drainage management and water use efficiency.[40] There is currently no effective water discharge mechanism due to the limited connectivity between groundwater systems and the Burdekin River.[15] Kelly and Lee Long (2012) suggest that particular information is needed on the hydrological connectivity of various aquifers as well as interactions with surface and groundwater along the Cape Bowling Green coastal margin and areas adjacent of the Haughton River and Burdekin River delta catchments.[42]

All systems have barriers to connectivity including dams, weirs, sand build up from erosion, bund walls, water irrigation, flood gates, water quality and weed barriers. Some barriers, such as water quality barriers, may be removed during high periods of river flow. Culverts and river modifications have increased flow velocity in some areas which can also be a barrier to fish passage (Figure 2.5.5).

Figure 2.5.5: Tailwater drainage. Note the gate (foreground) that prevents fish passage (even when open) due to the high flow velocity

Surface hydrology

The Burdekin delta, in which the Haughton basin lies, sits over a shallow groundwater aquifer which is hydrogeologically linked to environmentally sensitive wetlands, waterways, estuaries and the Great Barrier Reef. In addition to irrigation supply, the aquifer also supplies potable water for three towns in the delta. There has historically been an issue of seawater intrusion into the Burdekin aquifers[43] and this is now managed by artificial recharge from river water.

Modification of the floodplain and changes to overland hydrology has severely impacted the Haughton basin. Water released from the Burdekin Falls Dam is pumped from the Clare Weir (Burdekin River) into the channel network during the dry season into many locations across the basin, such as the balancing storage near the Haughton River (Figure 2.5.6) and from there into irrigation channels and streams for irrigation purposes (Figure 2.5.7). These systems now flow throughout the dry season. At the commencement of the wet season the water distribution is sometimes stopped. When this happens, it results in a reduction of flows which are supplemented by tailwater from adjacent plantations and inflows from the groundwater. The excess nutrients entering the watercourses in this tailwater are one of the drivers for the growth of floating aquatic weeds, such as hyacinth. This weed growth then often becomes submerged as water levels increase in the wet, leading to anoxic black water (which acts as a barrier to migrating fish that use the first rains as cues for migration). These ‘slugs’ of blackwater have been reported to wash downstream, causing fish kills.

F

Figure 2.5.6: SunWater balancing storages are used to hold water for controlled releases for irrigation (based on demand)

Figure 2.5.7: SunWater constructed channels with water control gates are used to deliver water to farms for irrigation across parts of the floodplain

Over 700,000 ML of water from the Burdekin Falls Dam is now distributed across the Burdekin-Haughton Water Supply Scheme area throughout the year in this naturally seasonally dry landscape.[9] This has led to the formation of freshwater wetlands in areas that were salt pans that hosted seasonal spike rush (*Eleocharis dulcis* – Bulkuru Sedge) swamps on Jerona Station, along the lower Barratta Creek distributary.

Nutrient enrichment, and the absence of tidal incursions has allowed wetland plant species (both introduced species, such as *Hymenachne* and native species, such as *Typha*) to become well established to the point where they have completely covered the wetland, leading to anoxia and a reduction in fish diversity. These impacts are also affecting adjacent marine ecosystems and are also detrimental economically where issues such as rising ground waters (caused by impeded drainage) are affecting agricultural production.[13]

Site visits in the Haughton basin identified areas of ecotone change. Flood irrigation of upstream agriculture with water from the Burdekin Falls Dam along with rising groundwater has turned the upper reaches of this seasonally flowing tidal dominated estuary into a freshwater system. As a result, the riparian vegetation in some stream systems has changed from dryland forests into rainforest assemblages. These changes pose no threat to the ecological processes provided to the World Heritage Area and reflect the altered nature of this basin.

Further downstream, these now perennial flows are driving an ecotone shift in the estuary of the lower Barratta Creek. Vegetation is changing from tidal saltmarsh/mangroves into freshwater melaleuca dominated forested floodplain ecosystems. As a result of this, the resident marine fish and invertebrates have disappeared from this area and the riparian mangrove forest is declining in health. The introduced pasture grass species *Hymenachne* (now a declared weed) has taken advantage of the freshwater present and colonised the understorey in some areas (Figure 2.5.8).

Figure 2.5.8: Mangroves in decline. The upper Barratta Creek estuary receives such high quantities of freshwater now that marine fauna (such as crabs) have long perished. Submerged freshwater aquatic plants (centre of photo) are flourishing (indicating the lack of tidal incursion) and introduced pasture grass (*Hymenachne* sp.) has become established in the mangrove understory (foreground)

Groundwater hydrology and groundwater dependant ecosystems

The lower Haughton delta is made up of sand and clay with granitic bedrock.[36] The floodplain land zones consist primarily of Land zone 1 (tidal flats and beaches), Land zone 3 (alluvium and creek flats) and Land zone 5 (old loamy and sandy plains).

The groundwater hydrology beneath the Haughton basin floodplain forms part of the greater Burdekin groundwater system. This area is unique, in that, it overlies a shallow groundwater system and is close to the Great Barrier Reef.[36] Groundwater is stored in two main underground aquifers which are recharged almost entirely by stream flows. The older aquifers are the deepest (15-45 meters) and extend from the slopes of Mount Elliott across the Haughton River to the Burdekin delta. The younger aquifers are shallower and limited in extent to the Haughton riverbed and some recently abandoned channels.

The groundwater hydrology in the Haughton basin has been substantially modified. Historically, overbank flows from the Burdekin and Haughton rivers flowed into coastal wetlands recharging groundwater aquifers. The modification of the floodplain into agriculture land and associated loss of wetlands has led to a range of impacts and the employment of management actions to retain functionality. These include:
A steady rise in groundwater salinity since the floodplain was opened to irrigation in the late 1980s and early 1990s. This is managed through artificial groundwater replenishment which is still ineffective in some coastal areas as saltwater intrusion is still occurring.[36]
Changes in groundwater behaviour since excess water introduced through farm irrigation and SunWater supply channels.[44]
Weirs built across the Haughton River for irrigation purposes are causing rising watertables and localised flooding.[41,43]

- Seasonality of flows lost due to water released through irrigation practices.
- Channelisation of the floodplain landscape allows water to run off rapidly from laser leveled agricultural lands. These changes reduce groundwater retention on the floodplain reducing natural groundwater recharge.

Unconfined alluvial aquifers exist in the Haughton basin. Within this area there is a long-term trend of rising groundwater. Half of the discharged groundwater flows into wetlands and rivers with the other half flowing into the coast including submarine discharges in Bowling Green Bay.[45]

Excessive water extraction in the Burdekin Delta aquifer has been reported since the 1930s, following expansion of the sugar cane industry and long periods of drought. As a result of lowered aquifer water levels, saline/fresh water groundwater interfaces have advanced inland[15,46,47] and saltwater intrusion is an increasing concern, especially under sea level rise scenarios.[15,42] Water is sourced from both surface and groundwater, although the Delta region uses predominantly groundwater (80-90 per cent) and the Burdekin-Haughton Water Supply Scheme (BHWSS) predominantly uses surface water (80 per cent).

Since the introduction of groundwater for irrigation, groundwater salinity levels have increased in the Burdekin River Irrigation Area from less than 1000 µS/cm towards 2500 µS/cm by 2000.[48] Meanwhile, the average rate of salt importation from surface water has been estimated at approximately 32,027 t/yr.[41]

Rectification measures, such as the construction of the Plantation Creek bund for the purposes of groundwater replenishment have led to other impacts that were observed during the field assessment at Plantation Creek. Weed chokes, loss of riparian cover, stream modification and water level management gates (Figure 2.5.9 and Figure 2.5.10) all impact on the connectivity of this system.

Figure 2.5.9: Downstream impacts of changes to connectivity is apparent within these mangroves in Plantation Creek. Bundwalls are widespread in this area and have been designed to prevent saltwater intrusion into shallow aquifers by maintaining an artificial head of freshwater. This bund, along Plantation Creek has backed freshwater up eight kilometres leading to sedges and exotic floating macrophytes clogging the waterway (above) and drowning trees. Freshwater is seeping through the bundwall into mangroves (below) causing smothering algae on pneumatophores and sedge growth in the mangrove understory. Further seepage may jeopardise the health of these well-established mangroves (right)

Figure 2.5.10: Modifications for groundwater management and irrigation has severely impeded the connectivity of Plantation Creek. Flow gates installed by the Burdekin Water Board regulate water levels for pumping. These gates act as barriers to fish migrations and pool water in which aquatic weeds (Hyacinth – top right) have become established. The Water Board removes these weeds which choke the system and otherwise create blackwater. The retention of water has also raised the watertable and drowned Melaleuca were evident at this site. Introduced pasture grasses are well established in the understory of the adjacent Livingstonia palms which show evidence of past hot fires linked with these grasses. Weed chokes under the palms are also causing blackwater

The Val Bird Weir near Giru is affecting the groundwater levels (and has the potential to affect groundwater salinity) in the adjacent areas (see section 2.5). Research by CSIRO shows that lowering the height of the weir will effectively lower the height of the watertable in the adjacent area. [36]

Chapter 3: Impacts on the values

3.1 Drivers of change

The primary drivers of change for the Haughton basin are climate change, economic growth population growth and technical development.

Climate change

The Queensland Government has carried out extensive mapping of coastal areas projected to be at risk based on climate change predictions up until the year 2070. The maps they produced factor in climate change impacts including sea-level rise of 30 centimetres and a 10 per cent increase in the maximum potential intensity of cyclones and associated storm surge at-risk areas and erosion prone areas.[49]

Information on climate change impacts is based on the most recent report from the Intergovernmental Panel on Climate Change (IPCC) – the international scientific authority on climate change. Property scale and area-based coastal hazard maps are available at http://www.ehp.gov.au/coastal/management/maps/index.html

The Haughton basin is expected to experience climate change impacts more than many other areas due to the low lying coastal floodplain delta. Woodlands in the Haughton basin will be most affected by invasive species, changed fire regimes and extreme weather events that will become more commonplace as a result of climate change. Coastal wetland ecosystems will be impacted by sea-level rise, extreme weather events and changes in the water balance and hydrology.[50]

Any impacts from to-date sea level rise may have already been mitigated by the groundwater recharge mechanisms in operation in the basin. Table 3.1.1 shows the regional climate change predictions that will apply to temperature, rainfall, evaporation and extreme events.[51] These changes will likely lead to further growth of exotic species, lowered in-water oxygen levels and more extreme events.

Table 3.1.1: Shows the regional climate change predictions for the Dry Tropics region for temperature, rainfall, evaporation and extreme events as of 2009

Element	Prediction
Temperature	Average annual temperature in the region has increased by 0.2°C over the last decade (from 23.3°C to 23.5°C). Projections indicate an increase of up to 4.2°C by 2070, leading to annual temperatures well beyond those experienced over the last 50 years. By 2070, Townsville may have ten times the number of hot days over 35°C (increasing from an average of four per year to an average of 40 per year by 2070) and Charters Towers may have more than double (increasing from an average of 50 per year to an average of 136 per year by 2070).
Rainfall	Average annual rainfall in the last decade fell more than four per cent compared with the previous 30 years. This is generally consistent with natural variability experienced over the last 110 years, which makes it difficult to detect any influence of climate change at this stage. Models have projected a range of rainfall impacts from an annual increase of 19 per cent to a decrease of 32 per cent by 2070. A decrease in rainfall is

Element	Prediction
	projected by the majority of models under all emissions scenarios.
Evaporation	Projections indicate annual potential evaporation could increase 7-15 per cent by 2070.
Extreme events	The 1-in-100-year storm tide event is projected to increase by 34 cm in Townsville if certain conditions eventuate. These conditions are a 30 cm sea-level rise, a 10 per cent increase in cyclone intensity and frequency, as well as a 130 km shift southwards in cyclone tracks.

Economic growth

Economic growth has been the driver for much of the land use change that has occurred in the Haughton basin. In recent times the collapse of the live cattle trade and economic value of sugar has driven a change in land use from grazing natural areas to irrigated sugar production. The availability of water has been the driver for much of the development that has occurred in the Haughton basin.

Population growth

The northern region of Queensland is projected to grow strongly between 2006 and 2031. The Queensland Government forecast for the northern region is an average annual population increase of two per cent.[52]

Technical development

Technical developments, primarily the construction of the Burdekin Dam, the availability of low cost heavy earthmoving equipment and water availability has forever changed the Haughton basin floodplain. In more recent times improvements to harvest and fertilising machinery has improved land management practices that are leading to reductions in sediments, nutrients and pesticide losses from agricultural land.

3.2 Activities and impacts

The dominant land use in the Haughton basin is grazing of natural and modified vegetation and irrigated cropping (sugar cane). These industries support the urban centres of Ayr, Giru, Brandon and beach side communities Alva Beach and Cungulla. Land use for 1999 and 2009 is shown in Table 3.2.1 and Figure 3.2.1 and Figure 3.2.2. Note that the appearance of water-marsh/wetland production is a result of the recognition of this land use in 2009. These areas were previously classified as grazing natural areas or natural environments and do not reflect a shift to this land use.

Table 3.2.1: Major land use categories (hectares) for the Haughton basin in 1999 and 2009 based on Queensland Land Use Mapping Program data

	Land use area (ha) - Haughton	**1999**	**2009**
	Conservation, natural environments (inc. wetlands)	71,330	64,576
	Forestry - production	0	3,289
	Grazing natural vegetation	248,904	239,334
	Intensive animal production	130	253
	Intensive commercial	692	789
	Intensive mining	140	183
	Intensive urban residential	2,068	2,040
	Production - dryland	178	179
	Production - irrigated	78,201	79,650
	Water - production ponded pastures	0	10,842
	Water storage and transport	2,090	2,884
	Not Mapped	1,053	767
	Total Area (h)	404,787	404,787

From Figure 3.2.1 the extent of irrigated cane in the lower floodplain is obvious, with much of the grazing occurring in the upper catchment. The extent of ponded pasture (water - marsh/wetland production) can be seen occurring on the marginal land closer to the coast in Figure 3.2.2.

