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Great Barrier Reef
Marine Park Authority

Expert Ecological Advisory Workshop II

Coastal ecosystems, connectivity & climate change – ecological services in changed landscapes.

Hosted by the Great Barrier Reef Marine Park Authority (GBRMPA) and the Department of Environment and Resource Management (DERM) — 10–11 August 2011

Expert Ecological Advisory Workshop II

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SUMMARY

The *Great Barrier Reef Outlook Report 2009* identified coastal development, water quality and climate change as the biggest threats to the health and resilience of the Great Barrier Reef. While the values provided by coastal ecosystems to the health of the Great Barrier Reef have been recognised for many years, prior to June 2010 a comprehensive and quantified assessment of the values of coastal ecosystems had not been undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA).

In June 2010, the Expert Ecological Advisory Workshop I (Workshop I) focused on assessing and quantifying the ecological services provided to the Great Barrier Reef by ecosystems in their natural unmodified state. During Workshop I, it was recognised that all basins within the Great Barrier Reef catchment are modified in some way. As a result, the need to assess the ecological services provided by modified systems was identified.

On 10 and 11 August 2011, GBRMPA and the former Queensland Department of Environment and Resource Management hosted a second Expert Ecological Advisory Workshop (Workshop II) to assess the ecological services provided by modified ecosystems. Five basins were selected as case studies: Herbert, Ross, Proserpine, Styx and Calliope basins. Along with assessing the ecological services provided by the modified ecosystems, an evaluation of the likely impact of climate change at a regional scale was carried out.

In order to maximise the understanding and assessment of the services provided within the study basins, approximately 50 experts across a range of disciplines were invited to participate. The range of disciplines represented by participants included: terrestrial, aquatic, coastal and marine ecology; climate change impacts; land capability assessment; catchment management; political science; and science communications.

This report summarises the information and outcomes compiled during Workshop II.

The outcomes of the workshop include:

- detailed descriptions of the five basin case study areas including basin background, hydrology and current status.
- detailed descriptions of at least two modified ecological services within each of the case study basins.
- detailed descriptions of the impacts of regional climate change based on ecological services and basin functionality for each basin.
- development of a pilot framework for collating spatial data and expert knowledge to better understand the components and processes of the five basin case study areas.

SECTION 1 – WORKSHOP INTRODUCTION

The *Great Barrier Reef Outlook Report 2009* (Outlook Report) identified coastal development, water quality and climate change as the biggest threats to the health and resilience of the Great Barrier Reef. In response, *Informing the Outlook for Great Barrier Reef Coastal Ecosystems* report has been developed by the Great Barrier Reef Marine Park Authority (GBRMPA). The *Informing the Outlook Report* aims to provide a greater understanding of the role and values of coastal ecosystems in protecting and managing the health of the Great Barrier Reef World Heritage Area.

In order to further understand the roles and values of the coastal ecosystems that are critical to the health and resilience of the Great Barrier Reef, it was identified that the following knowledge gaps needed to be addressed:

- How do the natural and modified coastal ecosystem areas function?
- What ecological services do both natural and modified ecosystems provide to the Great Barrier Reef?
- What threats exist now and in the long term for these ecosystems?
- What will the consequence of these threats be on long-term health and resilience of the Great Barrier Reef?

On 23 and 24 June 2010 an Expert Ecological Advisory Workshop I (Workshop I) was held with key researchers and managers working in the Great Barrier catchment and inshore marine areas. This workshop was the first opportunity for experts from a range of scientific disciplines to come together to discuss the ecological importance of coastal ecosystems from their respective specialist knowledge base. A number of recommendations were put forward and discussed and, as a result, a second workshop was proposed to look specifically at modified ecosystems and the functions/processes they provide to the Great Barrier Reef.

On 10 and 11 August 2011, the Expert Ecological Advisory Workshop II (Workshop II) was held. A number of participants from Workshop I attended, along with researchers and managers with local knowledge working in basins adjacent to the Great Barrier Reef and inshore marine areas. The second workshop provided the opportunity for participants to apply their knowledge to a specific basin case study and to consider the ecological services that modified ecosystems provide to the Great Barrier Reef.

This report summarises the material that was generated at Workshop II in regards to the value and function that coastal ecosystems play in protecting the health of the Great Barrier Reef World Heritage Area and the likely impacts of climate change at a basin level.

Following recommendations from Workshop II, additional work is to be undertaken to assess the social, cultural and economic values of natural and modified coastal ecosystems.

1.1 Workshop objectives

The workshop objectives and agenda are shown at attachment 1.

1.2 Design of workshop

The workshop was designed to facilitate input from participants who were identified as experts in various fields relating to natural resource management, environmental science and conservation. It was recognised in Workshop I that to maximise the understanding and capture of basin processes, attributes and issues, it would be beneficial to facilitate a wide range of participants from a variety of different fields and expertise. Subsequently, a wide range of vocations were represented amongst the various groups including: researchers; environmental scientists; terrestrial, freshwater and marine ecologists; local council officers; natural resource management (NRM) regional catchment bodies; GIS experts; and land managers.

The workshop was broken into seven main sessions, held over two days. Of the seven sessions, four sessions were used as workshop discussions, with participants assigned to one of five working groups. Each group was allocated a separate basin as a case study. Participants were organised into the working groups based on their expertise and basin knowledge

The five basins chosen as case studies were selected to represent the diversity basins within the Great Barrier Reef catchment. Basins were selected based on their location within the catchment, their climate (wet/dry tropics), and their land use (grazing/intensive/extensive agriculture). The five basins selected as case studies were:

- Herbert basin (Wet Tropics)
- Ross basin (Dry Tropics)
- Proserpine basin (Wet Tropics)
- Styx basin (Dry Tropics)
- Calliope basin (Dry Tropics)

1.3 Day 1 – 10 August 2011

The following four workshop sessions were held on the first day of the workshop.

Introduction of workshop and overview of workshop objectives

The workshop and objectives were introduced by Hugh Yorkston (Director, Coastal Ecosystems and Water Quality, GBRMPA) with acknowledgement given to the Traditional Owners of the area. Additional background presentations were delivered by: Donna-marie Audas (Manager, Coastal Ecosystems and Water Quality, GBRMPA); Hsuan Lammers, (Principal Project Officer, Queensland Wetlands Program); Mike Ronan (Manager, Queensland Wetlands Program); and John Bennett (Department of Environment and Resource Management).

Basin Assessment and Stocktake

Participants were provided with summary information on each catchment. The summary information provided included: background on the catchment; history of settlement and development within the catchment; information relating to land use; flood statistics; and risks within the catchment.

Participants were then asked to identify and list various features within the specific basin to which they were assigned. Participants were firstly asked to identify natural and anthropogenic features within the catchment which serve as assets within the basin. The assets identified incorporate a wide range of features including: habitat for flora and fauna; unique and iconic natural species and features; structures that change the landscape; heritage values; infrastructure; feral animals; non-rehabilitated sites from mining legacies; bund walls; agriculture practices; and industry. The assets were recorded directly on to reference maps or into notebooks, with entries corresponding to marks made on the reference maps.

Connectivity and basin hydrology

It was recognised in Workshop I that the services provided by an ecosystem are dependent on relationships with other ecosystems. It was also recognised that many external factors such as hydrology and the degree of connectivity between different ecosystems may affect the services provided by a particular ecosystem. To further explore this concept at a Great Barrier Reef basin scale, participants were asked to consider the degree of connectivity and hydrology within the case study basin to facilitate understanding of water flow within the basin, potential impediments to connectivity of ecosystems and resulting loss of ecosystem services.

Processes/Ecological services

An output of Workshop I was the identification and compilation of information on the processes and ecological services provided by natural systems.

During Workshop II participants considered the process and ecological functions provided by modified ecosystems. With reference to the modifications identified within the basins, participants were asked to specifically consider and address the question *'what do these changes mean for the natural assets, coastal ecosystems and ultimately the Great Barrier Reef?'*

The participants within each of the five working groups were provided with a table of processes which may occur within a basin and a list of the corresponding ecological services provided by those processes. Reference maps were provided for each basin and participants were asked to conduct an assessment of the ecological processes and services provided by natural and modified ecosystems within each basin. The tables provided to participants allowed for a qualitative assessment of those services and the capacity of the ecosystems to provide that service.

Groups were specifically asked to select a number of processes from the *processes and components table* which occur within their basins and to complete two tasks. Firstly, the groups were asked to identify how those processes occur and how the ecological service is provided within the modified ecosystem groups.

Secondly, the groups were asked to provide the qualitative assessment of the capacity of the modified ecosystem to deliver the ecological service in terms of whether the service provided was non-existent, low, medium, or high.

1.4 Day 2 – 11 August 2011

Three workshop sessions were held on day 2 of the workshop.

Overview of findings from Day 1

Groups were asked to provide their findings and results from day 1. Groups were asked to present the information for their catchment in response to the following series of questions in an effort to standardise the presentation of findings:

- What are the dominant components in the basin?
- What were the dominant processes/ecological functions in the basin?

- How have ecological processes and connectivity been affected spatially by the modifications to hydrology in the landscape?
- What information can be compiled about these changes (what do we know about the impact of these modifications)?