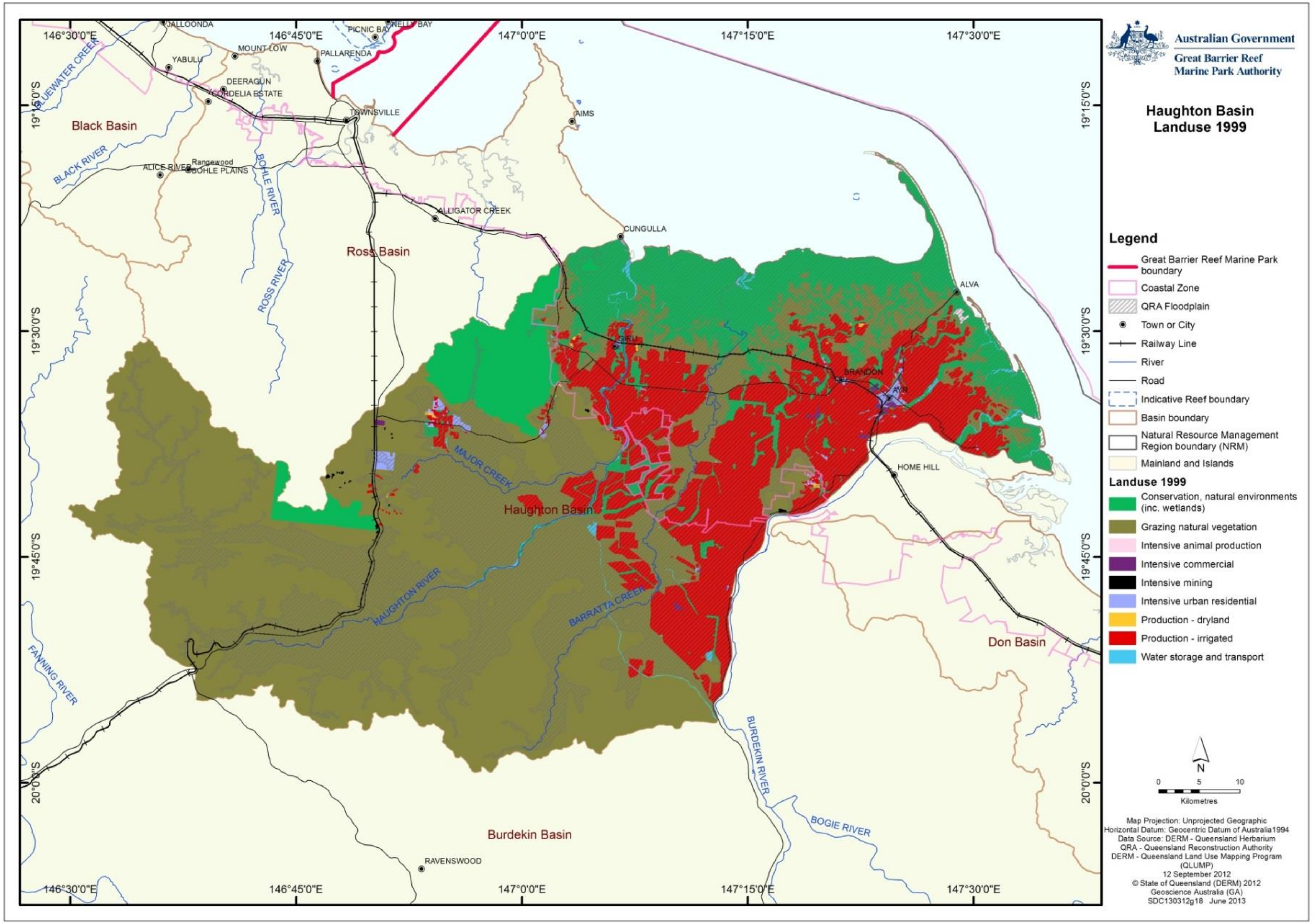

Figure 3.2.1: Map of land use for the Haughton basin based on 1999 QLUMP data

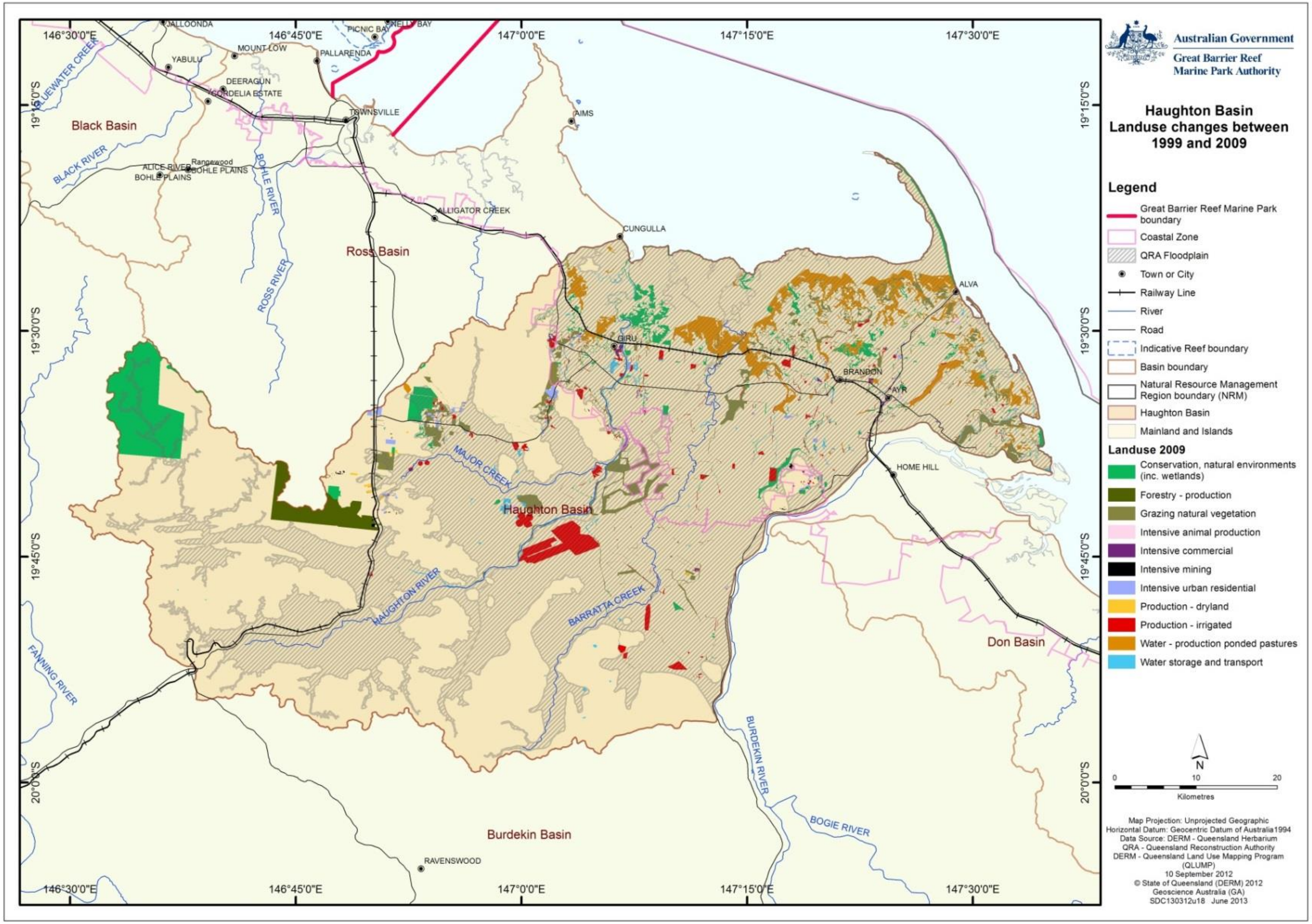

Figure 3.2.2: Map showing areas of changed land use in the Haughton basin based on 1999 and 2009 QLUMP data

Land use within the coastal zone

Land use adjacent to the coast (the coastal zone) can have the greatest impact on the Great Barrier Reef inshore waters. The coastal zone includes Queensland's coastal waters (which extend three nautical miles out to sea), coastal islands and land below 10 metres Australian Height Datum or within five kilometres of the coastline, whichever is greater. The land use occurring within the coastal zone for 1999 and 2009 is shown in Table 3.2.2.

Table 3.2.2: Major land use categories (hectares) for the Haughton basin coastal zone in 1999 and 2009 based on Queensland Land Use Mapping Program data. Note the decline in conservation natural environments is due to greater resolution of mapping which has delineated the water-marsh/wetland production areas (ponded pastures)

	Land use area (ha) - Haughton Coastal Zone	**1999**	**2009**
	Conservation, natural environments (inc. wetlands)	49,598	38,351
	Forestry - production	0	0
	Grazing natural vegetation	28,891	29,587
	Intensive animal production	130	180
	Intensive commercial	540	674
	Intensive mining	14	35
	Intensive urban residential	940	1,135
	Production - dryland	80	14
	Production - irrigated	52,019	51,437
	Water - production ponded pastures	0	10,776
	Water storage and transport	1,197	1,508
	Not Mapped	1,053	767

3.3 Actual and potential impacts from key activities

There have been some major landscape scale changes within the Haughton basin which have been shown to impact on the receiving marine environment. Other developments in the basin may be relatively small in area however may contribute significantly to the cumulative impacts on the World Heritage Area.

Forestry

There is 3289 hectares of forest and rainforest that was assigned as protected areas (QLUMP 1999) that are now assigned as production forestry (QLUMP 2009) in the Reid River sub-basin. Timber in this area does not appear to have been harvested to date and any harvesting of trees in this area would likely impact the natural values of Reid River and the Haughton River.

Grazing natural vegetation

Dryland grazing of natural areas occurs throughout much of the upper basin (239,334 hectares) mostly within remnant forest and woodland coastal ecosystems. Impacts vary according to the level of uptake of best management practice. The main impact is loss of topsoil as a result of over stocking of cattle, and legacy issues from historic tree clearing, which has contributed to the generation of a bed load of coarser material in the river systems. This may be occurring as a result of poor management practice or due to requirements dictated by financial institutions, which use a generic formula of cattle stocking rates that does not account for regional landscape variability.

Results from the 2009-2010 year showed that 13 per cent of graziers, 26 per cent of horticulture producers and 14 per cent of sugar cane growers have adopted improved land management practices (Figure 3.3.1). The greatest proportional catchment load reduction was with the pesticide loads with an estimated 225kg (10 per cent) less. Overall, progress towards Reef Plan targets has been encouraging; however, it will take time for these achievements to translate into improved marine condition.[53]

Figure 3.3.1: Healthy wetland amongst well managed grazing lands (Middle Barratta Creek). Feral pigs are having a greater impact on these systems due to digging behaviors (top left)

In many parts of the basin introduced pasture grasses have choked waterways, leading to detrimental impacts to waterways (such as eutrophication). Seasonal grazing trials have been been trialled in Collinson's Lagoon (Barratta Creek) to control *Hymenachne* from the waterway (Figure 3.3.2). These trials have improved the health of this area.

Figure3.3.2: This is a test site for managed grazing as a tool for rehabilitation. The site has improved, but water quality is still marginal. This lagoon flows into Barratta Creek. The photo above (1997) shows the lagoon choked with introduced pasture grass. The introduction of managed grazing (2012) shows the improvements that have occurred, including the establishment of native water lilies

Highly flammable introduced pasture grasses (such as para grass and guinea grass) have spread into the understory of the forest and woodland coastal ecosystems in many areas. Extremely hot fires are generated when these areas burn which generally results in the loss of native vegetation and ground cover in these areas (Figure 3.3.3). Fires late in the dry season leave bare scorched ground vulnerable to erosion at the commencement of the wet season. In areas where well managed grazing occurs, fire loads are greatly reduced

Field observations in late 2012 noted that in places the lack of riparian vegetation (as a result of fire) has leading to other problems such as aquatic weed infestations and rising in-stream water temperatures which may be impacting on terrestrial and aquatic biodiversity.

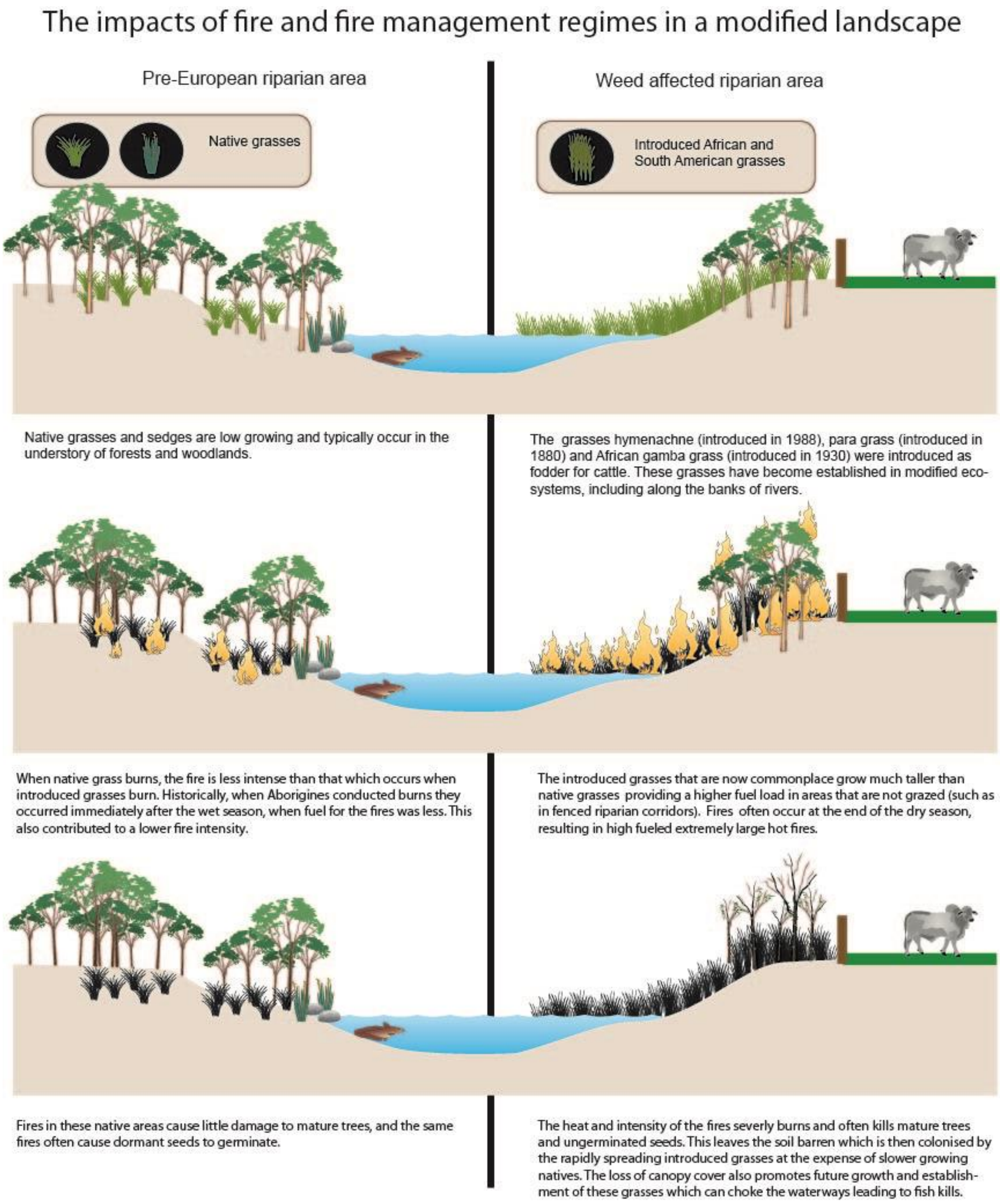

Figure 3.3.3: Impacts associated with fire in riparian vegetation assemblages

Intensive animal production

A small area of coastal floodplain is currently used as an aquaculture facility for prawns at Alva Beach. This facility has modified the estuary channel, contributed to the loss of mangroves and is contributing to nutrient discharge into the coastal waters (discharges are in accordance with permitted allowances). Discharges are onto salt flats adjacent to Alva Beach.

Intensive commercial

Commercial areas in the Haughton basin include three sugar mills (Kalamia north of Ayr, Invicta in Giru and Pioneer in Brandon) and other small scale local industries. These contribute to point source pollution in the basin (Figure 3.3.4) by discharging nutrient rich heated water into Collinson's lagoon.

Figure 3.3.4: The Burdekin Sugar Experiment Station (sugar mill) uses water from Collinson's lagoon as cooling water. Nutrient rich (from mill waste) water is discharged back into Collinson's lagoon. During heavy rain this lagoon connects with Barratta Creek and the World Heritage Area

Intensive mining

Mining is limited in the Haughton to one square kilometre quarries – one near Mount Kelly and a limestone quarry (north-west of Calcium), both of which are unlikely to have any significant impact on the World Heritage Area.

Intensive urban residential

The residents of the Haughton basin are located primarily within the town centres of Ayr, Giru and Brandon. The coastal settlements of Cungulla and Alva Beach are home to a mix of residential and holiday accommodation.[1] The only coastal developments (within the coastal zone) are the urban settlements of Cungulla, Alva Beach and Jerona. These are small urban settlements situated on low lying coastal plains with a large proportion of homes used as holiday residences. All of these are expected to be impacted by climate change (Table 3.3.1).[54]

Table 3.3.1: Expected impacts from climate change as outlined under the Queensland Coastal Plan

	General information	Under Queensland Coastal Plan mapping, this coastal urban settlement is
Cungulla	Subject to coastal erosion and residents have placed illegal retaining structures and breakwaters using waste materials to protect properties. A Shoreline Erosion Management Plan is under development. Cungulla was also identified as a high risk settlement under Townsville Flood Hazard Assessment Study.	• Within identified areas of likely storm impact and long-term trends of sediment loss and channel migration. • Likely to be exposed to permanent inundation due to sea level rise. • Within medium and high storm tide inundation areas.

Alva Beach	Coastal settlement with a good setback from the beach.	• Outside of areas of likely storm impact and long-term trends of sediment loss and channel migration. • Likely to be exposed to permanent inundation due to sea level rise. • Within medium and high storm tide inundation areas.
Jerona	Small settlement on the banks of the Barratta Creek estuary.	• Outside of areas of likely storm impact and long-term trends of sediment loss and channel migration. • Likely to be exposed to permanent inundation due to sea level rise. • Within the high storm tide/coastal hazard inundation area.

Production – dryland

A few small properties of dryland production occur in the upper Majors River. Impacts from these properties are likely to be minimal.

Production – irrigated

Irrigated sugar cane cropping represents the second largest land use in the Haughton basin (Figure 3.3.5). The infrastructure established in the 1970s to improve irrigated cropping has also had the largest impact on this basin. Approximately 80,000 hectares of grass and sedgelands, forested floodplains, wetlands and forests were modified into cane paddocks and for the supporting irrigation network. Irrigated cropping has continued to expand slightly each year. With the demise of the live cattle trade and subsequent reduction in viability of small cattle holdings, this trend is likely to continue.

Figure 3.3.5: Extensive sugar cane plantations in the Haughton basin floodplain

Almost all horticulture in the Haughton basin is irrigated, with furrow the dominant form of irrigation and sugar cane the dominant crop. Both river water and/or groundwater are used depending on proximity to the river and surface water supply channels, aquifer yields, and groundwater quality. At present, more than 1400 groundwater pumps are in operation, applying 10–40 ML/ha/yr[55], which is equivalent to 1000–4000 mm/yr. In general, most areas to the east of Mount Kelly are irrigated with groundwater (with some surface water use) while areas to the west use mainly surface water. The groundwater in this area is also artificially replenished.

Riparian condition and extent adjacent to cane farms vary throughout the Haughton basin. Some areas maintain healthy riparian strips along waterways and often these were seen to have higher water quality and biodiversity values. In areas where riparian vegetation was absent (either physically cleared or cleared as a result of ongoing fire mismanagement) water quality was visibly poorer (Figure 3.3.6).

Figure 3.3.6: Cane paddock adjacent to a waterway with poor riparian vegetation

Over 20 different herbicides have been detected during conditions of both low flow and flood events, the majority of which are associated with the sugar cane industry.[4,56,57,58] The dominant herbicides detected include diuron, atrazine, hexazinone and ametryn, which are now regulated under the Great Barrier Reef Protection Amendment Bill 2009.[4,56] A notable feature of the temporal herbicide dynamics in this region is that the highest herbicide concentrations and the majority of the total herbicide load transported from these catchments during the wet season occurs during the 'first-flush' event.[57] These flows either flow via channels into waterways (Figure 3.3.7) or into retention ponds for reuse.

Figure 3.3.7: Tailwater transport corridor that flows into the Barratta Creek estuary

The practice of burning cane still occurs in the Haughton basin (it has ceased in many other areas of the catchment) (Figure 3.3.8). After the cane has been burnt and harvested, soil remains exposed and vulnerable to erosion.

Figure 3.3.8: Cane fire in the Haughton basin

Furrow/flood irrigation (Figure 3.3.9) is commonly used in the Haughton basin. This practice results in increased run-off, changes to groundwater and nutrient enrichment of local waterways (refer Section 2.5).

Figure 3.3.9: Furrow irrigation in the Haughton basin promotes overuse of water that can change in-stream and underground hydrology and contribute to nutrient export into local waterways

Water – marsh/wetland production

Development in this basin has led to a number of perversive management issues affecting wetland condition in the lower floodplain. This includes the broadscale changes to hydrology through the use of flood irrigation and bund walls for irrigated cropping and grazing.[9,36] Historical management sought to increase the extent of grazing land in many parts of the catchment. This involved the bunding of coastal salt pan areas to prevent tidal ingress, allowing pasture grasses to become established. These areas, known as ponded pastures, are mapped as 'wetland production' under the Queensland Land Use Mapping Project classification (2009). Areas of ponded pasture restrict the exchange of tidal waters into freshwater (previously brackish) wetlands, a process which historically reduced the extent of grass and sedgelands seasonally. This in turn reduces the areas of natural production for inshore coastal waters, leading to likely declines in inshore fish and invertebrate productivity. According to QLUMP, there is 10,842 hectares of ponded pastures in the Haughton basin. These bunded areas are widespread throughout this basin.

Water – intensive use and water-storage and treatment

There are no ports or port infrastructure in this basin. Sewage dishcarge is limited to the Ayr/Brandon Sewage Treatment Plant. The other smaller settlements are currently unsewered and impact from these on the World Heritage Area are not known. Table 3.3.2 outlines the status of wastewater treatment in the main urban centres in the Haughton basin.

Table 3.3.2: Status of wastewater treatment in the Haughton basin

Urban centre	Wastewater treatment
Alva beach	Unsewered.
Cungulla	Unsewered.
Ayr	Sewered. Pilot tertiary treatment trials using duckweed undertaken in 2003. The Ayr/Brandon treatment plant is a trickling filter plant with a design capacity of 14,000 equivalent people. This plant is licensed to discharge 3.5ML/day.
Giru	Unsewered.
Brandon	Sewered.

As detailed in Section 2.5, the Haughton basin floodplain has been extensively modified with the construction of a canal network with water control gates and water storages (Figure 3.3.10). These are managed by SunWater for the purpose of irrigation water management and cover large areas of the floodplain, or by the Burdekin Water Board for the purposes of groundwater management.

Figure 3.3.10: Balancing storage - a man-made water reservoir used for delivery by SunWater

PART B: OUTCOMES OF BASIN ASSESSMENT

Chapter 4: Projected condition of Great Barrier Reef catchment values

4.1 Summary of current state of coastal ecosystems

The current status of coastal ecosystem of the Haughton basin varies across the basin. The current condition of the upper Haughton basin (the Reid River tributaries and rangelands for example) is in near pristine condition. The current condition of the Haughton basin floodplain however is poor due to decades of substantial modifications to the floodplain and floodplain function. The coastal zone, including the estuaries are in better condition however are stressed in parts and are unlikely to be functioning at their full capacity. There are many studies looking at the floodplain that focus on improving horticulture, managing water availability and assessing ecosystem health. These conflicting programs often fail to consider the basin as a whole and historic management to fix one problem has often led to another. The basin has changed, and any management actions to improve the condition of the adjacent World Heritage Area need to consider this system as a whole.

Coastal ecosystems that have been affected are forests, grass and sedgelands, forested floodplains and freshwater wetlands (Table 4.1.1). In the coastal zone, estuaries (saltmarsh and saltpan) in some areas have been bunded for the purposes of ponded pastures.

Table 4.1.1: Percentage of remaining coastal ecosystems in the Haughton basin, Haughton basin coastal zone and the Haughton basin floodplain. Orange cells indicate areas with 10-30 per cent remaining; yellow 31-50 per cent and green greater than 50 per cent. Note these figures provide no information about ecosystem condition or functionality

Haughton basin % coastal ecosystem remaining	Rainforests	Forests	Woodlands	Forested floodplain	Grass and sedgelands	Heath and shrublands	Freshwater wetlands	Estuaries
Basin wide	98	64	86	25	57	96	68	100
Floodplain	59	40	87	24	57	98	68	100
Coastal zone	39	19	79	15	64	95	68	100

Between 2006 and 2009, 356 hectares of coastal ecosystems were modified, those being 318 hectares of forest, 29 hectares of woodlands and 9 hectares of heath and shrublands. The current state of coastal ecosystems in the Haughton basin is summarised in Table 4.1.2.

Table 4.1.2: Summary of the current state of coastal ecosystems in the Haughton basin

	Coastal ecosystem	Current condition
	Rainforests	Coastal zone rainforests are most affected with 61 per cent modified and 41 per cent modified in the floodplain. Changes in seasonality of stream flows are leading to establishment of new riparian rainforest at some locations.
	Forests	Around 36 per cent modified with more used for grazing natural areas. Only 40 per cent of forests on the floodplain and 19 per cent of forests in the coastal zone remain.
	Woodlands	Reduced in extent by 14 per cent with much of the remainder under grazing regimes.
	Forested floodplain	Most heavily modified coastal ecosystem with 75 per cent loss throughout the basin and 85 per cent loss in the coastal zone. Most has been replaced with irrigated production (sugar cane).
	Grass and sedgelands	Modified with 43 per cent remaining. Remnant grass and sedgelands impacted by water from irrigation and land modification.
	Heath and shrublands	Status is good within minimal loss.
	Freshwater wetlands	Almost 32 per cent of wetlands have been modified across the basin. Remaining wetlands assessed vary in condition dependant on location, geology and hydrological regimes. Many degraded wetlands were observed during the field assessment.
	Estuaries	Mangrove systems are mostly intact and in near pristine condition. Much of the saltmarsh/saltpans have been modified with bund walls for ponded pastures and water quality assessments (Appendix G) suggest in-water impacts possible.

4.2 Outline of key current and likely future pressures and impacts on coastal ecosystems in the Haughton basin

Many ecosystem processes have been compromised in the Haughton basin. Around 32 per cent of wetlands (predominantly small ephemeral wetlands) have been lost in this basin and many of the remaining ones have been affected as a result of land use modifications such as altered flow regimes from irrigation. Weirs installed in some river systems have severely affected the physical processes that would normally occur, with repercussions for downstream ecosystems. The hydrology, connectivity and groundwater have changed significantly and are now controlled through management intervention. Nutrient enrichment, loss of riparian processes and weed infestations has forever altered the landscape in this basin. Development of adaptive and intervening management (such as managed grazing, weed control and environmental flows) is now needed to maintain the health of coastal ecosystem processes in this basin.

The Great Barrier Reef Outlook Report identified declining water quality as one of the greatest threats to the long-term health and resilience of the Great Barrier Reef. As a result, substantial investments have been made to improve land based practices with the goal of halting the decline in water quality. The water quality in the receiving waters adjacent to the Haughton River have been shown to regularly exceed Marine Park water quality guidelines and the condition of many indicator species (such as seagrass, coral cover and coral recruitment) have been reported as of moderate to low condition.[16,58,59,60,61]

A significant outcome of sub-catchment monitoring[4,56] is the substantial and persistent levels of herbicides found within the Barratta Creek system during low flow (dry season) conditions that were often above ecosystem protection guidelines of certain herbicides. These high concentrations were associated with crop irrigation (when the water system receives large volumes of tailwater from farms) and was often more than an order of magnitude higher than those documented for similar cane land dominated systems in the Great Barrier Reef.[56] Due to the low permeability of soils on older floodplain areas of the region, the amount of tailwater run-off sourced from local cane farms is significant and consequently, the middle and lower reaches of the Barratta Creek drainage complex are dominated by local irrigation tailwater input, compared to the systems previously irregular flow regime (i.e. low water levels during the dry season). Tailwater run-off and groundwater leachates contribute to increased inorganic nutrient loads, with nitrate concentrations in surface water from many systems, such as Barratta Creek, measuring above Australian water quality guidelines[62] for ecosystem protection.[15]

The upland region of the Haughton River (Figure 2.4.2) is a relatively healthy system in good overall condition. The floodplain section however is more impacted and in poor condition as a result of weirs, which is reducing flow velocity and slowing sediment transport to the coastal areas. Cungulla, a coastal settlement on the northern side of the Haughton River mouth is experiencing shoreline erosion that may be a result of the lack of coarse sediment transport.

The Barratta Creek freshwater reaches are considered to be one of the most important, healthy and productive creek systems in the Burdekin region. This system includes many large, permanent wetlands and long lengths of permanently-flowing creek where there are no major fish passage barriers.[2] Downstream reaches however have been significantly modified as a result of weed chokes that have come about from nutrient enrichment of these perennial flows. Excess nutrients have promoted growth of native sedges and introduced pasture grasses to the point where plant growth is removing much of the oxygen from the aquatic system. The construction of bund walls restricts tidal saltwater intrusion in the lower Barratta Creek which historically would have controlled growth of these weeds.

Ramsar site information is updated every six years or when substantial changes to the ecological character take place at the site as a result of technological developments, pollution or other human interferences. Notes from a recent Ecological Character Descriptions of the Bowling Green Bay Ramsar site identified that hydrological elements of ecological character (flow, level, salinity regimes of surface and groundwater) are moving towards limits of acceptable change.[42]

Sediment cores (up to four metres deep) were taken at various river delta sites within Bowling Green Bay as part of a larger study examining changes in past and present land use.[63] Cores were analysed for mercury levels and spatial and temporal excursion from those levels were detected. One core from Bowling Green Bay contained background mercury levels of 12 ppb (60 pmoles/gram) from 3.08-3.82 m depth. Within a distance of 0.4 m a sharp rise from 12 ppb (60 pmoles/gram) to 500 ppb (2500 pmoles/gram) was measured. From 2.52 m to the surface an exponential-type reduction in mercury concentration was measured. The sharp gradient of increase in mercury was attributed to a substantial input of mercury over a short period of time and may be a consequence of transport of mercury used in the amalgamation process of gold mining in the Charters Towers/Ravenswood area between 1870 and 1980.

Table 4.2.1: Summary of the current pressures and future outlook for coastal ecosystems in the Haughton basin

Pressure	Current status (1999-2009)	Description	Future outlook	Description
Agriculture (production)	Increase	Agriculture production (dryland and irrigated) has increased by 2% between 1999 and 2009. Some shift from grazing to sugar cane during in field assessment.	Increase	The lower Burdekin floodplain has been identified as a potential centre for future agricultural expansion.
Irrigation infrastructure	Increase	Water and water infrastructure increased by 27%.	Increase	Likely to increase to support an expansion of irrigated production.
Grazing	Decline	Grazing has decreased by 4% between 1999 and 2009 with shifts to irrigated sugar cane observed during field assessments.	Decline	Likely to decline further as land use shifts to more irrigated production.
Introduced species	Uncertain	Weeds (mostly introduced pasture grasses) are well established throughout the basin.	Uncertain	Ongoing control programs for weed management in place however climate change impacts are uncertain and may encourage proliferation of some weed species. Expansion of irrigation infrastructure may increase extent of aquatic and terrestrial weeds.
Climate Change	Uncertain	Not assessed.	Increase	Increase intensity of episodic events, droughts and changes in rainfall patterns all likely to impact on coastal ecosystems.
Vegetation removal	Decline	The introduction of the *Vegetation Management Act 1999* provided a regulatory framework for broad-scale land clearing across Queensland. Despite this, 269 hectares of coastal ecosystems were modified between 2006 and 2009.	Uncertain	Amendments proposed for the *Vegetation Management Act 1999.*
Urban development	No change	No major centres of urban expansion in this basin.	No significant change expected	

4.3 Current and likely future impacts on coastal ecosystems and likely resultant impacts on the World Heritage Area

The Haughton basin has changed, and any management actions to improve the condition of the adjacent World Heritage Area need to consider this system as a whole. The key current and likely future impacts on coastal ecosystems and likely resultant impacts on the World Heritage Area are summarised in Table 4.3.1.

The future prospects for the Haughton are largely dependent on the ability of managers of the lower floodplain irrigation schemes to manage the balance between irrigation, recharge groundwater and ecosystem health. If well managed, the potential to improve the health and resilience of wetland, estuarine and inshore coastal marine ecosystems (and the industries they support) are enormous. Failure to address these problems will however continue to impact on coastal ecosystems and the species they support.

Many projects have been undertaken in the Haughton basin with the goal of improving ecosystem health, especially within freshwater wetland systems. Some of these include:

- Building grower capacity to understand and better manage groundwater - Haughton/Upper Water Balance Study – Australian Government Sugar Research and Development Corporation and stakeholders.
- Burdekin Water Futures groundwater projects.
- NQ Dry Tropics – on-ground projects to restore connectivity.
- Wetlandcare Australia – delivering biodiversity dividends for the Barratta Creek catchment.
- CSIRO – modelling effects of Val-Bird Weir height on watertables along the Haughton River.
- CSIRO/North Burdekin Water Board – Water Resources Observation Network
- North Burdekin Water Board – Conceptual Water Management Plan for the Airdmillan area.
- Burdekin Bowen Integrated Floodplain Management Advisory Committee Incorporated – Grower groundwater water quality monitoring project in the Barratta Creek sub-basin.
- TropWATER – Aquatic Ecosystems of Barratta Creek (June 2007).

Substantial investment is needed to evaluate the research to date, to consider future objectives for the basin (i.e. balancing land use with ecosystem health) and to progress a way forward keeping in mind the Haughton basin has changed.

Agriculture/grazing

The Burdekin Bowen Integrated Floodplain Management Advisory Committee Inc. (BBIFMAC) promotes an integrated, strategic and community-driven approach to the management of natural resources within these regions. BBIFMAC supports the sustainable development of primary industries and the local economy for the long-term benefit of present and future generations through running, supporting and collaborating on various projects.

BBIFMAC has addressed concern regarding the current state of the Haughton River and engaged with the North Queensland Dry Tropics (NQDT) NRM group to address the problems faced by the Haughton River and to become involved with remedial actions.

Reef Plan (2009) set specific ‘water quality’ targets for the reduction of pollutant loads to the Great Barrier Reef lagoon across the adjacent catchment area. Pollutants were chosen based on their risk to receiving water environments (nitrate, herbicides, particulate nitrogen and phosphorus and sediment) and targets were based on a combination of previous targets set for the Great Barrier Reef catchment area by the Great Barrier Reef Marine Park Authority. Improved sugar cane management practices have been designed to benefit the Reef and water quality targets have been set for the export of pollutants from the Haughton basin.