Climate change and the effect on processes/ ecological services

After the morning break, the participants were asked to consider the potential effects of climate change, based on the Department of Environment and Resource Management's FNQ2 'Towards A Greener Queensland' report predictions, on the processes/ecological services of their respective basins.

Dan Metcalfe (CSIRO) presented on the potential shifts in floral assemblages as a result of climate change and how their movement may be affected by man-made barriers.

Participants were asked to consider what the implications would be on the Great Barrier Reef if the ecological services within the basin/s were altered as a result of climate change.

Final session – where to from here?

In the final session of the workshop participants were invited to consider how the information collected could be used to facilitate further understanding on processes and ecological services within other catchments and were given an opportunity to provide feedback on the operation of the workshop. Participants were specifically invited to discuss the following questions:

- How could we apply this catchment exploration process to other catchments?
- What worked and what didn't?
- Where to from here?

The workshop was concluded by Hugh Yorkston who presented an overview of the future use of the findings of the workshops and its application to the broader management of the Great Barrier Reef catchment.

1.5 Workshop Materials

Workshop materials included reference material for each basin case study. The reference material consisted of the summary basin information and assessment and reference maps for each basin. The results from this workshop have been incorporated into the basin summaries and are available at www.gbrmpa.gov.au.

The reference maps consisted of a series of basin maps provided by the GBRMPA Spatial and Information Technologies group. The reference maps were constructed from a variety of data sets consisting of:

GBRMPA Datasets

- GBRMP Zoning 2003 (2009)
- Marine Bioregions of GBRMP (non-reefal) (2005)
- Marine Bioregions of GBRMP (reefal) (2005)

DERM Datasets

- Regional Ecosystems of Queensland (Pre-clear) (2009) v6.0b
    - Regional ecosystems
    - Broad Vegetation groupings
    - Land zones

- Regional Ecosystems of Queensland (Remnant) (2009) v6.0b (collected in 2006)
    - Regional ecosystems
    - Broad Vegetation groupings
    - Land zones
- Queensland Wetlands Data (2009)
    - Water Bodies
    - Wetland Regional Ecosystems
- Digital Cadastre Boundary Database – (Tenure) (2011)
- Queensland Landuse Mapping Project (QLUMP) (1990,1999, 2005, 2009)
- Stream Ordered Rivers (Hydrology) (2009)
- Queensland Coastal Plan (2011)
    - Draft Hazard Erosion Prone Area
    - Draft Hazard Sea Level Rise
    - High Risk of Storm Tide Inundation
    - Medium Risk of Storm Tide Inundation
- Dams and Weirs (2002)
- SEDNET Soils Data Set (2006)

CSIRO (Joint dataset with other agencies)

- GBR Seabed Biodiversity July 2007 (Site clusters)
- GBR Seabed Biodiversity July 2007 (Assemblages)

JCU

- Seagrass Model (Dry-season) (2007)
- Seagrass Model (Wet-season) (2007)

NRM Datasets

- Healthy Water Management Plan

Using the above data sets, analysis and groupings were created to investigate:

- changes between pre 1940s and post 1940s regional ecosystem data
- simplified Coastal Ecosystem groupings using regional ecosystems data

1.5 Recording of outcomes

Each working group was provided with a set of AO sized maps of their case study basin and notebooks developed by GBRMPA's Spatial Data Centre. Notes were written either directly onto the maps or into notebooks with reference to areas marked on the maps. The results of group discussions were recorded by GBRMPA Coastal Ecosystems staff.

All results were collated by GBRMPA Coastal Ecosystems staff post-workshop. These results are presented in Section 2 of this report.

1.6 Workshop participants

Fifty participants attended the two day workshop. A list of workshop participants is shown at Attachment 7. Participants represented a number of government and non-government organisations including:

- Department of Environment and Resource Management (DERM)
- Department of Employment, Economic Development and Innovation (DEEDI)
- James Cook University (JCU)

- Australian Institute of Marine Science (AIMS)
- CSIRO
- Townsville City Council
- Central Queensland University (CQU)
- Terrain
- NQ Dry Tropics
- Wetland Care
- Cassowary Coast Regional Council
- Burnett Mary Regional Group
- WWF
- Consultants

1.7 Outputs

The key outputs of the workshop were:

- This workshop document
- Development of a framework for assessment of ecosystem services within the basins located in the Great Barrier Reef catchment with a focus on improving the health and resilience of the Great Barrier Reef
- Basin summaries for each of the five basins assessed.

SECTION 2 – WORKSHOP RESULTS

2.1 GENERAL DISCUSSION

The general discussion between participants of the five working groups revealed many differences between the basin case studies, including between basins with similar classifications (ie. comparisons between 'wet' basins and between comparisons of 'dry basins).

Many similarities were also identified from comparisons of the five basins including: potential impacts of climate change, the general ecological processes and components and the potential management actions identified to ensure basin health. The results and outputs from the five case study basins assessments are shown as follows:

2.2 HERBERT RIVER BASIN – WET TROPICS NRM AREA

2.2.1 Group Members

Name	Organisation
John Armour	Department of Environment and Resource Management
Kelly Bryant	Department of Environment and Resource Management
Dan Metcalfe	CSIRO
Damon Sydes	Cassowary Coast Regional Council
Donna-marie Audas	Great Barrier Reef Marine Park Authority
Nick Heath	WWF
Marcus Sheaves	James Cook University
James Butler	CSIRO

2.2 Hydrology

The Herbert basin is one of the largest basins in the wet tropics and the largest basin of the case studies in the project. There are relatively natural flows in the upper part of the basin where as the lower part of the basin, the floodplain, is highly modified and channelised due to intensive agriculture practices around the major centre, Ingham.

The basin has two different hydrological regimes with a unique mist rainforest ecosystem separating them.

2.2.3 Basin Assessment and Stocktake

The basin stocktake and identification of assets for the Herbert River Basin is shown at Attachment 2.

2.2.4 Basin Specific Processes

The results of the processes provided by modified ecosystems for the Herbert River basin are shown as Attachment 3 and 4. Notes from the groups are detailed below.

Regulation of water regimes

Floodplain system in the upper part of the basin provides a substantial sink for groundwater. This sink is impacted by a number of aspects namely:

- compaction from grazing which reduces percolation rates
- woody thickening caused by weed species can result in non-natural fire regimes, increased rates of overland flow and sheet erosion
- There may be a reduction of recharge in high flow periods resulting in reduced discharge into river systems in winter. This would have downstream effects as the mist rainforests adjacent to the gorge rely on airborne water to support them.

The upper part of the basin is currently connected and there are no weirs or dams. However, the upper and lower basins are disconnected by a natural feature – a narrow gorge and associated steep waterfall system (Wallaman Falls system).

Recent changes to the environmental management and pastoral management in the upper Herbert basin should reduce woody thickening through a reduction in stocking rates, an increase in organic matter and a more natural fire regime.

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Water flows are highly modified on the flood plain and lower Herbert basin. Bunding from road and rail infrastructure and weeds (Hymenachne) diverts flows throughout the floodplain. Over-bank flows have been also been reduced substantially due to channelization for efficient agriculture. By decreasing the overland flows a number of agricultural objectives are obtained including:

- faster discharge rates/drainage
- reduced retention due to actions such as laser levelling.
- In addition to the benefits attained, a number of negative actions also occur including:
- Increased sediment loading, resulting in more movement of sediment to inshore habitats. This has negative impacts on near shore species including seagrass.
- Increased delivery of pesticides and other pollutants.

However, cane may be providing some ecological services that native grassland once provided.

Carbon and nutrient cycling
A number of factors affect the carbon and nutrient cycling within the Herbert basin:
Cattle:

- Methane source
- Light stocking rate – no change
- Heavy stocking rate – decreased soil organic matter – higher levels of erosion

Fires:

- High fire frequency leading to woody thickening, suppressing fire
- Reduced biochar into soil
- Occasional high intensity fire with major volitisation of carbon
- Gamba grass could generate fire events which would reduce live biomass carbon storage and potential biochar formation

Other nutrients:

- Carbon exported/released rather than sequestered/ cycled within the system
- Huge inputs of nitrogen and phosphorus per hectare
- Increased export through changed flow – all year rather than a pulse
- Increased nutrients in ground water – released in low flows

Biological
The upper Herbert basin has natural systems which are quite intact. There may be possible loss of in-stream habitat due to increased sedimentation caused by erosion and grazing impacts. This would reduced dry season flows and decrease retention capacity.

One major feature affecting biological processes is the one way connection to the reef through the narrow gorge and waterfalls. This physically restricts all aquatic flora and fauna from heading up from the lower to upper basins.

The lower Herbert basin is highly modified which has many potential impacts on biological processes including:

- loss of open water habitat due to sedimentation/weeds/Dissolved Oxygen barriers
- pathway blockages
- large nutrient rich first flushes
- acid sulphate soil
- tidal bunding – effect recruitment and passage for fish
- loss of tidal flat
- channel section increased flows
- during low flows: minimal connections, sedimentation, increased drainage.

There is, however, increased winter habitat due to ponded pastures which is favourable for migratory birds including storks, brolgas and egrets.

2.2.5 Climate Change

Groups were asked to look at regional climate change predictions and how they might affect the process and hydrology of the basin. Results for the Herbert are shown as Attachment 5.