One of the aims of Reef Plan is to reduce the amount of pollutants entering coastal waterways and reef ecosystems.[64] Reef Plan began the Great Barrier Reef Coastal Wetlands Protection Program in 2003 with the goal of implementing long-term conservation and management of priority wetlands in the Great Barrier Reef Catchment.[15] Program outputs have included management investment strategies for wetlands including the Barratta Creek,[30] as well as positive impacts on weed management, vegetation management and fish passage constraints.[65]

In 2008, Reef Rescue funded on-ground land management projects across the catchment area that focus on sugar cane and grazing industries, as well as dairy farming and horticulture to a lesser extent.[15] New farming practices such as machinery modifications, fertiliser and pesticide application gear, cultivation and tillage equipment and practices have been introduced. Research conducted by Davis et al. (2008; 2011) has highlighted that although much of the water quality management is focused on the Reef environment, freshwater and estuarine ecosystems in this region currently face the highest risks from agriculture related water quality reductions.[4,56]

Reef Rescue initiatives have been implemented in the Haughton River catchment that include grazing grants to promote better soil health, control gully and stream bank erosion, improve water quality through riparian fencing and spreading of waters to exclude stock from creeks and rivers. Water quality improvement grants are also attainable for growers that use effective chemical application rates, reduce off-farm run-off, and apply fertiliser in a precise manner to promote better soil health.

Table 4.3.1: Key current impacts and likely future impacts in the Haughton basin and likely consequences for the World Heritage Area

Current impacts on Coastal Ecosystems	Trend 1999-2009	Current likely impacts as a result on the World Heritage Area	Future likely impacts on Coastal Ecosystems	Future likely impacts on the World Heritage Area
Broadscale clearing of coastal ecosystems for agriculture, urban or industry	Rates of clearing have declined as a result of the *Vegetation Management Act 1999.*	Loss of ecological process and connectivity, replacement of some ecological processes depending on the nature of the modified system.	Coastal ecosystems unlikely to be returned to their former state and further losses expected.	Some clearing likely to occur as land use shifts from grazing natural areas to agricultural production.
Farm run-off	Improvements as a result of increasing rates of Best Management Practice uptake.	Improvements to water quality expected, although delayed due to lag effects. Changes in land use will not be obvious for a few years.	Dependant on extent of new horticulture and uptake of Best Management Practice.	Water quality expected to improve over time although may be offset by expansion of irrigated agricultural production.
Groundwater changes	Increasing salinity occurring in the basin; rising watertables and flooding in parts; seasonal streams now perennial in some areas.	Potential decline in biological and biogeochemical processes, changes to connectivity.	Groundwater is currently managed by two different organisations with conflicting focuses.	Significant impacts to inshore coastal ecosystems.
Stream/river bank erosion	Increasing as a result of extreme weather events. Legacy issues from historical clearing.	Increases in suspended sediments and turbidity in coastal waters; increases in sediment (sand) build up in waterways (e.g. Haughton River).	Management actions (e.g. Reef Plan) underway to restore riparian areas.	Likely to improve under uptake on Best Management Practice and restoration projects.
Declining water quality	Improvements in recent years.	Decline in inshore ecosystem health and resilience from nutrients and pesticides in irrigation tailwater.	Likely to improve as a result of management actions targeted at improving water quality.	Improvements expected but will take time to take effect.
Barriers to fish migrations	Sand has built up in the Haughton River.	Reduction/loss of connectivity and fish passage. Barriers may be cause of lack of sand replenishment in coastal areas.	Ongoing loss of coarser sands to the coastline.	As for current impacts.
Introduced terrestrial weeds	Established throughout the basin (mostly in modified landscapes).	Introduced grasses generate hotter fires that can destroy forest canopies and expose soil which can be eroded, especially when fires occur late in the dry season	Eradication to date has been ineffective and many grasses are still used for pasture grass. Strategic basin scale management	Likely to lead to increases in erosion and therefore more suspended sediments in the World Heritage Area unless management actions

			actions are needed to manage.	implemented.
Introduced aquatic weeds	Introduced aquatic weeds are well established in the basin. Changes in flow are removing periods of seasonal drying that normally 'cull' native sedges. As a result native sedges are overgrowing effected wetlands.	Leads to lowered oxygen levels in aquatic ecosystems that render habitats unsuitable for most native fish species. Create blackwater pulses that cause downstream fish barriers. Act as a barrier to fish movement.	Ongoing decline of wetlands and associated floodplain ecosystems.	If weeds continue to proliferate a reduction in water quality, fish habitat and connectivity are likely to occur.
Changed overland hydrology	Most development/modification has occurred on the floodplain and coastal zone.	Changes to connectivity and water retention which has impacted on all ecological processes.	Ongoing weed problems.	Likely decline in water quality and aquatic biodiversity in the GBRWHA.
Ponded pasture/wetland production	It became illegal to establish new ponded pastures in the coastal zone in 2001 (policy for development and use of ponded pasture).	Loss of connectivity and declines in fish productivity, blackwater, and the potential release of acid sulphate soils.	Plans to modify ponded pastures to improve ecosystem health. Bunds can be rebuilt if lost however.	Improved productivity, ecosystem health and resilience.

Water quality

Water quality remains the greatest current and future risk to the World Heritage Area from the Haughton basin. Declining water quality in the Haughton basin can be attributed to the accumulation of:

- Irrigation tailwater
- Nutrient and herbicide application
- Septic tanks from coastal development
- Aquaculture discharge
- Changes to hydrology from irrigation pumping, changed flow regimes
- Weed infestation
- Sugar refinery discharge.

Any further loss of coastal ecosystems will continue to reduce the capacity to provide ecological functions (such as nutrient assimilation) for the World Heritage Area. In addition, the extent of habitat for species with connection to the Reef has been reduced and, if these reductions continue, will reduce the gross value of production of commercial and recreational species. This includes the changes to hydrology, which also pose a risk to farming and urban infrastructure in some parts of the Haughton basin.

Figure 4.3.1 provides an example of the relationships between pressures, state and impact from increased pollutants being delivered to the Great Barrier Reef.[66] Note that these sequential impacts are linked primarily to nutrient loading scenarios, and do not define the cumulative impacts from increasing temperature and nutrients, or from other pollutants such as suspended sediment and pesticides. Recent work[67,68,69] indicates that the combined impacts of rising temperatures and increasing nutrients, particularly dissolved inorganic nitrogen (DIN), will result in reduced resilience of coral reefs to recover from more frequent bleaching events.[66]

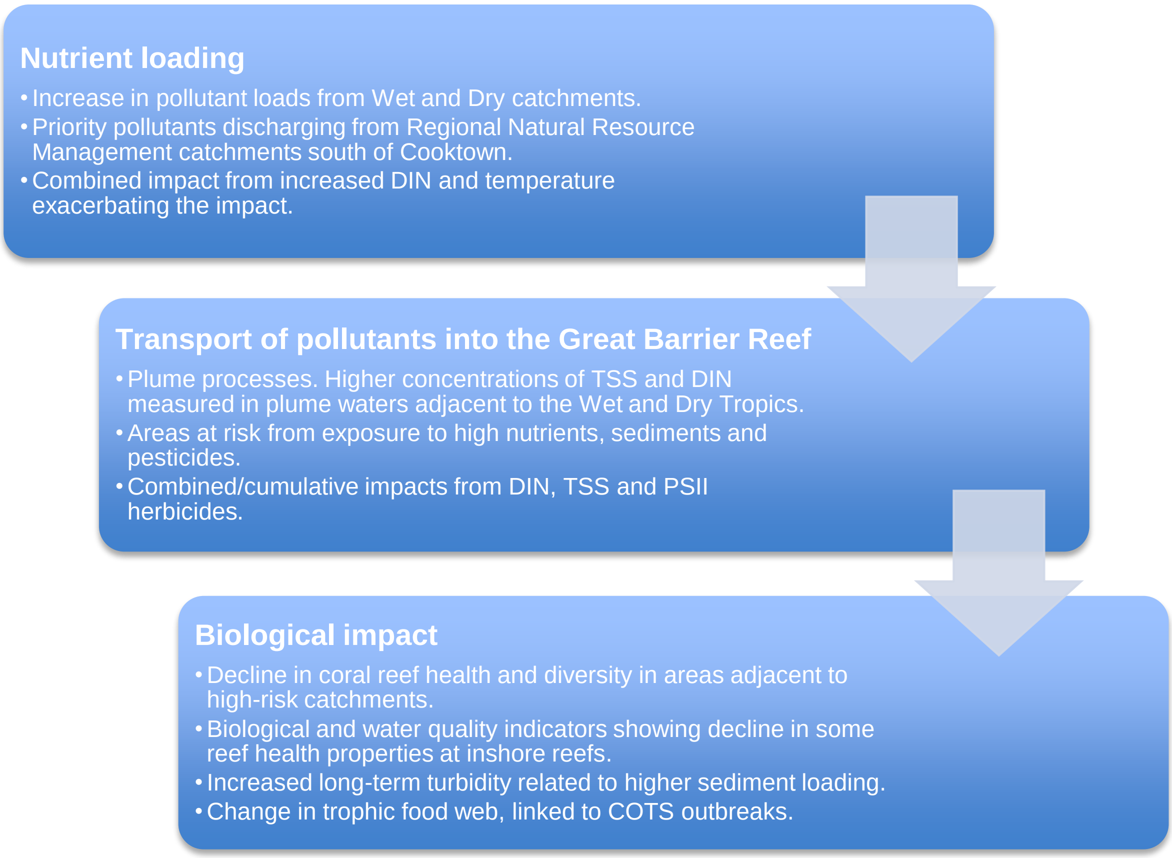

Figure 4.3.1: Pathway from nutrient enrichment to biological impact from total suspended solids (TSS); dissolved inorganic nitrogen (DIN); photosynthesis inhibiting herbicides (PSII); and crown-of-thorns starfish (COTS)

The impacts of increasing sediments and nutrients on coral reefs (Figure 4.3.2) and seagrass (Figure 4.3.3) include shading, reduced resilience and reduced recruitment.[66,70] Abundances of a range of other reef associated organisms have also been shown to change along water quality gradients.[66]

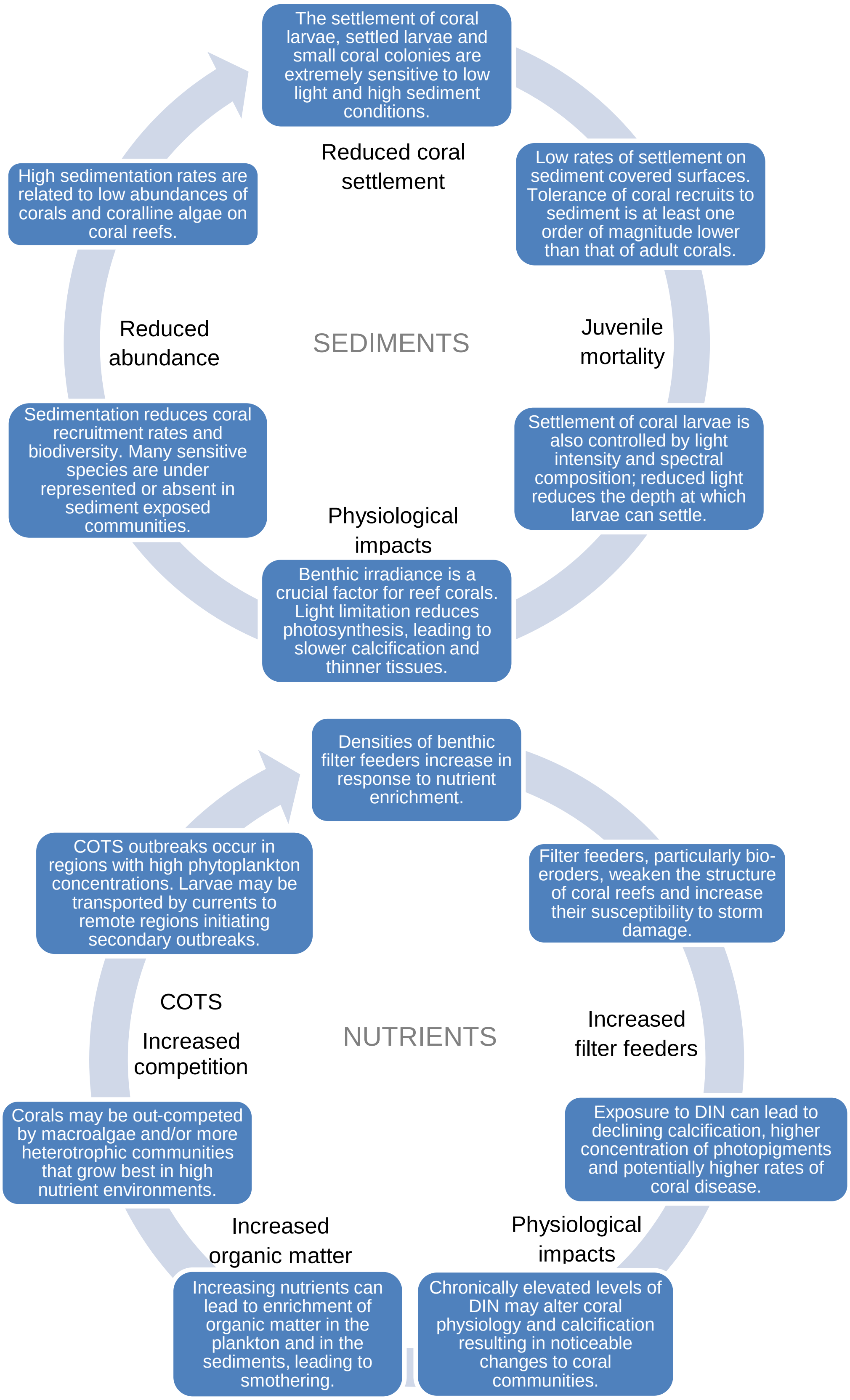

Figure 4.3.2: Potential and known impacts of increasing nutrients and sediments on coral reefs[66]

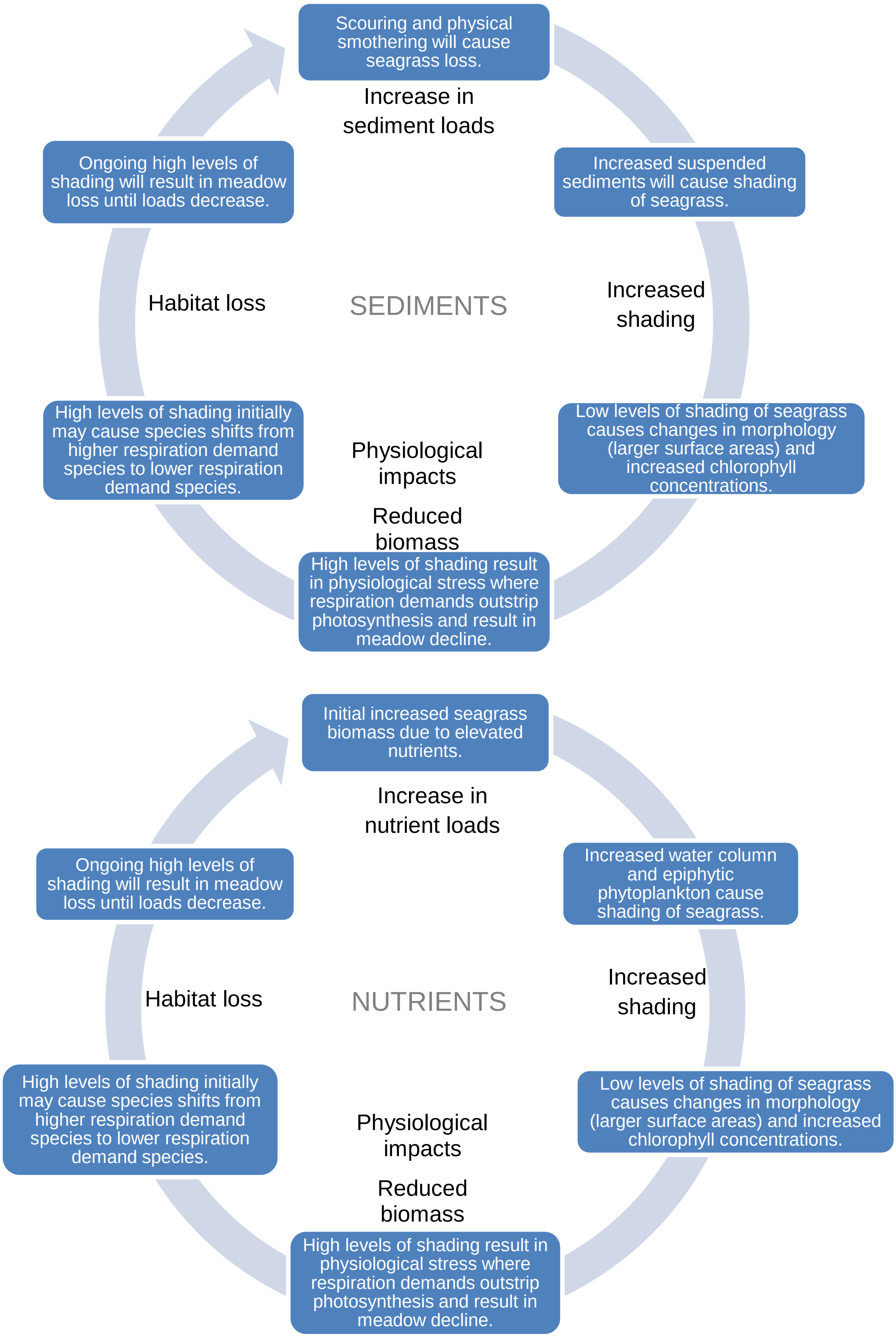

Figure 4.3.3: Potential and known impacts of increasing nutrients and sediments on seagrass beds[66]

The current best estimates of modelled loads leaving the Haughton River basin are provided in Table 4.3.2.[71] After the implementation of the Reef Rescue program in 2008, an improvement in load values was observed for TSS, DIN, PN, TN, PSII herbicides, PP and TP. For example, modelled dissolved inorganic nitrogen (DIN) export values from the

Haughton River basin showed that the total export in 2008/2009 (502 t/yr) had increased approximately 18-fold compared to pre-development loads (28 t/yr). However, after the implementation of the Reef Rescue program (2009/2010) values decreased to 362 t/yr, which is a 29.5 per cent improvement. Improvements for DON, DIP and DOP loads have not yet been measured.

Table 4.3.2: Best estimates of modelled total pre-development values, current values, and anthropogenic changes in water quality parameters. Reef Rescue values represent the values after the commencement of the Reef Rescue program and Reef Rescue change represents the improvement (%) after implementation

	Pre-development	Current (2008/2009)	Current (2009/2010)	Anthropogenic Baseline	Reef Rescue (2009/2010)	Reef Rescue change (%)	Total Change (%)
TSS (kt/yr)	78	250	248	172	249	0.6	1.1
DIN (t/yr)	28	502	362	474	362	29.5	29.5
DON (kt/yr)	120	205	205	85	205	0	0
PN (t/yr)	83	272	270	189	270	0.8	1.3
TN (t/yr)	231	980	837	749	838	18.9	19.0
PSII (kg/yr)	0	1426	1276	1426	1276	10.5	10.5
DIP (t/yr)	10	41	41	31	0	0	0
DOP (t/yr)	10	19	19	9	0	0	0
PP (t/yr)	32	140	138	108	139	0.9	1.3
TP (t/yr)	52	200	199	148	199	0.7	0.9

4.4 Priorities for conservation and restoration

The coastal ecosystems in the Haughton basin have changed significantly over the last century. These changes are mostly irreversible and future management needs to be adaptive and innovative. The changes to hydrology and the establishment of African and South American weeds have changed the coastal ecosystems in much of this basin. Conservation and restoration design needs to consider the changed hydrology and more intense fire regimes. This needs to occur strategically at a whole of landscape scale in partnership with industry.

Coastal ecosystems located in the floodplain and coastal zone are those that have experienced the greatest losses and those most at risk in the future. Future conservation measures should include protection of these ecosystems from further decline and impacts and restoration efforts should focus on these areas. These areas are also the areas at greatest risk from flooding, storm and climate change impacts so high value infrastructure, such as residential and industrial development should be avoided in these areas. Current infrastructure in these areas needs to be managed to current best practice.

Coastal ecosystems outside of these zones should be retained where possible. As it stands today, the Haughton basin can no longer afford to lose any more coastal ecosystems. There is a strong need to restore ecological processes through improvements to land use management, ecological sustainable design and ecosystem restoration. The floodplain coastal ecosystems are currently at greatest risk.

As with much of the Great Barrier Reef catchment, many of the issues affecting the health and resilience of the Marine Park adjacent to this basin stem from legacy issues such as broadscale vegetation clearing. Current legislation should prevent recurrence of many of these issues however management actions to recognise and rectify these problems are rare. Riverbank erosion is still occurring due to upstream channelisation, clearing, loss of riparian vegetation and weed species all of which reduce habitat for native species with connections to the Reef. While the rate of loss has been reducing over the last decade, riparian vegetation continues to decrease.[17,72]

Coastal zone

Coastal ecosystems in the coastal zone generally have the closest connections to the World Heritage Area and generally have a higher capacity to provide physical, biological and biogeochemical processes for the World Heritage Area. Some coastal ecosystems in the coastal zone also fall within the World Heritage Area. The coastal zone is also the area at greatest risk from the impacts of climate change. Actions that could be taken to reduce pressure on the coastal zone in the Haughton basin include:

- Limit further loss of remaining coastal ecosystems.
- Increased protection provided to remaining coastal ecosystems.
- Restore riparian corridors in this area to a standard that provides effective ecological functions. Any revegetation should consider the appropriateness of using species adapted for future climate scenarios.
- Improve agricultural practices to current best practice standards including a shift from furrow irrigation to trickle irrigation.
- Limit further intensive development in the coastal zone. This will not only reduce environmental impacts, but may also reduce the risk of economic impacts resulting from future climate change, as scenarios predict that the coastal zone will be at greatest risk from sea-level rise and storm surge.
- Consider measures (including compliance) to restrict vehicle and pet access to sensitive areas (such as turtle nesting beaches and important migratory bird sites).
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.
- Hydrological regimes need to be holistically managed to assist conservation and restoration activities.

Floodplain

Floodplains support particularly rich coastal ecosystems, especially in terms of diversity and abundance. These areas are important for the physical, biological and biogeochemical processes they provide for the long-term health and resilience of the World Heritage Area.

The floodplain in the Haughton basin has been heavily modified. Actions that can be taken to reduce pressure on the floodplain include:

- Limit further loss of remaining coastal ecosystems.
- Increased protection afforded to remaining coastal ecosystems.
- Restore riparian corridors in this area to a standard that provides effective ecological functions. Any revegetation should consider the appropriateness of using species adapted for future climate scenarios.
- Lower the height of ponded pasture bund walls distributed throughout the coastal zone to a height that allows king tides to flow over the bunds, providing for fish passage and natural weed control. Seawater has been shown to be an effective tool for preventing overgrowth of native sedges and introduced pasture grasses such as *Hymenachne*.
- Improve connectivity between remnant coastal ecosystems within the floodplain.
- Improve agricultural practices to current best practice standards including a shift from furrow irrigation to trickle irrigation and the use of tailwater retention, recycle and treatment ponds.
- Future urban developments that cannot be sited outside of the floodplain should be constructed to current best practice, employing principles such as water sensitive urban design, gross pollutant traps and tertiary sewage treatment.
- Limit further intensive development in the floodplain. This will not only reduce environmental impacts, but may also reduce the risk of economic impacts resulting from future climate change, as scenarios predict that the floodplain will be at increased risk from flooding.
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.
- Hydrological regimes need to be holistically managed to assist conservation and restoration activities.

Riparian zones and waterways

Riparian vegetation provides important physical, biological and biogeochemical processes essential for the long-term health and resilience of the World Heritage Area. Riparian vegetation slows water velocity and provides areas of nutrient cycling, fish habitat and pathways for fish passage and connectivity across the basin. Actions that can be taken to reduce pressure on the riparian zones include:

- Restore riparian corridors to a standard that provides effective ecological functions. Any revegetation should consider the appropriateness of using species adapted for future climate scenarios and should consider adjacent land use.
- Seek to protect or reinstate in-stream habitat to provide improved flow regulation and fish habitat structure.
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.

- Limit further construction of dams and weirs in this basin where they might impact on coastal ecosystems or the Marine Park, and consider the lowering or removal of dams and weirs to improve connectivity and lower groundwater levels.
- Further development adjacent to waterways should not increase point and non-point source pollutants entering waterways.

Wetlands

Wetlands provide habitat for many species with connections to the World Heritage Area and are often referred to as the 'kidneys of the Reef'. Wetlands provide important physical, biological and biogeochemical processes that support the long-term health and resilience of the World Heritage Area. Actions that can be taken to reduce pressure on wetlands include:

- Limit further loss of wetlands.
- Increased protection of remaining wetlands.
- Restore wetlands where possible.
- Improve connectivity between wetlands and the World Heritage Area.
- Control and manage introduced species that compromise wetland health.

Hydrological Connectivity

The hydrological processes within catchments set the backbone of all ecosystem functions and water quality outcomes. These catchment ecosystems and water quality outcomes in turn are in direct connection with the health of the marine environment to which they drain, and have therefore been of increasing concern for the long-term health of the Great Barrier Reef.[73] Potential management actions for improving hydrological connectivity include:

- Accurately assessing and modifying dams, weirs and ponded pastures to promote hydrological connectivity.
- Appropriate modification of fish barriers to improve fish populations through increased access and opportunity for species migration.
- Restore stream, river and waterway connectivity to achieve effective fish passage.

Other Areas

Areas outside of the coastal zone and floodplain still provide some physical, biological and biogeochemical processes to the World Heritage Area. Potential management actions for these areas include:

- Restore riparian corridors in this area to a standard that provides effective ecological functions. Any revegetation should consider the appropriateness of using species adapted for future climate scenarios.
- Improve agricultural practices in areas where riparian vegetation is minimal or non-existent.
- Add currently assigned logging areas to the protected area estate as these are adjacent to relatively natural waterways.

4.5 Potential management actions

This report has been developed as a baseline for the Haughton basin. In order to ensure that the basin is best represented, consideration of additional finer scale data, local knowledge and information will further enhance this assessment.

Restoration of the ecological functions in this basin is not simple. Land use change, artificial barriers and drainage channel construction is an issue in the Haughton basin and affect overland flow and groundwater. Despite major ecosystem disturbance, in general many freshwater ecosystems have shown recent improvements in health. This may be due to major investment in aquatic weed management and riparian vegetation planting, improved knowledge and management, or as a result of several years of flooding that has effectively 'reset the system'. Based on the information collected in this basin assessment, potential management actions include:

1. Encourage strategic vegetation management, including planting climate change adapted species and plants designed to address the modified landscape (e.g. rainforest species in areas where water is perennial due to irrigation, deep rooted trees planted on the floodplain to assist in managing the rising groundwater and salinity).
2. A coordinated effort incorporating the vast array of data and reports and recognition that any planning for the area (in particular water use) could consider the Burdekin and Don basins. The Haughton basin itself was once part of the lower Burdekin delta and as such, is strongly influenced by the Burdekin River.
3. Public participation and engagement in the development of plans and prioritisation of works.
4. Incorporation of this basin assessment into regional and local planning documents.
5. Plan and manage new land use to have no net impact on the World Heritage Area.

4.6 Knowledge gaps

A considerable amount of local research has been conducted in the cane growing region of the lower Burdekin which includes the Haughton basin. Research has addressed pesticide movement dynamics over a range of scales including surface water-groundwater interface,[74,75] floodplain waterway and drainage systems,[56,76,77] end of riverine catchments,[56] riverine flood plumes in adjacent marine environments,[11,56,78] riparian vegetation,[79] groundwater[74,80,81,82,83,84,85,86]sediment movement patterns,[87,88] and seawater intrusion.[43,56,57] (refer Appendix G).

In assessing this basin, a number of knowledge gaps were identified. These included:

- Reef Plan focuses on sediments, nutrients and pesticides, but further water quality research is required that relates to pollutants that are not covered by Reef Plan, such as microplastics, pharmaceuticals etc., and their effects on the World Heritage Area.
- Implications of agricultural chemicals on the marine environment.
- Effectiveness of current marine monitoring sites. Current sites in this basin are limited to locations that provide ease of access and do not necessarily reflect monitoring at specific river mouths. Integrated monitoring of in-stream and river mouth water

quality and ecosystem health would provide more pertinent information on the ability of remaining coastal ecosystems to provide functions to maintain the health and resilience of the Great Barrier Reef.
- Lack of ongoing freshwater water quality monitoring.
- Best adaptive management practices for modified systems.
- How to re-introduce seasonality.
- Merits of conjunctive use of groundwater-surface water in the Burdekin Haughton Water Supply Scheme.
- Role of institutional issues in water management outcomes.
- Impact of blackwater/anoxia and perennial wet organic/nutrient loads versus seasonal drawdown.

Much of the Haughton basin floodplain is afflicted by cumulative impacts, many of which have downstream impacts on other systems. Ecosystems have changed as a result of these impacts (such as introduced weeds and changed hydrology) and these changes are likely irreversible. A new holistic adaptive management approach is required to develop management actions that consider this changed landscape and lead to the development of integrated adaptive management of the floodplain as a whole. Such an approach should consider the cost/benefits of more natural versus modified floodplain wetlands as instigators of pollutant loads in nearshore coastal areas and the World Heritage Area.

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Appendix A – Field Assessment Template

<table>
<tr><td>Date</td><td>Basin Name</td><td>Latitude (-18.861499)</td><td>Camera No</td><td>Photo No</td></tr>
<tr><td>Time</td><td>Way Point</td><td>Longitude (145.865234)</td><td colspan="2">Photo no.</td></tr>
<tr><td colspan="5">Team Members</td></tr>
<tr><td colspan="5">Experts</td></tr>
<tr><td colspan="5">Site Name</td></tr>
<tr><td colspan="5">Site Description</td></tr>
<tr><td colspan="5">Site Condition (circle): Excellent Good Average Poor Very poor Unknown</td></tr>
<tr><td colspan="5">Coastal Ecosystems: Coral Reef Open Water Lagoon Floor Seagrass Coastline Estuaries Freshwater Wetlands Mangroves Saltmarshes Heath and Shrublands Grass and sedgelands Forested Floodplain Woodlands Forests Rainforests</td></tr>
<tr><td colspan="5">Condition: intact fragmented cleared other</td></tr>
<tr><td colspan="5">Landuse: Conservation and natural environments (inc wetlands), Forestry: dryland or irrigated plantation, Grazing: dryland, irrigates or natural vegetation Intensive: commercial, mining, animal production, urban residential Production: dryland or dryland sugar, Production forestry, Water: marsh wetland production or intensive use, water storage and treatment, uncertain</td></tr>
<tr><td colspan="5">Direct Impacts (threats):</td></tr>
<tr><td colspan="5">Direct Impacts (threats):</td></tr>
<tr><td colspan="5">Indirect Impacts / Threats:</td></tr>
<tr><td colspan="5">MNES or threatened species</td></tr>
<tr><td colspan="5">Other Information</td></tr>
</table>

Appendix B – Key Terminology used in this report

Basins:	An extent or an area of land where surface water channels to a hydrological network and discharges at a single point i.e. river, stream, creek. Defined by Queensland Government and may include many sub-basins.
Coastal zone:	Area of coast as defined by the *Coastal Protection and Management Act 1995* (Queensland)
Coastal Ecosystem:	Marine, estuarine, freshwater and terrestrial ecosystems that connect the land and sea and have the potential to influence the health and resilience of the Great Barrier Reef. For this study, this includes the Great Barrier Reef catchment and 10% of the Reef waters seawards of the coastline.
Ecosystem:	A dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit. Source: Millenium Ecosystem Assessment 2005.[89]
Ecosystem function:	The interactions between organisms and the physical environment, such as nutrient cycling, soil development and water budgeting.
Inshore marine areas:	Include (but not limited to) those areas extending up to 20 km offshore from the coast and which correspond to enclosed coastal and open coastal water bodies as described in the *Water Quality Guidelines for the Great Barrier Reef Marine Park (2010)*.[90]
Great Barrier Reef catchment (catchment):	The 35 river basins in Queensland which drain into the Great Barrier Reef (Table 1).
Natural Resource Management (NRM) regions:	A group of basins managed by non-government organisations (NRM bodies) within Queensland (Table 1).
Natural Resource Management (NRM) bodies:	Non-government organisations focused on environmental and sustainable agriculture programs and activities.
Non Remnant:	Vegetation that does not meet the criteria of remnant vegetation as defined under the Vegetation Management Act 1999.
Pre-clear:	Queensland Government reconstruction of regional ecosystems to represent vegetation pre-European settlement.
Post-clear:	Queensland Government mapping of the state of regional ecosystems that occurred in 1999 and 2009.
Remnant vegetation:	Vegetation that meets all of following criteria: • 50 per cent of the predominant canopy cover that would exist if the vegetation community were undisturbed. • 70 per cent of the height of the predominant canopy that would exist if the vegetation community were undisturbed. • Composed of the same floristic species that would exist if the vegetation community were undisturbed.
Regional ecosystem:	Regional ecosystems (REs) are vegetation communities that are consistently associated with a particular combination of geology, land form and soil in a bioregion. The Queensland Herbarium has mapped the remnant extent of regional ecosystems for much of the State using a combination of satellite imagery, aerial photography and on-ground studies. Each regional ecosystem has been assigned a conservation status which is based on its current remnant extent (how much of it remains) in a bioregion. Some areas of Cape York have not been mapped.
Sub-basin	Smaller catchment area situated within a basin.
Vulnerability:	The degree to which a system or species is susceptible to, or unable to cope with, adverse effects of pressures. Vulnerability is a function of the character, magnitude, and rate of variation or change to which a system or species is exposed, its sensitivity, and its adaptive capacity.