2.3 ROSS RIVER BASIN

2.3.1 Group Members

Name	Organisation
Michael Warne	Department of Environment and Resource Management
Cr Vern Veitch	Townsville City Council
Shauna Naron	Department of Environment and Resource Management
Adam West	Department of Employment, Economic Development and Innovation
Ian Dight	NQ Dry Tropics
Peter Gibson	NQ Dry Tropics
Scott Fry	Wetland Care
Melissa Evans	Great Barrier Reef Marine Park Authority

2.3.2 Hydrology

The Ross River basin has an altered flow regime dominated by the Ross River Dam at the top of the basin. The flows of the Ross River are additionally modified by the presence of three weirs downstream of the dam. The dam and weirs were built for flood mitigation and restrict the natural flows across the floodplain.

Flows from distributaries such as the Bohle River are largely unmodified, however there is increasing pressure on the systems from urban development.

2.3.3 Catchment Stocktake

Groups were asked to do a stocktake of the major assets (natural and anthropogenic) within their basins. Results for the Ross River basin are shown as Attachment 6.

2.3.4 Processes/Components

The results of the processes provided by the ecological ecosystems for the Ross River basin are shown as Attachment 7. Notes from the groups are detailed below.

Sediment

The Ross River Dam, three main and two minor weirs have dramatically increased coarse sediment retention and settling. This leads to an increased proportion of fine sediment in the discharge areas (beaches) and a decreased proportion of coarse sediments depositing on the beaches. Another contributing factor to the disproportionate deposition of sediment on the beaches to the north-west of Townsville is the port rock wall and reclaimed land. The deeper water adjacent to the rock wall prevents sediment transport along the coast to the north-west. Land use over time has changed to grazing which has increased soil erosion, however its transport through the basin to the marine region has been largely affected by the dams and weirs. Grazing and land development has increased soil erosion into the Bohle River distributary, the flow of which is unaffected by man-made barriers and flows into Townsville's northern beaches region. Although flow is unaffected, sediment from the Bohle River has changed in composition. This has changed the composition of beaches adjacent to the outflow at Bushland Beach. Bushland Beach is now composed of the finer sediment, as courser sediment is not being deposited onto the beach.

There are also composition changes to beaches on Magnetic Island due to the increased fine sediment discharged from the Ross and the Bohle Rivers. This is exaggerated by the fine sediment moving northwards from the Haughton and Burdekin rivers into neighbouring basins especially in times of flood.

Although the Ross catchment is highly urbanised, there is generally an initial large spike in soil erosion which reduces afterwards because of revegetation and hard surfaces.

The Alligator Creek region to the south of Townsville is impacted by erosion due to over-grazing. There is one weir which has minimal retention capacity under high flow conditions. This increased sedimentation settles out and impacts on the freshwater wetlands downstream. The main shipping lane into the Port of Townsville is frequently dredged for access of vessels into the Ross Creek. The sediment is dumped out to sea.
Survival and reproduction

The Ross basin has a high amount of urban development which can lead to fragmented habitat, particularly coastal, with few corridors. The weirs within the urban areas prevent large marine species (eg sharks, turtles) from using the rivers fully. However the weirs and dam still retain some ecological values. They support large bird populations so there must be something there for them to eat!

The Ross Creek distributary is not a favourable area for aquatic organisms. It has highly modified banks and lack of in water vegetation which allows for increased predation due to lack of habitat or refugia. Water quality in this river may also limit which aquatic species can use the area. This may also be the case for the Bohle and Alligator creeks, however these rivers do provide good habitat for many migratory aquatic species.

The foreshore adjacent to Townsville has seen large scale habitat changes including sand renourishment, which involves having large machinery on beaches. This has affected the ability for marine organisms, including turtles, to use beaches. Humans and domestic pets also use the beaches in close proximately to urban areas which can also affect marine and intertidal flora and fauna.

Seagrasses in the near-shore marine waters are potentially affected by increased fine sediment suspended in the water column through smothering and reduced light penetration and decreased photosynthesis. This has flow on effects for dugongs and turtles who feed almost solely on seagrasses.

Deposition and mobilisation
In the Ross catchment there are some gross pollutant traps that cannot deal with the amount of rubbish entering waterways. Many of the pollutant traps in Townsville are constantly full and could benefit from more regular cleaning. If they are not emptied regularly they can over-top which releases the trapped rubbish back into the system. Plastic is a hazard to turtles, crocodiles, whales and birdlife. Cigarette butts are eaten by some fish and other marine animals where toxins leach out and cause damage.

There is a general lack of knowledge on endocrine disruptors, pharmaceuticals, industrial chemicals, personal care products and outputs from sewage treatment plants and stormwater. This is an area which remains a relative uncertainty in the Ross basin.

The Townsville Port accommodates large ships which have the potential to pollute the near shore area adjacent to the Ross River and Ross Creek. The Port Authority regulates organisations that discharge into port. The port may soon be undergoing a major extension which may increase the potential for discharge of foreign materials into the marine environment and stir up bottom sediment due to propeller motion.

Industry south of Townsville has potential problems from the tailings dams associated with the two metalliferous (Zinc,Copper,Nickel) refineries. There may be problems associated with the breaching of off-site storage and transport during wet seasons.

Long-shore transport of water and contaminants from the southern Haughton and Burdekin rivers affects the water quality on the ocean in front of Townsville. The affect of neighbouring catchments must be looked at when determining where pollutants and sediment originate from.

2.3.5 Climate Change

Groups were asked to look at regional climate change predictions and how they might affect the process and hydrology of the basin. This is shown for the Ross River basin as Attachment 8.

2.4 PROSERPINE RIVER BASIN

2.4.1 Group Members

Name	Organisation
Hugh Yorkston	Great Barrier Reef Marine Park Authority
Jim Tait	Consultant
Jon Brodie	James Cook University
John Bennett	Department of Environment and Resource Management
Margaret Gooch	Great Barrier Reef Marine Park Authority
Judith Wake	University of Queensland

2.4.2 Hydrology

The Proserpine catchment has high seasonal flows which are regulated by the Peter Faust Dam at the upper end of the catchment. The highly modified lower catchment restricts overbank flows and the flow of water across the floodplain. The modified lower catchment has reduced flows, which reduces the amount of flushing out of accumulated macrophytes and exotics, resulting in areas of black water with low dissolved oxygen.

Flows across the floodplain are also highly channelized therefore there is minimal recharge of the floodplains. In addition, there are coastal bunds which remove the mixing of tidal & freshwater flows. The bunds are a marked demarcation between freshwater and saltwater which results in a loss of connectivity between marine and freshwater systems as well as reducing the function of intertidal ecosystems.

2.4.3 Catchment Stocktake

Groups were asked to do a stocktake of the major assets (natural and anthropogenic) within their basins. This is shown for the Proserpine as Attachment 9.

2.4.4 Processes/Components

The results of the processes provided by the ecological ecosystems for the Proserpine River basin are shown as Attachment 10. Notes from the groups are detailed below.

Sediment transport/load

The Peter Faust Dam is the biggest regulatory component for sediment in the Proserpine catchment. The dam retains upland sediment delivery and there is almost no overflow. The lack of course sediment from the upper catchment impacts on beach development, resulting in finer sand and silt making up beach composition adjacent to the river mouth (Conway Beach). The lowland part of the catchment is very flat, so erosion rates are low. This also reduces sediment delivery to the river mouth.

Additional sediment is delivered to marine communities from urban development on steep slopes in major tourist townships such as Airlie Beach. Increased clearing of mangroves for marina developments has reduced the opportunity to slow transported sediments.

Nutrient transport/load

Historically, overbank flow would have delivered particulate nitrogen and particulate phosphorous to the flood plain however particulate nutrients are now replaced by dissolved form. Particulate nitrogen and particulate phosphorous would have been delivered to coastal sedgelands, however the flows of dissolved nutrients now travel through coastal wetlands, depositing in the inshore marine environment.

Particulate nitrogen and phosphorous levels have also been altered. Predominantly, dissolved nitrogen and dissolved phosphorous would be increased by runoff from canelands. Dissolved nitrogen and phosphorous have varying effects on coastal systems including:

- stimulating weed growth in coastal wetlands. These large areas of weeds rot when inundated and contribute to reduced dissolved oxygen in the water.
- Urea from canelands. This acts differently from other dissolved inorganic nitrogen in stimulating bacteria growth as well as autotrophs.
- delivery of sewage to marine communities from Airlie beach and other locations
- an impact on the main channel in Proserpine River. Nutrients from infiltration to aquifers are discharged into main channel, stimulating aquatic weeds which are submerged, floating and emergent
- increasing nutrients which are also high in distributed flow channels
- growth of aquatic weeks during dry season. As water levels fall, emergents die if water surface is kept high.

2.4.5 Climate Change

Groups were asked to look at regional climate change predictions and how they might affect the process and hydrology of the basin. This is shown for the Proserpine as Attachment 11.

2.5 STYX RIVER BASIN

2.5.1 Group Members

Name	Organisation
Mark Read	Great Barrier Reef Marine Park Authority
Chloe Schauble	Great Barrier Reef Marine Park Authority
Sue Sargent	Burnett Mary Regional Group
Chris Carroll	Department of Environment and Resource Management
Glen Moller	Department of Environment and Resource Management

2.5.2 Hydrology

The dominant features of the Styx catchment are the relatively low population and lack of major impediments to natural flows through the basin. The lack of any major water storage facilities within the catchment means the major township of St Lawrence sources its water from the adjacent Calliope Basin. There is good connectivity through the basin due to minimal changes to the hydrology.