Appendix C – Values and their elements that underpin matters of national environmental significance

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance (MNES)						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Biodiversity - Habitats							
Islands	✓	✓				✓	✓
Beaches and coastlines	✓	✓				✓	✓
Mangroves	✓	✓				✓	✓
Seagrass meadows	✓	✓				✓	✓
Coral reefs (<30m)	✓	✓				✓	✓
Mesophotic (deep water) corals	✓	✓				✓	✓
Lagoon floor	✓	✓				✓	✓
Shoals	✓	✓				✓	✓
Halimeda banks	✓	✓				✓	✓
Continental slope	✓	✓				✓	✓
Open waters	✓	✓				✓	✓
Saltmarshes	✓	✓	✓			✓	✓
Freshwater wetlands	✓	✓	✓			✓	✓
Forest floodplain	✓	✓				✓	✓
Heath and shrublands	✓	✓				✓	✓
Grass and sedgelands	✓	✓	✓			✓	✓
Woodlands	✓	✓				✓	✓
Forests	✓	✓				✓	✓
Rainforests	✓	✓		✓		✓	✓
Biodiversity - Species							
Dune & saltmarsh plants	✓	✓					
Mangroves	✓	✓				✓	✓
Seagrasses	✓	✓				✓	✓
Macroalgae	✓	✓				✓	✓
Benthic microalgae	✓	✓				✓	✓
Corals	✓	✓				✓	✓
Seahorses and allies	✓	✓				✓	✓
Other invertebrates	✓	✓				✓	✓
Plankton and microbes	✓	✓				✓	✓
Bony fish	✓	✓				✓	✓
Sharks and rays	✓	✓		✓	✓	✓	✓
Sea snakes	✓	✓				✓	✓
Marine turtles	✓	✓		✓	✓	✓	✓
Estuarine crocodile	✓	✓			✓	✓	✓

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance (MNES)						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Seabirds	✓	✓		✓	✓	✓	✓
Shorebirds	✓	✓		✓	✓	✓	✓
Whales	✓	✓		✓	✓	✓	✓
Dolphins	✓	✓			✓	✓	✓
Dugongs	✓	✓				✓	✓
Ecosystem Processes – Physical processes							
Ocean currents	✓	✓				✓	✓
Cyclones & wind	✓	✓				✓	✓
Freshwater inflow	✓	✓				✓	✓
Sedimentation	✓	✓	✓			✓	✓
Sediment re-suspension	✓	✓				✓	✓
Sea level	✓	✓				✓	✓
Sea temperature	✓	✓				✓	✓
Light	✓	✓				✓	✓
Aquatic connectivity	✓	✓	✓				
Ecosystem Processes – Geomorphological processes							
To be determined (SEWPaC advice)							
Ecosystem Processes – Chemical processes							
Nutrient cycling	✓	✓	✓			✓	✓
Pesticide accumulation	✓	✓	✓			✓	✓
Ocean acidity	✓	✓				✓	✓
Ocean salinity	✓	✓				✓	✓
Ecosystem Processes – Ecological processes							
Microbial processes	✓	✓				✓	✓
Particle feeding	✓	✓				✓	✓
Primary production	✓	✓	✓			✓	✓
Herbivory	✓	✓				✓	✓
Predation	✓	✓	✓			✓	✓
Symbiosis	✓	✓				✓	✓
Bioturbation	✓	✓				✓	✓
Reef building	✓	✓				✓	✓
Competition	✓	✓				✓	✓
Ecological connectivity	✓	✓	✓			✓	✓
Recruitment	✓	✓	✓			✓	✓
Heritage – Outstanding Universal Value							
Superlative natural phenomena, exceptional natural beauty and aesthetic importance (Criterion VII)	✓	✓	✓				
Geological processes and geomorphic	✓	✓	✓				

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance (MNES)						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
features (Criterion VII)							
Ecological and biological processes (Criterion IX) See Ecosystem Processes	✓	✓	✓				
Natural habitats for conservation of biodiversity (Criterion X) See Biodiversity - Habitats	✓	✓	✓				
Integrity	✓	✓	✓				
Heritage – Natural							
See Biodiversity and Ecosystem Processes above							
Heritage – Indigenous							
Cultural practices, observances and customs						✓	✓
Sacred sites, sites of significance, places for cultural tradition						✓	✓
Stories, song lines and marine totems	✓	✓				✓	✓
Indigenous structures, tools and archaeology	✓	✓				✓	✓
Places of historic significance - Indigenous						✓	✓
Places of aesthetic value - Indigenous						✓	✓
Heritage – Non-Indigenous							
Places of historic significance – historic shipwrecks						✓	✓
Places of historic significance - World War II features and sites						✓	✓
Places of historic significance - lighthouses							
Places of historic significance – other							
Places of scientific significance (research stations, expedition sites)						✓	✓
Places of aesthetic value See OUV - Criterion VII	✓	✓	✓			✓	✓
Places of social significance – iconic sites			✓			✓	✓
Community benefits derived from the Great Barrier Reef Region							
Income	✓	✓	✓			✓	✓
Employment	✓	✓	✓			✓	✓
Understanding and appreciation	✓	✓	✓			✓	✓
Enjoyment			✓			✓	✓
Access to Reef resources			✓			✓	✓
Personal attachment			✓			✓	✓
Social relationships			✓			✓	✓

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance (MNES)						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Health benefits			✓			✓	✓

Appendix D – Threatened species of the Haughton basin

Birds

Erythrotriorchis radiatus
Fregetta grallaria grallaria
Geophaps scripta scripta
Neochmia ruficauda ruficauda
Poephila cincta cincta
Rostratula benghalensis (sensu lato)
Sternula nereis nereis

Frogs

Litoria rheocola

Mammals

Dasyurus hallucatus
Dasyurus maculatus gracilis
Megaptera novaeangliae
Phascolarctos cinereus (combined populations of QLD, NSW and the ACT)
Pteropus conspicillatus
Rhinolophus philippinensis (large form)
Saccolaimus saccolaimus nudicluniatus
Xeromys myoides

Plants

Bulbophyllum globuliforme
Croton magneticus
Eucalyptus raveretiana
Hydrocharis dubia
Leucopogon cuspidatus
Marsdenia brevifolia
Omphalea celata
Streblus pendulinus
Tylophora williamsii

Reptiles

Caretta caretta
Chelonia mydas
Dermochelys coriacea
Egernia rugosa
Eretmochelys imbricata
Lepidochelys olivacea
Natator depressus

Appendix E – Migratory species of the Haughton basin

Aves (Birds)
Bar-tailed Godwit
Black-faced Monarch
Black-tailed Godwit
Broad-billed Sandpiper
Cattle Egret
Common Sandpiper
Curlew Sandpiper
Double-banded Plover
Eastern Curlew
Fork-tailed Swift
Great Egret, White Egret
Great Knot
Greater Sand Plover, Large Sand Plover
Grey Plover
Grey-tailed Tattler
Latham's Snipe, Japanese Snipe
Lesser Sand Plover, Mongolian Plover
Little Curlew, Little Whimbrel
Marsh Sandpiper, Little Greenshank
Oriental Plover, Oriental Dotterel
Pacific Golden Plover
Painted Snipe
Red Knot, Knot
Red-necked Stint
Ruddy Turnstone
Rufous Fantail
Sanderling
Sarus Crane
Satin Flycatcher
Sharp-tailed Sandpiper
Spectacled Monarch
Terek Sandpiper
Whimbrel
White-bellied Sea-Eagle
White-throated Needletail
Mammalia (Mammals)
Dugong
Humpback Whale
Reptilia (Reptiles)
Flatback Turtle
Green Turtle
Hawksbill Turtle

Leatherback Turtle, Leathery Turtle, Lute
Loggerhead Turtle
Olive Ridley Turtle, Pacific Ridley Turtle
Salt-water Crocodile, Estuarine Crocodile

Appendix F – Ecological processes

Ecological processes of natural coastal ecosystems linked to the health and resilience of the Great Barrier Reef. Islands have been excluded as they vary considerably between island types.

Process	Ecological Service	Coral Reefs	Lagoon floor	Open water	Seagrass	Coastline	Estuaries	Freshwater wetlands	Forest floodplain	Heath and shrublands	Grass and sedgelands	Woodlands	Forests	Rainforests
	Physical processes- transport and mobilisation													
Recharge/discharge	Detains water						MH	H	✓					
	Flood mitigation						M	✓	H		L			
	Connects ecosystems						✓	H	H					
	Regulates water flow (groundwater, overland flows)	H	L		✓	✓	MH	H	✓		L	MH	MH	H
Sedimentation/ erosion	Traps sediment	M	MH	ML	M		H	H			L	MH	MH	MH
	Stabilises sediment from erosion		✓		M	H	✓	✓	✓	✓	L	MH	MH	M
	Assimilates sediment					✓	✓	H				MH	MH	H
	Is a source of sediment							M				MH	MH	
Deposition and mobilisation processes	Particulate deposition & transport (sed/nutr/chem. etc.)							H						
	Material deposition & transport (debris, DOM, rock etc.)							H						
	Transports material for coastal processes							H						
	Biogeochemical Processes – energy and nutrient dynamics													
Production	Primary production	✓	✓	H	H	✓	H	H				M	M	H
	Secondary production				H	✓	H	✓						
Nutrient cycling (N, P)	Detains water, regulates flow of nutrients							H						
	Source of (N,P)				M	L	H					M	M	H
	Cycles and uptakes nutrients	L	H	H	M	L	H	MH		✓	✓			
	Regulates nutrient supply to the reef				M	L	H	M	H			M	M	H

Carbon cycling	Carbon source				M	L	H	H						H
	Sequesters carbon	✓	H	L	M	L	H	H	✓					
	Cycles carbon	L	H	H	M	L	H					H	H	H
Decomposition	Source of Dissolved Organic Matter						H	H						H
Oxidation-reduction	Biochar source											H	H	
	Oxygenates water		H	H		L	✓							
	Oxygenates sediments		✓		M	L	✓							
Regulation processes	pH regulation				M			H						
	PASS management						H	H						
	Salinity regulation													
	Hardness regulation							H						
	Regulates temperature					✓	✓	✓	✓					ML
Chemicals/heavy metal modification	Biogeochemically modifies chemicals/heavy metals	L			M		✓	H						
	Flocculates heavy metals						✓	H						
Biological processes (processes that maintain animal/plant populations)														
Survival/reproduction	Habitat/refugia for aquatic species with reef connections	H	M	L	✓	H	H	H		✓				
	Habitat for terrestrial species with connections to the reef	H						H						
	Food source		✓		H	✓	✓	✓		H				
	Habitat for ecologically important animals	H	✓		H	L	H			✓	✓			
Dispersal/ migration/ regeneration	Replenishment of ecosystems – colonisation (source/sink)	H			H	M	H	H						
	Pathway for migratory fish							H						
Pollination														
Recruitment	Habitat contributes significantly to recruitment	H			H	H	H	H		H				

Capacity of natural coastal ecosystems to provide ecological services for the Great Barrier Reef[91]

H – high capacity for this system to provide this service, M – medium capacity for this system to provide this service, L – low capacity for this system to provide this service, N – no capacity for this system to provide this service, X – not applicable, ✓– service is provided but capacity unknown. Boxes with no data indicate a lack of information available. Note that the capacity shown for modified systems assumes periods of low hydrological flow.

Ecological processes of modified systems linked to the health and resilience of the Great Barrier Reef. Islands have been excluded as they vary considerably between island types.

Process	Ecological Service	Groundwater Ecosystems	Irrigated agriculture	Non-irrigated agriculture	Dams & Weirs	Urban	Mining – operational open cut	Forestry Plantation	Extensive agriculture	Ponded pastures
	Physical processes- transport & mobilisation									
Recharge/Discharge	Detains water	✓[1]	M			L	M		H	
	Flood mitigation	✓	N			L	X		X	
	Connects ecosystems	H	L			L	N		L	
	Regulates water flow (groundwater, overland flows)	H	M			L	L		M	
Sedimentation/ erosion	Traps sediment	N	M[4]			L	M		H	
	Stabilises sediment from erosion	✓	M[4]			H	N		H	
	Assimilates sediment		M			L	N		H	
	Is a source of sediment		L			L[11]	M		L	
Deposition & mobilisation processes	Particulate deposition & transport (sed/nutr/chem. etc.)	✓[2]	L			L	L		H	
	Material deposition & transport (debris, DOM, rock etc.)		L			L	L		L	
	Transports material for coastal processes		N			M	L			
	Biogeochemical Processes – energy & nutrient dynamics									
Production	Primary production	N							M	
	Secondary production	✓[3]							H	
Nutrient cycling (N, P)	Detains water, regulates flow of nutrients	✓							M[13]	
	Source of (N,P)	✓							M	
	Cycles and uptakes nutrients	✓							H	
	Regulates nutrient supply to the reef	✓							H	
Carbon cycling	Carbon source	✓							M	
	Sequesters carbon	✓							MH	
	Cycles carbon	✓							H	
Decomposition	Source of Dissolved Organic Matter	✓							L[14]	

Oxidation-reduction	Biochar source								X	
	Oxygenates water	N							L	
	Oxygenates sediments	N							✓[15]	
Regulation processes	pH regulation	✓							✓[15]	
	PASS management								L	
	Salinity regulation								✓[15]	
	Hardness regulation								✓[15]	
	Regulates temperature								L[16]	
Chemicals/heavy metal modification	Biogeochemically modifies chemicals/heavy metals	✓							X[17]	
	Flocculates heavy metals	✓							L	
	Biological processes (processes that maintain animal/plant populations)									
Survival/reproduction	Habitat/refugia for aquatic species with reef connections	N	L[5]	L[5]	L[8]	L[12]	N	N	L	M[18]
	Habitat for terrestrial species with connections to the reef	N	L	L	H[9]	L	N	N	L	L[19]
	Food source	N	N	N	M	L	N	L	M	L
	Habitat for ecologically important animals		N	N	L[10]	N	N	N	M	L[19]
Dispersal/ migration/ regeneration	Replenishment of ecosystems – colonisation (source/sink)	N	N	N	L	N	N	N	M	L[20]
	Pathway for migratory fish	-	N[6]	N[6]	L[8]	N	N	N	✓[15]	L[21]
Pollination		-	L[7]	L[7]	N		N			
Recruitment	Habitat contributes significantly to recruitment		N	N	L	N	N	N	M	N

Capacity of natural coastal ecosystems to provide ecological services for the Great Barrier Reef[91]

H – high capacity for this system to provide this service, M – medium capacity for this system to provide this service, L – low capacity for this system to provide this service, N – no capacity for this system to provide this service, X – not applicable, ✓– service is provided but capacity unknown. Boxes with no data indicate a lack of information available. Note that the capacity shown for modified systems assumes periods of low hydrological flow. End-notes 1 – capacity depends on hydraulic characteristics of the aquifer (porosity, permeability); 2 - particulate transport occurs sometimes in subterranean systems; 3 - secondary production is variable; 4 - dependent upon crop cycle; 5 - habitat for crocodiles and turtles; 6 - especially in channels, but is dependent on water quality; 7 - depends upon crop; 8 - only where fish passage mechanisms exist; 9 - especially water & shorebirds; 10 - particularly aquatic species (though may lack connectivity); 11 - refers to new developments; 12 - impoundments, ornamental lakes and stormwater channels; 13 - hoof compaction of soil increases run-off; 14 - particulate organic carbon is high, dissolved is low; 15 - unchanged from natural ecosystem capacity; 16 - relates more to extent of vegetation clearance of riparian zone; 17 - contaminant; 18 – in the dry season amongst Hymenachne; 19 - particularly for birds; 20 - sink biologically as species move into areas but reduced water quality can affect badly; 21 - subject to water quality and grazing regime.

Appendix G – TropWATER report on the Haughton basin

Haughton River basin

Summary
The Haughton River basin contains the largest area of irrigated caneland and high nitrogen fertiliser application rates. The Burdekin delta overlies a shallow groundwater aquifer that is hydrogeologically linked to wetlands, waterways, estuaries and the Great Barrier Reef (GBR). Consequently, agricultural expansions have had detrimental impacts on the function of coastal wetlands. Excessive water extraction has been occurring for almost a century and saltwater intrusion is a concern in the region. During low flow conditions and flood events, over 20 different herbicides have been detected, the majority of which are associated with the sugarcane industry. The dominant herbicides in the Haughton River Basin are diuron, atrazine, hexazinone and ametryn. Monitoring of coastal waters within the GBR lagoon has shown that 80% of the time a herbicide was detected more than one herbicide was present. Diuron samples from the Haughton River basin have been found to exceed the PSII inhibition value for the Great Barrier Reef.

1. Introduction

The Haughton River Basin (Figure 1) is located within the lower Burdekin region, north -west of the Burdekin River. The basin consists of the Haughton River, Barratta Creek, Barramundi Creek, Mud Creek, Sheep Station Creek and Plantation Creek. Barramundi Creek, Mud Creek and Plantation Creek have been largely unmodified, while the Haughton River and Barratta Creek have been modified by anthropogenic activities.[1] The annual rainfall across the catchment is 888 mm/year, and run-off is 183 mm/m^2.[2] Stream flow is highly variable seasonally and temporally, with approximately 80% of the annual flow occurring between December and April.[3]

Much (77%) of the land within the Haughton River catchment has been cleared (3120 km^2) and the dominant land uses include grazing (3441 km^2), sugar crops (528 km^2) and horticulture (21 km^2).[2] The lower Burdekin floodplain is Australia's largest, most intensively developed agricultural floodplain and this cane growing region has unique farming practices in comparison to other sugarcane growing areas in Australia.[4] The region is unique in the following ways: the region comprises the largest area of furrow irrigated land, sugarcane crops are fully irrigated, approximately 75% of the crops are burned (25% are cut green), therefore trash blankets are generally not used, there are high nitrogen fertiliser application rates, yields are very large and as a result the lower Burdekin is the largest sugarcane producing region in Australia.[4] The nitrogen fertiliser application rates were approximately 231 kg/ha in 2010, which was above average for sugarcane growing regions in Australia.[5] Due to these high application rates the lower Burdekin has the potential for higher nitrogen loss than other sugarcane growing regions. Downstream from this extensive agricultural region is a complex of internationally and nationally significant wetland environments.[3]

The floodplain is drained by minor rivers and creeks such as the Haughton River, which is one of the main contributing catchments to Bowling Green Bay.[3] The average width of the channel is 50 km and stretches to 2 km at the river mouth.[6] The basin houses a total population of approximately 10,343 people (Ayr (8,093 population), Giru (371 population) and Brandon (850 population)). Point sources of pollution include sewage discharge from these towns, 3 sugar mills (Kalamia north of Ayr, Invicta in Giru, and Pioneer in Brandon) and a prawn farm facility at Alva Beach.

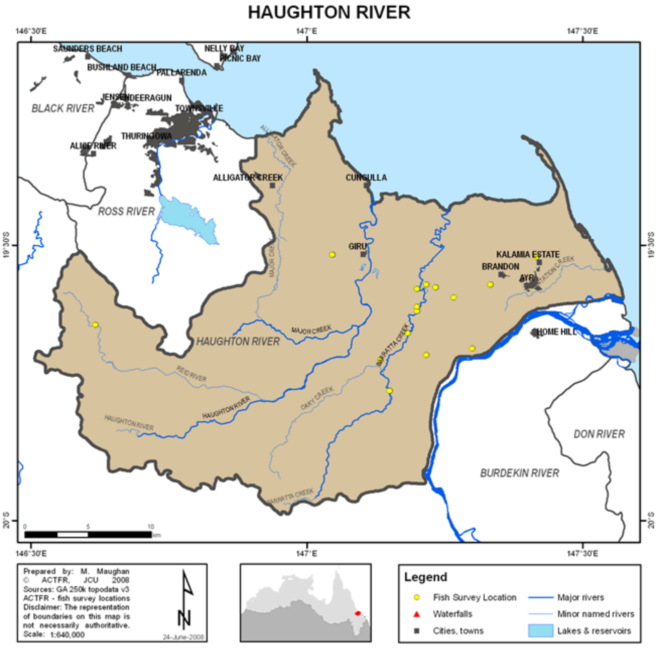

Figure 1: Haughton River basin

2. Hydrology and drainage

The Burdekin delta overlies a shallow groundwater aquifer which is hydrogeologically linked to environmentally sensitive wetlands, waterways, estuaries and the Great Barrier Reef. In addition to irrigation supply, the aquifer also supplies potable water for three towns in the delta. There has historically been an issue of seawater intrusion into the Burdekin aquifers[7] but this has been controlled in more recent times by artificial recharge from river water.

Approximately 80,000 ha are currently under irrigation, with furrow the dominant form of irrigation and sugarcane the dominant crop. Both river water and/or groundwater are used depending on proximity to the river and surface water supply channels, aquifer yields and groundwater quality. At present, more than 1400 groundwater pumps are in operation, applying 10–40 ML/ha/yr[8], which is equivalent to 1000–4000 mm/yr. In general, most areas to the east of Mount Kelly are irrigated with groundwater while areas to the west use mainly surface water.

Excessive water extraction in the Burdekin Delta aquifer has been reported since the 1930s, following expansion of the sugarcane industry and long periods of draught. As a result of lowered aquifer water levels, saline/fresh water groundwater interfaces have advanced inland[3,9,10] and saltwater intrusion is an increasing concern, especially under sea level rise scenarios.[3,11] Water is sourced from both surface and groundwater, although the Delta region uses predominantly groundwater (80-90%) and the Burdekin-Haughton Water Supply Scheme (BHWSS) predominantly uses surface water (80%).

In 1987 the Burdekin Falls Dam was completed, creating the Burdekin River Irrigation Area (BRIA).[3] The dam is located approximately 80 km from the river mouth and is the largest water reservoir in Queensland (1,860,000 ML). Expansion of cane agriculture followed in 1988, which has also contributed to the detrimental impacts on the function of local coastal wetlands.[3] The Haughton River and lower Burdekin allocate water (150,000 ML per annum) for crop irrigation through the Burdekin-Haughton Water Supply Scheme (BHWSS). The establishment of the BHWSS led to an increased diversity of irrigated horticultural and tree crop areas that are situated upstream of coastal zone wetland complexes.[3] Both the Haughton River and Barratta Creek have been modified hydrologically as a result of the BHWSS.

Additionally, after the completion of the Burdekin Falls Dam and the introduction of surface water for irrigation, ground and surface water flows have been impacted and water table levels across the BHWSS have shown significant changes.[3] The water table has risen from 10 m to 2 m below ground level upstream of the BHWSS site since 1987[12] and is expected to continue rising.[13] Groundwater is rising because the BHWSS aquifer is receiving an increased average of 67,576 ML/year compared to pre-development conditions[3], and there is a lack of deep drainage management and water use efficiency.[13] There is currently no effective water discharge mechanism due to the limited connectivity between groundwater systems and the Burdekin River.[3] Kelly and Lee Long (2011) suggest that particular information is needed on the hydrological connectivity of various aquifers as well as interactions with surface and groundwater along the Cape Bowling Green coastal margin and areas adjacent of the Haughton River and Burdekin River delta catchments.[11]

Since the introduction of groundwater for irrigation, groundwater salinity levels have increased in the Burdekin River Irrigation Area from < 1000 µS/cm towards 2500 µS/cm by 2000.[14] Meanwhile, the average rate of salt importation from surface water has been estimated at approximately 32,027 t/yr.[15]

3. Basin water quality

a) Water quality

1) Status of monitoring in basin and rivers

A considerable amount of local research has been conducted in the cane growing region of the lower Burdekin. Research has addressed pesticide movement dynamics over a range of scales including surface water-groundwater interface,[16,17] floodplain waterway and drainage systems,[18,19,20] end of riverine catchments,[20] riverine flood plumes in adjacent marine environments,[20,21,22] riparian vegetation,[23] groundwater,[24,25,26,27,28,29,30,31] sediment movement patterns,[32,33] and seawater intrusion.[7] Davis et al. (2008; 2012) completed an extensive monitoring of pesticide surface water quality within the catchment, which involved working closely with local farmers and consisted of a total of 275 samples over the monitoring period (205 samples collected during high flow and 70 collected during low flow events).[20,34] The study determined the dynamics of off-site paddock-scale pesticide movement and subsequent concentrations. Herbicide losses were measured from irrigated sugarcane farms in addition to water quality data from adjacent stream networks during both dry and wet seasons. This monitoring program is ongoing.

In a recent study by Lymburner & Dowe (2007),[23] LandSat imagery of the Burdekin catchment from 1970 was compared to that from the year 2000 to determine any changes in this 30-year period. The authors found large loss and removal of riparian vegetation in a number of sub-catchments.

2) Status of Water Quality in Basin and Rivers

Over 20 different herbicides have been detected during conditions of both low flow and flood events, the majority of which are associated with the sugarcane industry.[4,20,34,35] The dominant herbicides detected include diuron, atrazine, hexazinone and ametryn, which are now regulated under the Great Barrier Reef Protection Amendment Bill 2009.[4,20] A notable feature of the temporal herbicide dynamics in this region is that the highest herbicide concentrations and the majority of the total herbicide load transported from these catchments during the wet season occurs during the 'first-flush' event.[34]

A significant outcome of the sub-catchment monitoring[4,20] were the substantial and persistent levels of herbicides found within the Barratta Creek system during low flow (dry season) conditions that were often above ecosystem protection guidelines of certain herbicides. These high concentrations were associated with crop irrigation (when the water system receives large volumes of tailwater from farms) and was often more than an order of magnitude higher than those documented for similar caneland dominated systems in the GBR.[20] Due to the low permeability of soils within this region, the amount of tailwater run-off sourced from local cane farms is significant and consequently, the middle and lower reaches of the Barratta Creek drainage complex are dominated by local irrigation tailwater input, compared to the systems previously irregular flow regime (i.e. low water levels during the dry season). Tailwater run-off and groundwater leachates contribute to increased inorganic nutrient loads, with nitrate concentrations in surface water from many systems, such as Barratta Creek, measuring above Australian water quality guidelines (ANZECC and ARMCANZ 2000) for ecosystem protection.[3]

The transport of this groundwater nitrate to coastal wetlands and the GBR is poorly understood. Some denitrification potential is postulated on the basis of iron values in the groundwater.[31,36] Transport of nitrate containing groundwater to the GBR may take place through paleochannels of the Burdekin River but the discharge process is still highly uncertain.[27,37]

Davis et al. (2011) analysed dry season herbicide concentration data with the Predict the Ecological Risk of Pesticides in freshwater ecosystems (PERPEST; Version 3.0) model.[4,38,39] PERPEST modelling scenarios depicted the effects of herbicides on eight structural and functional community endpoints (community metabolism; fish and tadpoles; macrocrustaceans and insects; macrophytes; molluscs; periphyton; phytoplankton; and zooplankton). Data was used from 7 sub-catchment monitoring sites that were sampled during dry season conditions. The results showed that sites within the Barratta Creek catchment are at a high risk of impaired ecosystem function compared to other monitored locations within the lower Burdekin. Probabilities of clear effects were calculated to be greater than 25% for macrophytes and community metabolism, and greater than 50% for macrocrustaceans and insects, periphyton, phytoplankton and zooplankton. Within the Haughton River site probabilities of clear effects greater than 25% were predicted for periphyton, phytoplankton and zooplankton community endpoints.

b) Ecological effects of water quality and hydrological changes in basin

The effects of chronic turbidity on floodplain ecosystems is not yet certain, however, it has been speculated that as a response to perennial turbidity, aquatic plant beds have become increasingly sparse, scattered and dominated by emergents.[40] For example, fringing water lilies and other submerged aquatic plants are now largely absent from the lower East Barratta Creek system.[3]

The change from natural conditions consisting of a low flow dry season, to a perennial system with sustained inflows of turbid, nutrient rich water has resulted in the modification of the floodplain and lower catchment wetlands, as the environmental conditions now favour exotic pasture species such as Olive Hymenachne (*Hymenachne amplexicaulis*) and Para grass (*Urochloa mutica*), as well as floating exotic weeds such as salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*).[3,41,42] It is currently unclear what the impacts of this shift from native species to exotic species will have on the floodplain and wetland ecosystems.

4. Coastal Water Quality

a) Water Quality

1) Status of Monitoring in Coastal Areas

There is a long history of monitoring initiatives conducted in this river basin and include: riverine flood plumes in the adjacent marine environments[20,22,34,43,44] and in coastal sites within the GBR lagoon.[21,33,45]

2) Water Quality Data

Output from the lower Burdekin region rivers are the largest contributor of sediments to the Great Barrier Reef and a large portion of this output is trapped in the eastern portion of Bowling Green Bay.[46] The dry season dynamics of the shallow coastal waters in Bowling Green Bay were modeled by Wolanski and Ridd (1990) and revealed that the tidal dynamics in the shallow waters of the bay generate coastal trapping and poorly flushed waters during the dry season.[47] The wetland-fringed estuaries have a residence time in the order of several weeks[48], making Bowling Green Bay a pollutant trap that could potentially impact ecosystem function and services.[3]

Lewis et al. (2009, 2012) sampled selected sites within the Great Barrier Reef lagoon (Burdekin-Townsville region) following the wet season using passive samplers in order to examine the duration of PSII herbicide exposure.[21,45] Results across the GBR lagoon showed that 80% of the time a herbicide was detected more than one was present. Samples taken from off the mouth of the Haughton River showed that no individual herbicide guideline was exceeded. Atrazine concentrations reached 13% of the guideline value. Twelve diuron sample concentrations exceeded the PSII inhibition value for the GBR. Sediment samples collected from 9 estuarine and near shore marine sites across Bowling Green Bay (all within the Ramsar wetland site and the GBR World Heritage Area) detected only one herbicide, diuron. Two thirds of the sample sites (6 out of 9) contained detectable levels of diuron, which ranged from 0.12 – 1.62 μg kg^{-1}. No organochlorine (DDT, aldrin, dieldrin etc.) or organophosphate pesticide residues were detected.

An assessment of inshore ecosystems exposed to different categories of surface pollutants within the Burdekin region (Table 1) showed a total of 2,079.82 km^2 of coral reefs and 586.05 km^2 of seagrass beds are exposed to PSII, TSS and DIN.[49]

Table 1: Number and area of exposed coral reefs and seagrass beds to surface pollutants in the Burdekin region. Photosynthesis inhibiting pesticides and herbicides (PSII), total suspended solids (TSS) and dissolved inorganic nitrogen (DIN)

Exposure			Coral reefs		Seagrass beds	
PSII	**TSS**	**DIN**	**Num.**	**Km^2**	**Num.**	**Km^2**
0.00	0.00	0.00	0	0.00	0	0.0.0
0.06	0.36	0.14	13	20.30	0	0.00
0.13	0.72	0.28	126	1,266.17	0	0.00
0.19	1.07	0.41	39	533.38	0	0.00
0.25	1.43	0.55	13	205.96	3	0.29
0.32	1.79	0.69	80	54.01	86	585.76
				2,079.82		**586.05**

Source:[49]

Flood plumes have been extensively studied within the lower Burkedin region, however emphasis has been paced on discharge from the Burdekin River as this is the channel where the large majority of floodplain water is drained and released into the ocean. Bainbridge et al. (2012) monitored the extreme wet season floods from December 24 – January 18 in 2010/2011 that resulted in highly elevated discharge from the Burdekin River into the GBR lagoon for 200+ days.[22] Prior to the extreme flood event smaller plumes were already observed off the Haughton River and Barratta Creek mouths, which were still present on the 4th of January, 2011 (Fig. 2). During peak conditions the Burdekin River extended > 50 km offshore and spread 100 km north of the river mouth.