2.5.3 Catchment Stocktake

Groups were asked to do a stocktake of the major assets (natural and anthropogenic) within their basins. This is shown for the Styx as Attachment 12.

2.5.4 Processes/Components

The results of the processes provided by the ecological ecosystems for the Styx River basin are shown as Attachment 13. Notes from the groups are detailed below.

Habitat for ecologically important animals

The Styx catchment provides the ideal habitat for many ecologically important animals including:

- shorebirds/waders. This is especially due to a mix of saline and fresh water in ponded pastures which is useful for feeding and roosting.
- dugongs and green turtles. Feed and habitat can be found here.
- crabs
- prawns
- barramundi
- flying fox.

Salinity regulation

The Styx basin has some barriers to saltwater ingress tidal movements. This changes upstream productivity from saline tidal to ponded lacustrine. This limits connectivity for fish, although overtopping occurs frequently. Ponded pasture is the most common artificial barrier which retains freshwater (for grazing pasture). These bunds modify and regulate water flow through the basin. There is an increased risk of acid sulphate soils in bunded areas although this is often not realised (as submerged).

Groundwater dependant ecosystems

There are a number of recharge areas throughout the Styx basin. This assessment is based on the soil type mapping provided and stream flows in the area. There are some anomalies including a potential outflow in the highly permeable soils and in mangroves.

There are large stands of forested floodplain which have a high likelihood of being a groundwater dependant ecosystem.
There is also a riparian groundwater dependant ecosystem (from pre-clearance maps).
Seagrasses growing in the near shore region have links to groundwater and productivity.

2.5.5 Climate Change

Groups were asked to look at regional climate change predictions and how they might affect the process and hydrology of the basin. This is shown for the Styx as Attachment 14.

2.6 CALLIOPE RIVER BASIN

2.6.1 Group Members

Name	Organisation
Jason Vains	Great Barrier Reef Marine Park Authority
Bruce Wilson	Department of Environment and Resource Management
Kate Hughs	Department of Environment and Resource Management
David Scheltinga	Consultant
Maria VanderGragt	Department of Environment and Resource Management
Fergus Malloy	Great Barrier Reef Marine Park Authority
John Platten	Department of Environment and Resource Management

2.6.2 Hydrology

The Calliope basin is a steeper system which allows for faster flows. The flows are perennial as they are fed by low-flow groundwater systems. Recharge of groundwater aquifers may be impacted by grazing and loss of permeable soils.

There are no major dams or other barriers within the Calliope basin and it is relatively well connected. The basin has limited extractions in terms of hydrology, but there are some inputs to the system including a large warm water input from the power station located near the mouth of the Calliope River.

2.6.3 Catchment Stocktake

Groups were asked to do a stocktake of the major assets (natural and anthropogenic) within their basins. This is shown for the Calliope as Attachment 15.

2.6.4 Processes/Components

The results of the processes provided by the ecological ecosystems for the Calliope River basin are shown as Attachment 16. Notes from the groups are detailed below.

Sedimentation/erosion

Before extensive European modification (pre-1940s) the Calliope basin had generally natural rates of erosion, good infiltration and natural rates of runoff. The Calliope basin is now extensively grazed which has led to a number of effects on sedimentation and erosion:

- Compacted soil. This has resulted in reduced infiltration, increased runoff and mobilized sediment. This is particularly important in highflow times and results in coarser sediment from the upper reaches of the catchment being mobilised.
- Increased sedimentation has resulted in increased sedimentation of nearshore reef environments and higher turbidity of lower reaches and nearshore reef environments.-

Gladstone is the largest urban centre within the Calliope basin but it has little ongoing affect on sedimentation. Within the Calliope basin, urban and industry impact less on sedimentation than grazing. There is a risk of overflow at the bauxite refinery of material stored within their dam structures (sediment and water quality).

Curtis Island is located in the near shore marine region adjacent to the Calliope catchment. Curtis Island is not extensively developed, however it is earmarked for some large-scale developments. Currently there are small changes to sedimentation and erosion but proposed development could alter that.

Biological connectivity - fish

This is the current situation for biological connectivity for fish in the Calliope basin:

- Good realized connectivity levels. There has been observed presence of migratory marine species in the upper catchment.
- Limited presence of floodplain wetlands.
- Terrestrial connectivity is impacted by the reduced riparian zone.
- Connectivity enhanced by base flow streams. The Calliope is a perennial system.
- There are no large barriers to passage throughout the basin. There is one small weir.
- Calliope provides important refugia. There are few major rivers without impoundments.

The Calliope is an important basin for habitat refugia and connectivity. It is the only basin case study which has limited barriers or impoundments.

Biological connectivity – seagrass/wetlands

This is the current situation for biological connectivity for seagrass/wetlands in the Calliope basin:

- Seagrass and salt pans are important for enclosed coastal food webs
- The floodplain is vulnerable to development and is highly modified already
- Seagrass and wetlands are important for some migratory species
- The Calliope has a lucrative mud crab fishery. Approximately 15-20 per cent of the Queensland catch is from enclosed coastal waters
- Fisheries are an important industry influenced by Boyne and Calliope.
- Social implications with regards to fishing within the nearshore areas of the Calliope.

Water regulation

Before extensive European modification (pre-1940s) the Calliope floodplain provided storage, infiltration and groundwater recharge. In the current state, runoff is increased because of reduced infiltration in high flow situations.

This is the current situation in low flows:

- Localised impacts of limited irrigation: reduction in base flow and groundwater inputs reduced because there is less infiltration.
- Low flows are a key aspect because of extraction and reduced recharge.
- Probable reduced groundwater recharge due to less infiltration and micro-climate changes (vegetation clearing) as well as the subsequent impacts on stream ecology.
- Increased runoff from urban industrial.
- The channelized flow from urban areas reduces water flows to saltpans and wetland environments.

2.6.5 Climate Change

Groups were asked to look at regional climate change predictions and how they might affect the process and hydrology of the basin. This is shown for the Calliope as Attachment 22.

2.7 Process and Components Table

Groups were provided with a processes and components table which was developed in Workshop I for natural ecosystems. They were then asked to contemplate the process and components of modified systems. The results across all catchments were compiled into the table ′ Capacity of natural and modified coastal ecosystems to provide ecological services for the Great Barrier Reef' as shown at Attachment 23.

2.8 Management recommendations

Groups were asked to discuss potential management recommendations for their catchments. Many of the recommendations were similar across each case study catchment. A table of collated recommendations is shown as Attachment 17.

SECTION 3 – WORKSHOP CONCLUSIONS AND NEXT STEPS

3.1 Next Steps

The next steps for the information collected in this workshop II involve incorporating the information into the Great Barrier Reef World Heritage Area Strategic Assessment and to progress the socio-economic factors. Consultation is underway with CSIRO and GBRMPA's Social Science group to develop a socio-economic component of coastal ecosystems.

3.2 Participant feedback

At the end of the workshop, participants were asked for their views on the effectiveness of the workshop, the workshop materials and the venue/catering. In general, positive feedback was received. Participants were happy that their recommendations from Workshop I were considered. Participants were notably happy with the variety of reference material available for use for their case study assessments.

Areas which worked well in the workshop were:

- Being able to apply the process/components theory to case studies made this complex work understandable.
- Having various and extensive spatial data available on each case study made assessment possible even for catchments where there was limited local knowledge in the group (ie. Styx).
- A larger workshop venue allowed for more space to move around.
- Workshop groups were mixed across areas of expertise. This allowed for group members to learn from their colleagues and develop a rich assessment of their case study area.

Areas which could be improved upon were:

- More local and scientific expertise needed to develop comprehensive studies for each Great Barrier Reef catchment.

Recommendations for future work included:

- Look at the socio-economic factors contributing to each catchment, including:
  - scenario planning
  - multi-generational information
  - Indigenous heritage and current use
  - farmers and fishers
- Develop a source 'formal' science to back up hypotheses

ATTACHMENT 1: WORKSHOP OBJECTIVES AND AGENDA

Objective 1:

Become familiar with case study catchments (*Wet Tropics* - Herbert, Proserpine; *Dry Tropics* - Styx, Ross, Calliope) and how changing land use affects hydrological flows across these catchments.

Objective 2:

- Identify:
    - a. *Components: natural and modified assets,*
    - b. *Processes/ecological services, and*
    - c. *Connectivity across the case study catchments.*
- How will the natural assets within this catchment and the Reef be affected by the current land use changes?

Objective 3:

Identify (and quantify?) the *key functional changes (to processes/ecological services) that are likely to have occurred with the change in land use.*

- How this will affect the natural assets and the GBR?

Objective 4:

Consider *how climate change impacts will be reflected in the natural and anthropogenicmodified landscape, superimpose regional Bureau of Meteorology climate change scenarios and Queensland Coastal Plan sea-level and storm surge spatial information onto objectives 1-3.*

- Assess how processes/ecological services will be affected

Objective 5:

Identify how can we complete this process and apply it to other catchments.

- What worked?
- What didn't?
- Way forward?

Time	Agenda	Who/where
Agenda - Day 1		
09:45	Morning tea provided on arrival	On site
10:15	Keynote presentation	Russell Reichelt
10:25	Workshop plan, objectives & outcomes – about the day ✓ Background information– recap on coastal ecosystems ✓ Connectivity Paradigm ✓ Groundwater & Groundwater Dependant Ecosystems ✓ Paddock to Reef Program	Donna Donna Mike , Hsuan Mike , Bruce Wilson, John Bennett
12:15	Lunch (provided)	Outside deck
1:00 1:20	Presentation: Introduction to the case studies for considering connectivity & the impacts of land-use change on connectivity and processes/ecological services Workshop activity – *Components* Using the maps and spatial tools available: • *Become familiar with the marine values, Coastal Ecosystems, species, soils and human assets in and adjacent to your case study catchment (Styx, Ross, Proserpine, Herbert or Calliope rivers).* Workshop activity – *Hydrology* • Consider how water moves across this catchment a. *How does it respond in periods of high, low and no flow?* b. *How does the hydrology REALLY work in the study catchment?* Presentation: About BAMM, AQUABAMM	Paul / Mike Mike, Donna, Paul, Hsuan, Mel, Elodie, Laise and Michael Mike, Donna, Paul, Hsuan, Mel, Elodie, Laise and Michael Mike
3:00	Afternoon tea (provided)	Outside deck
3:15-5:00	Workshop activity –*Processes/Ecological Services* • Assuming land use is managed to 'best practice' review the list of processes/ecological services provided for the modified landscapes: a. *Assess the capacity of the modified systems to perform the ecological services under high, low and periods of no flows?* • Consider the processes/ecological services provided by both natural and modified ecosystems in your case study catchment. b. *How have they affected/been affected by the components within the catchment?* • Consider and apply processes/ecological services (biological, physical and biogeochemical processes) provided by the current systems with what was there previously. c. *What do these changes mean for the natural assets, coastal ecosystems and ultimately the Great Barrier Reef?*	Mike, Donna, Paul & Hsuan

Agenda - Day 2

08:30	Presentation: recap on the work so far Group presentations/discussions: Report back to the group on the previous days findings. • *What are the dominant components in your catchment?* • *What were the dominant processes/ecological services, in your catchment?* • *How have ecological processes and connectivity been affected spatially by the modifications to hydrology in this landscape?* • *What do we know about these changes?* General discussion on the process so far.	Mike, Donna, Paul & Hsuan
10:00	Morning tea (provided)	Outside deck
10:15	Workshop activity – *Climate Change* Workshop: Superimpose the regional climate change pressures to the ecological services identified for the modified landscapes and connectivity processes using the case study catchments. Consider sea-level rise and storm surge mapping from the Queensland Coastal Plan *Group presentations:* • *How will climate change affect the processes in your catchment?* • *What are the implications for the health and resilience of the Great Barrier Reef*	Chloe, Mike, Donna, Paul & Hsuan
12:00	Lunch (provided)	Outside deck
12:30	Discussion: How can we complete this process and apply it to other catchments. • *What worked and what didn't work?*	Mike & Donna
2:45	Where to from here – what will happen to the work from these two days?	Hugh Yorkston
3:15	Finish	

ATTACHMENT 2: HERBERT RIVER BASIN VALUES

Dairy - non-irrigated

Rural residential area -Milstream estate has 1000m2 recently developed hobby blocks

National Park protected

Power lines

High grazing values - international $ - close to export ports. majority of land use modified for grazing. Intact canopy cover with degraded understory

Tin mining in Herberton. There is a legacy of mining in this region

Farming - potatoes and peanuts

Groundwater dependant ecosystem. Broad area across the top of the basin

Irrigated farming - tomatoes and other horticulture

Mining town legacy issues - spoil structure still present

Grassland/forested floodplain network dominates - also a Groundwater Dependant Ecosystem

Opportunities for carbon sequestration

National Parks has recently taken over this area of land (AWC) - 2 blocks - cattle are to be removed from this area

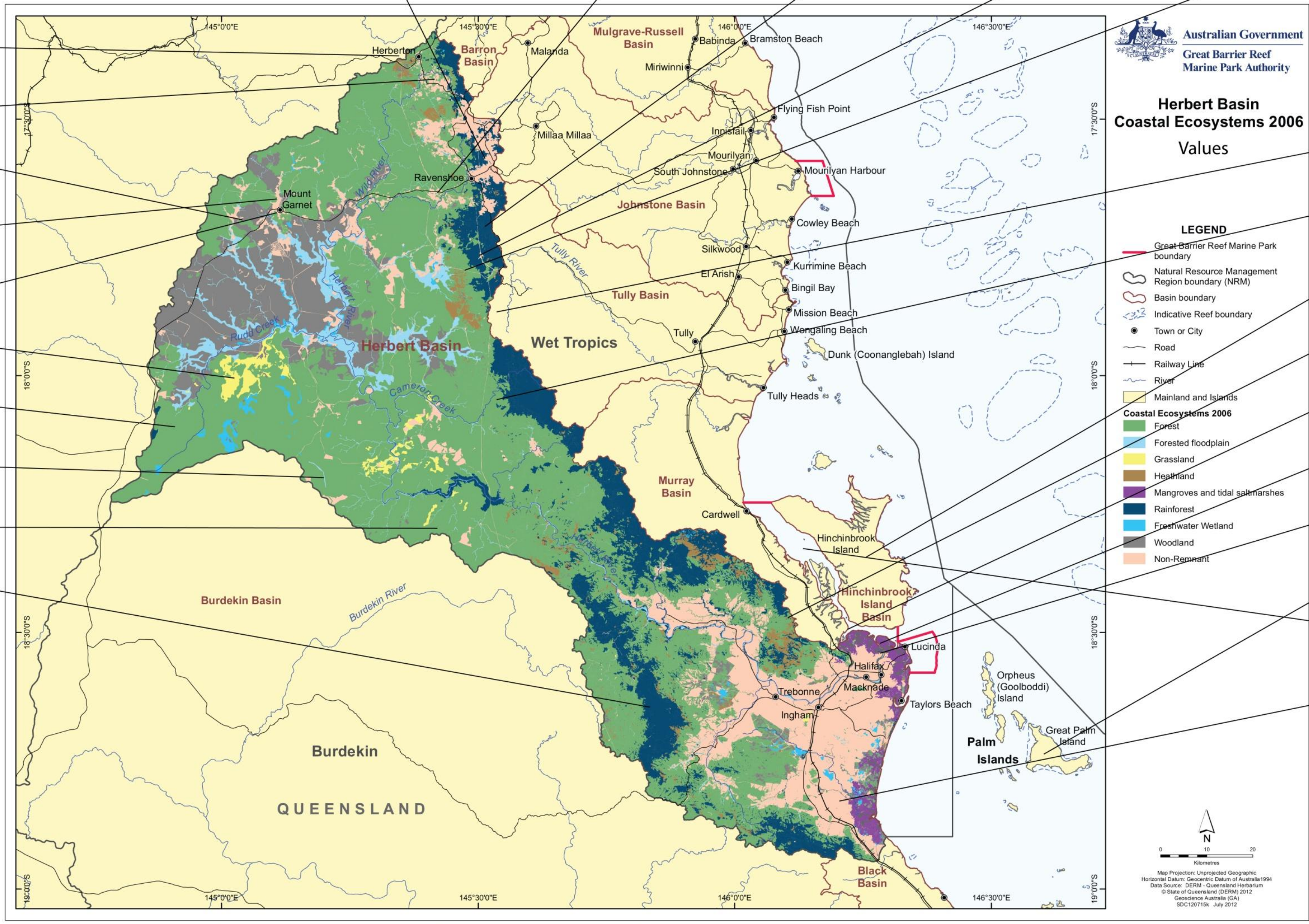
Waterfalls - tourism values

National Park - World Heritage Area

Non-natural fire regimes

Significant non-native cover all over the country with high infestation of weeds

Feral animals present - cats & pigs particularly



Bunchabula, Cerima and Yorka (Australian Conservation) Indigenous areas

Heathlands upper catchment modified due to Hymenachne, Siam and para grass

High grazing values in the upper catchment - International $ and close to export ports