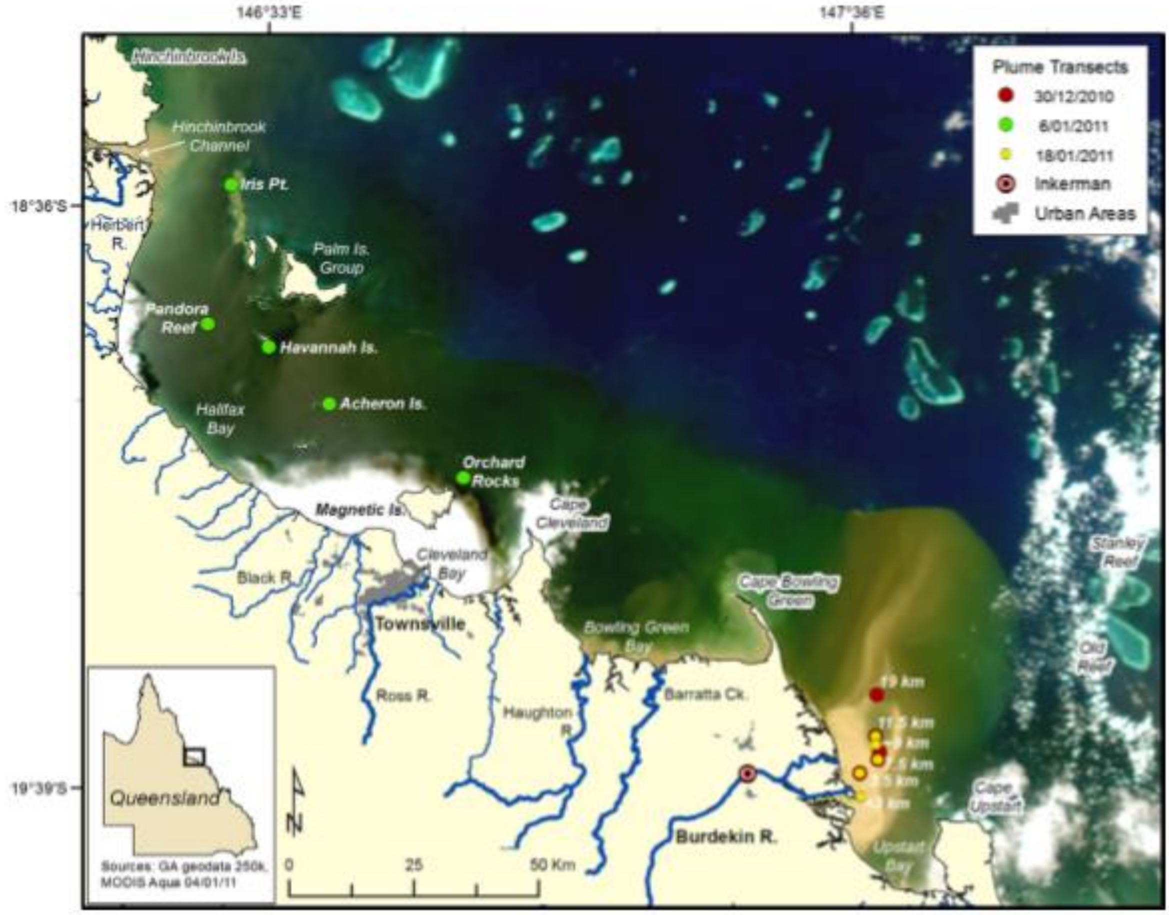

Figure 2: Flood plume sampling map superimposed on a MODIS satellite image of the Burdekin River flood plume captured on the 4th January, 2011. The turbid inner plumes from the Haughton River, Barratta Creek and the Burdekin River are clearly visible along the coast adjacent to the river mouths. Source:[22]

Initial sediments released from the Burdekin River are only deposited in Bowling Green Bay to a low extent, however when dry season strong winds (> 9 m s -1;[50] occur sediment is resuspended and transported northward via longshore currents[51] and are deposited in Bowling Green (80-90%) and Cleveland (5-10%) Bays. Dissolved nutrients were transported in the plume reaching as far north as Halifax Bay. It was shown that these nutrients increase particulate organic matter in the water column, enhancing the formation of large floc aggregates (composed of mud and bound organic matter content) that stay in suspension longer than mineral particles and maintain higher turbidity in the plume water for longer periods. Such sediment flocs were found within the surface sediment layer in places like Cleveland Bay suggesting that they are also likely within Bowling Green Bay sediments. Sedimentation of fine sediments and associated nutrient/organic matter cause greater damage to corals than inorganic sediment particles due to bacterial growth, which causes anoxia at the coral surface and subsequent mortality.[52,53] The large area covered by the flood plume for 10 weeks reduced the light climate (i.e. PAR) for benthic phototrophic organisms and created an extended period of low salinity. The impact of these conditions on seagrass meadows and coral reefs are under continued investigation.[54]

The spatial distribution of various water quality variables were predicted and mapped across 6 regions and 3 cross-shelf (coastal, inner shelf and outer shelf) positions in the GBR using measurements from 1985-2006.[55] The values predicted for the Burdekin are provided in table 2. All variables decreased with increased distance from the coast with the exception of Secchi depth, which increased at more offshore sites. Compared to the other 5 analysed regions (Cape York, Mackay Whitsunday, Fitzroy, Burnett Mary and Wet Tropics), the Burdekin contained: the lowest Secchi depth (3.7m) and the lowest coastal and offshore chlorophyll *a* (Chl a) values. SS and PN values were highest and cross-shelf changes most pronounced from the Burdekin to Port Douglas and highest coastal values of PN were found between the Burdekin and Hinchinbrook Island. PP values were highest and cross shelf changes most pronounced between the Whitsundays and Cairns (i.e. in the Burdekin and Wet Tropics). TDN and TDP values were second highest and highest in the Burdekin, respectively. Total nitrogen (TN) and particulate phosphorus (PP) values were second highest and highest in the Burdekin, respectively, with the greatest cross-shelf changes measured in the Burdekin region for both variables.

Table 2: Mean annual values of water quality variables predicted in 3 cross-shelf regions of the Burdekin region

Variable	Coastal	Inner Shelf	Outer Shelf	Across all zones
Secchi depth (m)	3.7 ± 0.6	13.3 ± 0.6	18.7 ± 0.8	15.7 ± 0.7
Chl a (µg L^{-1})	0.9 ± 0.07	0.5 ± 0.04	0.3 ± 0.04	0.4 ± 0.04
SS (mg L^{-1})	5.5 ± 0.4	2.5 ± 0.2	0.9 ± 0.1	1.9 ± 0.2
PN (µmol L^{-1})	2.6 ± 0.2	1.9 ± 0.1	1.4 ± 0.1	1.6 ± 0.1
PP (µmol L^{-1})	0.18 ± 0.01	0.10 ± 0.01	0.07 ± 0.01	0.09 ± 0.01
TDN (µmol L^{-1})	6.7 ± 0.3	5.8 ± 0.3	4.9 ± 0.3	5.4 ± 0.3
TDP (µmol L^{-1})	0.39 ± 0.04	0.33 ± 0.03	0.18 ± 0.03	0.24 ± 0.03
TN (µmol L^{-1})	8.7 ± 0.5	7.4 ± 0.4	7.2 ± 0.6	7.5 ± 0.5
TP (µmol L^{-1})	0.59 ± 0.06	0.46 ± 0.04	0.33 ± 0.06	0.39 ± 0.05

The current best estimates of modelled loads leaving the Haughton River basin are provided in Table 3. The estimated loads have increased substantially from pre-development values. Dissolved organic phosphorus (DOP) has increased the least (9 t/yr) since pre-development, while PSII herbicides (1426 kg/yr) and total nitrogen (749 t/yr) have increased the most. After the implementation of the Reef Rescue program in 2008, an improvement in load values was observed for TSS, DIN, PN, TN, PSII herbicides, PP and TP. For example, modelled dissolved inorganic nitrogen (DIN) export values from the Haughton River basin (Table 3) showed that the total export in 2008/2009 (502 t/yr) had increased approximately 18-fold compared to pre-development loads (28 t/yr). However, after the implementation of the Reef Rescue program (2009/2010) values decreased to 362 t/yr, which is a 29.5% improvement. Improvements for DON, DIP and DOP loads have not yet been measured.

Table 3: Best estimates of modelled total pre-development values, current values, and anthropogenic changes in water quality parameters. Reef Rescue values represent the values after the commencement of the Reef Rescue program and Reef Rescue change represents the improvement (%) after implementation

	Pre-development	Current (2008/2009)	Current (2009/2010)	Anthropogenic Baseline	Reef Rescue (2009/2010)	Reef Rescue change (%)	Total Change (%)
TSS (kt/yr)	78	250	248	172	249	0.6	1.1
DIN (t/yr)	28	502	362	474	362	29.5	29.5
DON (kt/yr)	120	205	205	85	205	0	0
PN (t/yr)	83	272	270	189	270	0.8	1.3
TN (t/yr)	231	980	837	749	838	18.9	19.0
PSII (kg/yr)	0	1426	1276	1426	1276	10.5	10.5
DIP (t/yr)	10	41	41	31	0	0	0
DOP (t/yr)	10	19	19	9	0	0	0
PP (t/yr)	32	140	138	108	139	0.9	1.3
TP (t/yr)	52	200	199	148	199	0.7	0.9

Source:[56]

b) Ecological effects of Water Quality and Hydrological Changes in Coastal Areas

The lower Burdekin region contains one of the highest concentrations of high value freshwater, estuarine and marine wetlands in Australia, which are listed on either Australia's National Directory of Important Wetlands or included on Ramsar's list of wetlands of international significance.[3] Bowling Green Bay contains seasonal estuaries, large coastal wetlands consisting of: mud flats, 17 species of mangroves, salt marshes, tidal freshwater wetlands, patches of seagrass, intertidal algae, saline grasses and herbs, sedges and other aquatic species.[34] With an area covering approximately 188,000 ha, these wetlands constitute one of the largest coastal wetland complexes along the entire east coast of Australia[40], which play an important role in nutrient assimilation and sediment stabilization to areas adjacent and downstream in the Great Barrier Reef lagoon.[57] A portion (47,274 ha) of Bowling Green Bay was listed as Ramsar wetland of international importance under the Ramsar Convention in 1993.[58] This area is an important habitat for protection, foraging and breeding for a large number of waterbirds, marine reptiles and large mammal species.[3] At least four species of turtles (loggerhead, *Caretta caretta*; green turtle, *Chelonia mydas*; hawksbill turtle, *Eretmochelys imbricata*; and flatback turtle, *Natator depressus*) that are considered as “vulnerable” under the EPBC Act feed in this area. The Ramsar site is one of four areas along the Queensland coast that is considered of “high” conservation value to dugong.[3]

Since the commencement of irrigation in the BHWSS, turbid water has been constantly trapped and released from the Burdekin Falls Dam before being transported through the lower Burdekin floodplain systems (Haughton River, Barratta Creek and Sheep Station Creek) for irrigation water delivery.[3] As a result of supplemental water flows the water clarity and hydrological regime of the Haughton River, Barratta Creek and Sheep Station Creek have been greatly altered.[3] Alterations include river flow regulation, increased nutrient and pesticide loads, loss of wetland connectivity, altered sedimentation patterns, vegetation clearing and species invasions by introduced plants and animals.[3,42] Consequently, the underlying function of most wetland environments across the floodplain has been altered.[3]

Pesticide monitoring within the Barratta Creek[20,34] was extended beyond the freshwater reaches through to the estuarine environments to assess pesticide dynamics within the Bowling Green Bay Ramsar site. Passive samplers detected a progressive attenuation of pesticide concentrations from the upper catchment monitoring sites (BHWSS area) into the downstream Bowling Green Bay Ramsar site. In general, pesticide concentrations decreased in the downstream reaches of the Barratta estuary, which was attributed to increased groundwater inputs in the middle reaches of the system as well as dilution. Several herbicides such as diuron and atrazine still exceeded available ANZECC and ARMCANZ (2000) ecosystem guidelines for consistent periods during the year.

Ramsar site information is updated every six years or when substantial changes to the ecological character take place at the site as a result of technological developments, pollution or other human interferences. Notes from a recent Ecological Character Descriptions of the Bowling Green Bay Ramsar site identified that hydrological elements of ecological character (flow, level, salinity regimes of surface and groundwater) are moving towards limits of acceptable change.[11]

5. Other potential pollutants

Sediment cores (up to 4 m deep) were taken at various river delta sites within Bowling Green Bay as part of a larger study examining changes in past and present land use.[59] Cores were analysed for mercury levels and spatial and temporal excursion from those levels were detected. One core from Bowling Green Bay contained background mercury levels of 12 ppb (60 pmoles/gram) from 3.08-3.82 m depth. Within a distance of 0.4 m a sharp rise from 12 ppb (60 pmoles/gram) to 500 ppb (2500 pmoles/gram) was measured. From 2.52 m to the surface an exponential-type reduction in mercury concentration was measured. The sharp gradient of increase in mercury was attributed to a substantial input of mercury over a short period of time and the authors suggested that this was a consequence of transport of mercury used in the amalgamation process of gold mining in the Charters Towers/Ravenswood area between 1870 and 1980.

6. Management

a) In basin for basin

There is much Commonwealth legislation that is relevant to the conservation and protection of the Bowling Green Bay Ramsar and Barratta Creek. These include the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth); the Great Barrier Reef Marine Park Act 1975 (Commonwealth); Coastal Protection and Management Act 1995; and Environmental Protection Act 1994. Unfortunately, many of these legislative acts do not have the capacity to exercise direct management change on the water quality and hydrological issues that have now been identified as posing threats to this ecosystem.[3]

b) In basin for Great Barrier Reef

Bowling Green Bay is considered as critical nursery grounds for fish and crustacean species and was therefore declared as Fish Habitat Area, as well as Dugong Protection Area (level "B") under the Queensland Fisheries Act 1994.[60]

One of the aims of Reef Plan is to reduce the amount of pollutants entering coastal waterways and reef ecosystems.[61] Reef plan began the Great Barrier Reef Coastal Wetlands Protection Programme (GBRCWPP) in 2003 with the goal of implementing long term conservation and management of priority wetlands in the Great Barrier Reef Catchment.[3] Program outputs have included management investment strategies for wetlands including the Barratta Creek[42], as well as positive impacts on weed management, vegetation management and fish passage constraints.[62]

In 2008, Reef Rescue funded on-ground land management projects across the Great Barrier Reef catchment area that focus on sugarcane and grazing industries, as well as dairy farming and horticulture to a lesser extent.[3] New farming practices such as machinery modifications, fertilizer and pesticide application gear, cultivation and tillage equipment and practices have been introduced. Research conducted by Davis et al. (2008; 2011) has highlighted that although much of the water quality management is focused on the GBR environment, freshwater and estuarine ecosystems in this region currently face the highest risks from agriculture related water quality reductions.[4,20]

7. Potential future land use changes

There is a low to moderate possibility that there will be a change in the emphasis of cropping to increased cotton over the next years, which would result in the building of cotton gins and increased disposal of their associated wastes (J. Brodie Personal Communication). The plantation of genetically modified Bt cotton and/or glyphosate resistant cotton will result in the increased use of glyphosate based herbicides and a decline in insecticide use.

There is also a possibility of increased coastal aquaculture, which could alter coastal foreshore, estuarine, mangrove, salt marsh and marine and other aquatic environments.[63] Environmental impacts associated with aquaculture are water pollution, pest species, strain placed on wild fish populations for feeding and brooding, as well as the culling of natural predators.[63]

8. Knowledge Gaps

There is currently a knowledge gap regarding the effects of chronic turbidity on floodplain ecosystems in the Haughton River basin. Since there are no effective water discharge mechanisms due to limited connectivity between groundwater systems, it has been suggested that additional information is required on the hydrological connectivity of various aquifers and interactions with surface water and groundwater along the Cape Bowling Green coastal margin and areas adjacent of the Haughton River. With regards to pollutants that are not linked to agricultural land uses, there is a large knowledge gap related to micropollutants such as microplastics, TBT and pharmaceutical wastes.

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