Traditional burning techniques, mosaic burnings. Indigenous holdings at Kirrania

Tourism

Cassowaries

Aquaculture

Significant wetlands - EPBC species

Heavy sedimentation has resulted in loss of navigational access

Traditional Owner management ie Palm Island

Turtle and dugong habitat

Return to grazing

No or little riparian vegetation

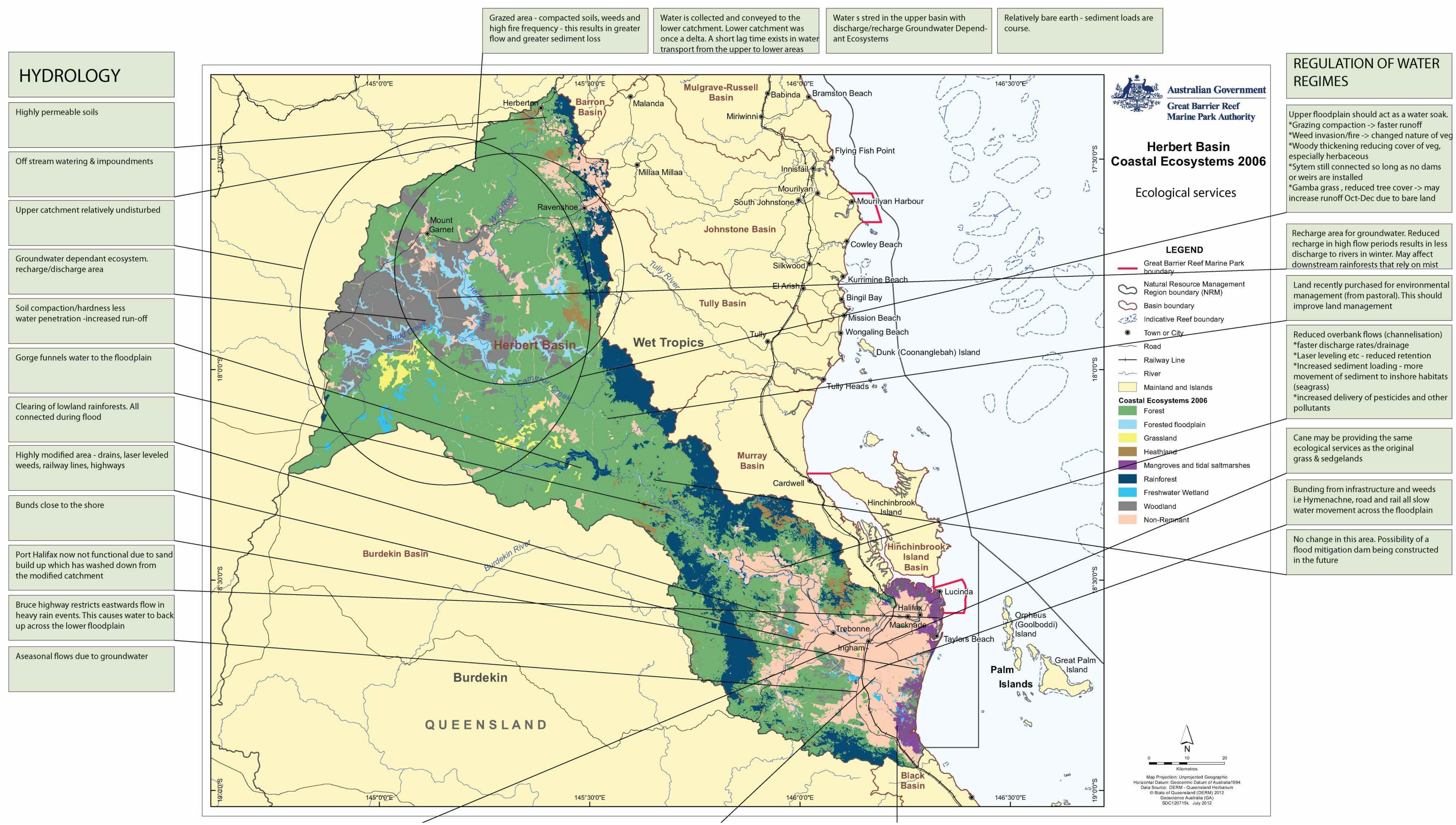
Hymenachne weed infestation

Small creeks and wetlands choked by water weeds. These areas have low dissolved oxygen and poor productivity

Bunding to reduce intertidal habitats

Sand slugs (sediment)

ATTACHMENT 3: HERBERT RIVER BASIN ECOLOGICAL SERVICES



ATTACHMENT 4: HERBERT RIVER BASIN ECOLOGICAL SERVICES CONTINUED

Carbon & nutrient cycling

Cattle grazing
*methane source
*light stocking rate will be no change to C
*heavy stocking rate will decrease Soil OM

Less frequent fires reduce carbon cycling ability

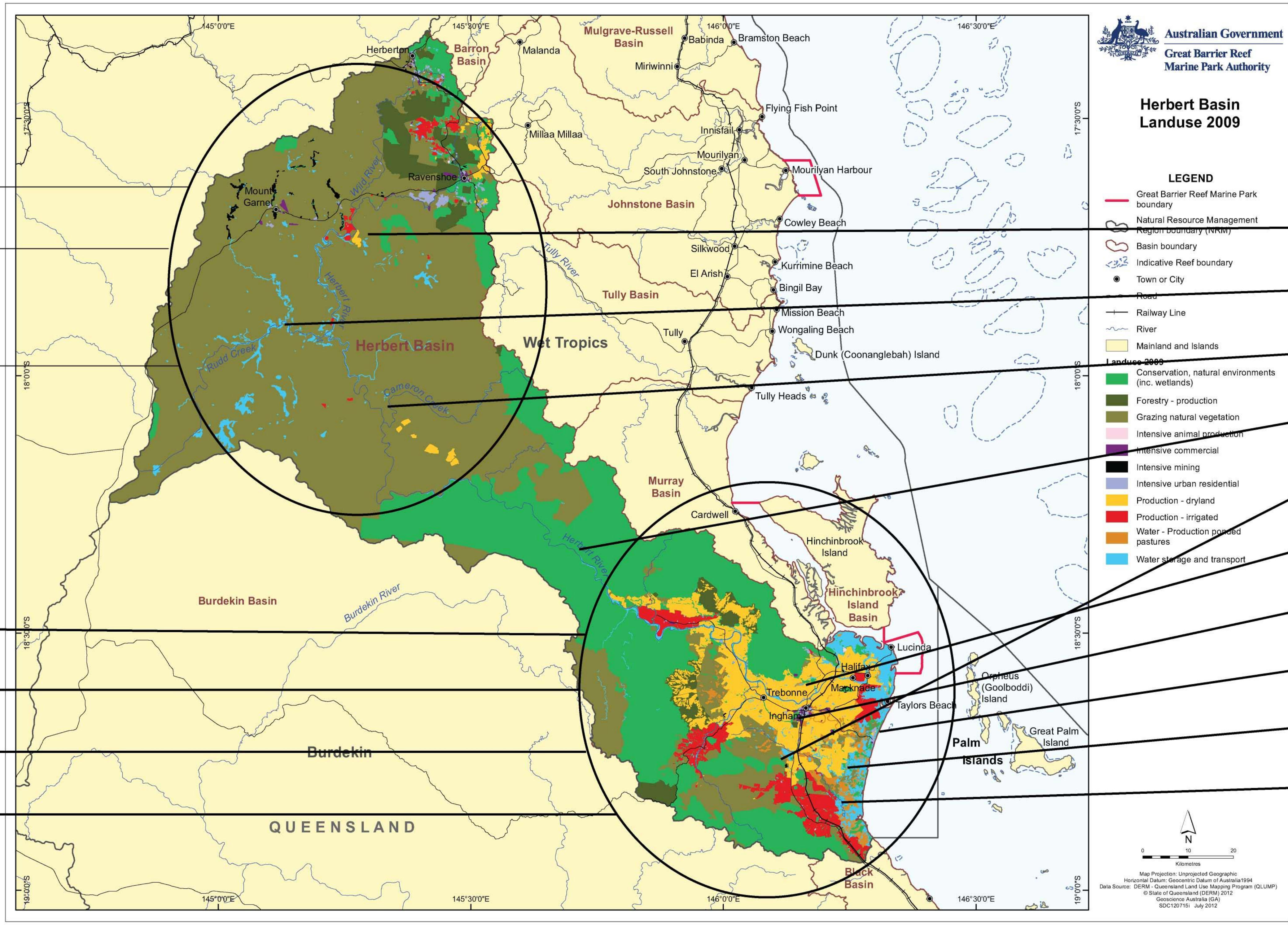
High fire frequency leading to woody thickening, supressing fire
Reduced biochar into soil
occasional high intensity fire with major volitisation of carbon
Gamba grass would generate fire events which would reduce live biomass carbon storage and potential biochar formation

Carbon exported/released rather than sequestered/cycled within the system

Huge inputs of Nitrogen and Phosphorous per hectare

Increased export through changed flow - all year rather than pulsed flow

Increased nutrients in ground water - released in low flows



Service part II

BIOLOGICAL PROCESSES

Possible water draw down for irrigation - reduced downstream flows - affects feeder creek flows

Increased winter habitat due to ponded pastures (migratory birds - storks, brolgas egrets)

Natural systems pretty much still in place although may be loss of in-stream habitat due to sediments from grazing areas and reduced dr season flows

One way connection to the reef. The narrow gorge and waterfalls block all aquatic flora and fauna from heading up past this point

Pathway blockages
*loss of open water habitat due to sedimentation/weeds/dissolved oxygen barriers & high nutrient first flushes

During low flows - minimal connections sedimentation, increased drainage

Blocked access - channel section increased flows

Loss of tidal flats

Tidal bunding - affects recruitment and passage for fish

Acid sulphate soils

ATTACHMENT 5: HERBERT RIVER BASIN CLIMATE CHANGE SCENARIOS

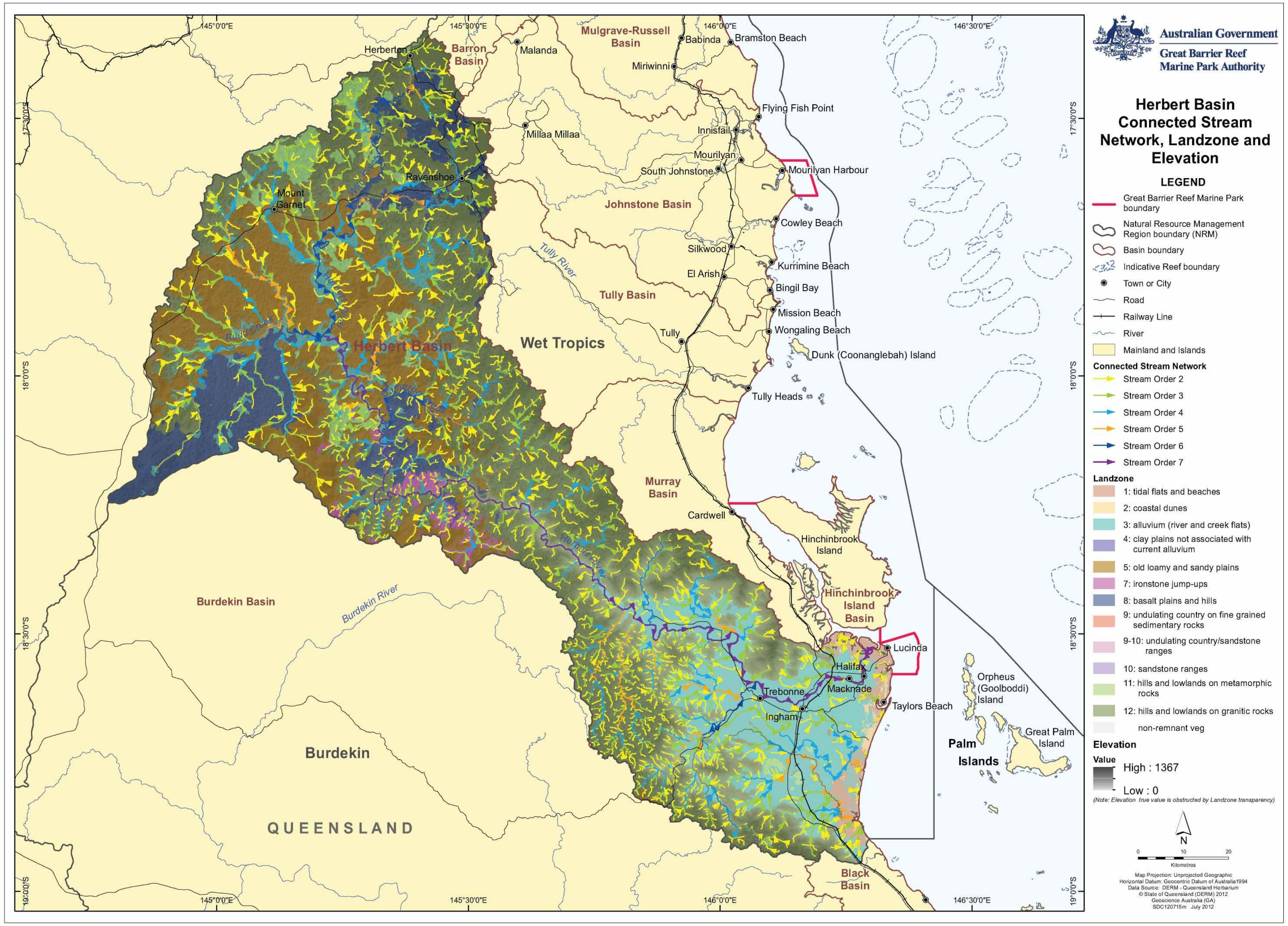
HYDROLOGY

Retention area - sponge action. Under climate change this soak area could potentially dry up which will affect the hydrology of the entire area

Rainforest species in this area are reliant on the spray/humidity from the passage of water through the gorge. Under climate change, the reduced water in the system would reduce the spray from the rivers in the gorge and affect rainforest health

Currently year round precipitation allows growth of rainforests. The effect of climate change will reduce the presence of clouds and alter the levels of timing and precipitation patterns

Relatively healthy with high dissolved oxygen due to waterfalls. Reduced water flow will reduce this and lead to:
Changed composition
Loss of rainforest
Increase in gamba grass
Loss of the eastern margingal rainforest (which may reduce winter recharge
Upland floodplain communities will change
Water retention will change
Increased flooding in the wet season
Decreased flows in the dry season
Increased hill/slope erosion
Significant reduced surface flow
Water table decrease form more bores
Rainforest slopes may dry out
Increase in hot fires
Greater erosion in the upper basin
Increased sedimentation in the lower basin
Cloud stripping from rainforests would decline, leading to more erosion, less stream flow, retreat in rainforest extent and loss of riparian rainforest extent
Less warmer water
Decrease in river health
More sediments, shallower and warmer streams due to upland stripping in upper basin
Edge interface - wet/dry - change to extended dry season



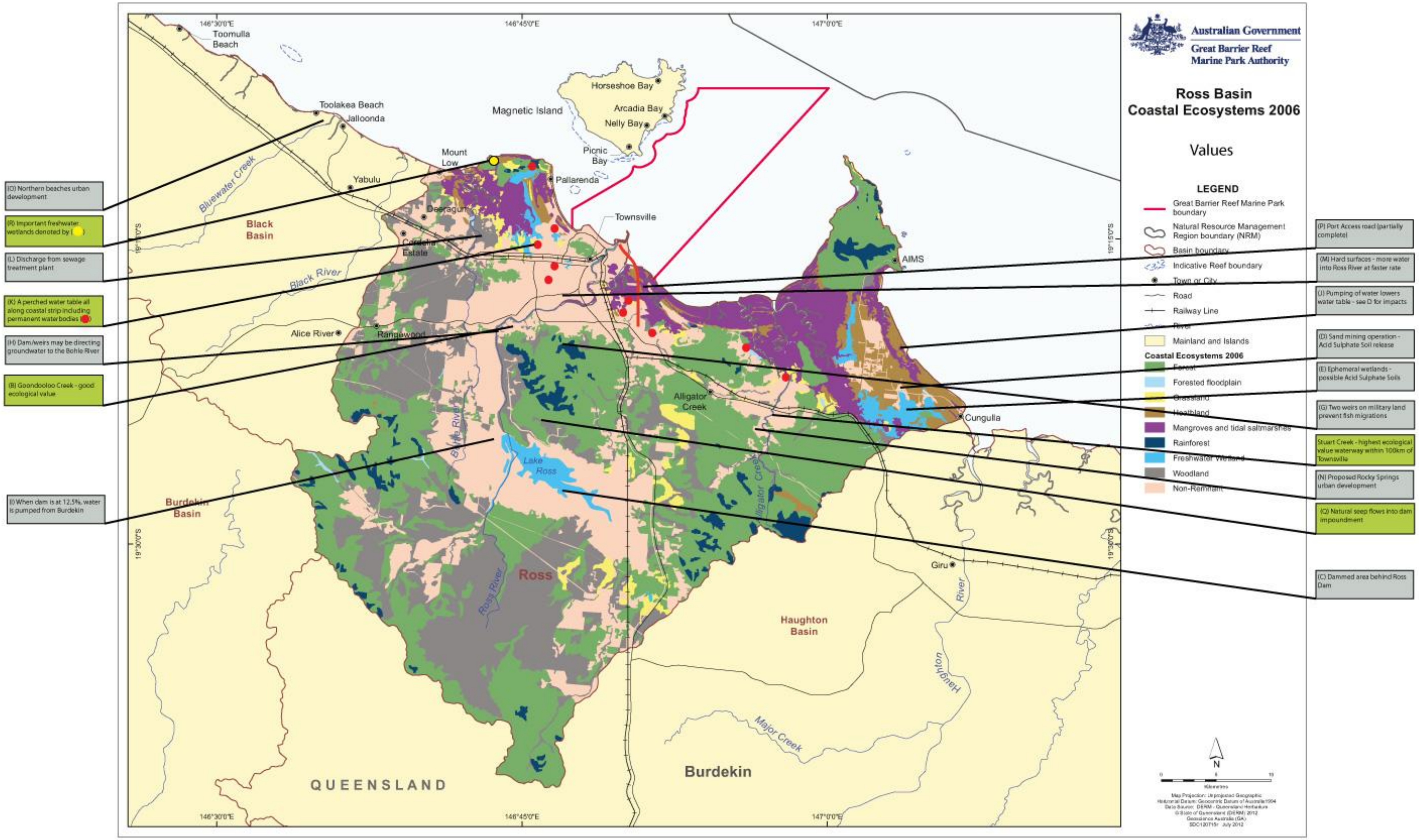
Climate change

Low flow issues with low dissolved oxygen and weed blockages away from the river. This will only increase with the affects of climate change. Would also expect to see:
Lower dissolved oxygen in dry season
Less water
Warmer water
Increased evaporation
Increased weed species
Water table drop
Cane industry may switch to irrigation
Saline intrusion
Semi saline groundwater
Increase in estuarine areas
Increased hard structure
Loss of small communities like Forest Beach
Abandonment of land
Cane area reduced and decline in viability
Loss of fringing mangroves in channel
Some sedimentation in channel

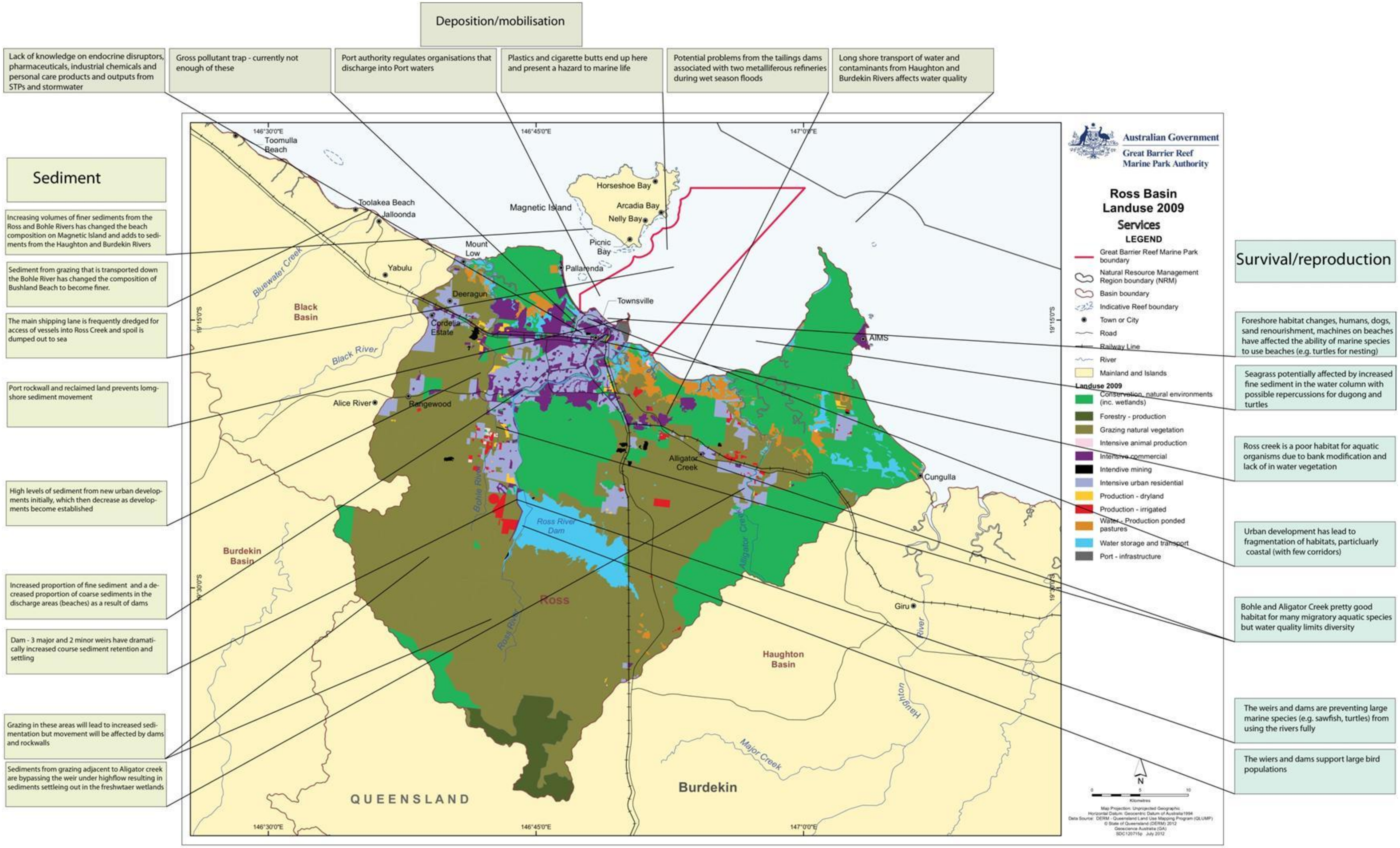
Carbon/Nutrient Processes

Mangroves well established - lots of biomass
Edge - carbon mobilised - peat
Pulse of carbon release, gradual after this
Fire increase and carbon increase
Loss of carbon storage
Decreased sequestration
If gamba grass present, sped up
Freshwater mangroves lost at the melaleuca/mangrove interface
Decrease of mangrove communities that rely on freshwater inputs
Increase saltpan and increase mangrove community structure - change to saline spp
Cane will become saltpan not saltmarsh
Upland changes will be subtle
More sediment
Increase in tidal retreat
Mangrove community structure change
Different seagrasses - longer dry clearer water - increase in dudong/turtle
Lucinda Port extended
Increase in mahogany glider due to increased habitat
Herbert may be the Burdekin/Fitzroy function
Camels/buffalo may become established

ATTACHMENT 6: ROSS RIVER BASIN VALUES



ATTACHMENT 7: ROSS RIVER BASIN ECOLOGICAL SERVICES



ATTACHMENT 8: ROSS RIVER BASIN CLIMATE CHANGE SCENARIOS

Near shore resuspension from storm activity will increase impacts on seagrasses and associated ecosystems

Estuarine wetlands will be flooded. Bunds may be built to prevent salt water intrusion

Estuarine wetland plant systems will try to move landwards into current grazing lands

Likely response is increased modifications to reducing impacts from flooding

Increased saltwater intrusion into groundwater will impact vegetation and infrastructure

New development/key infrastructure may be relocated to higher ground

Due to increased frequency of heavy rain, there will be additional stress on stormwater and STP infrastructure

Due to changing rainfall patterns expect to see reduced vegetation cover and increased soil erosion. However, dams & weirs will still trap most course particles

Railway lines and major roads could be flooded and may be elevated

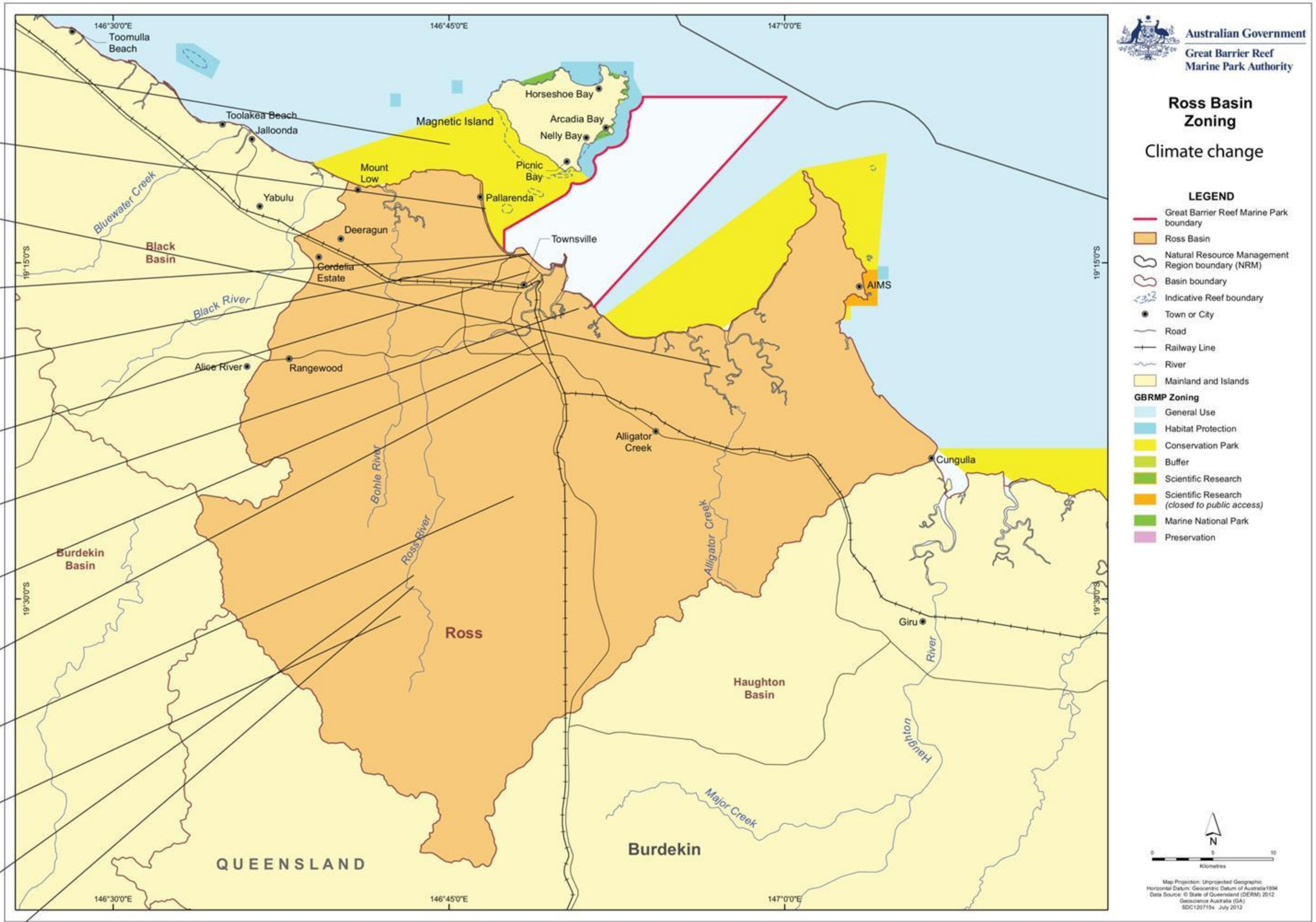
Rainforest areas likely to be impacted or lost with flow on impacts to associated species

Grazing land may become less viable

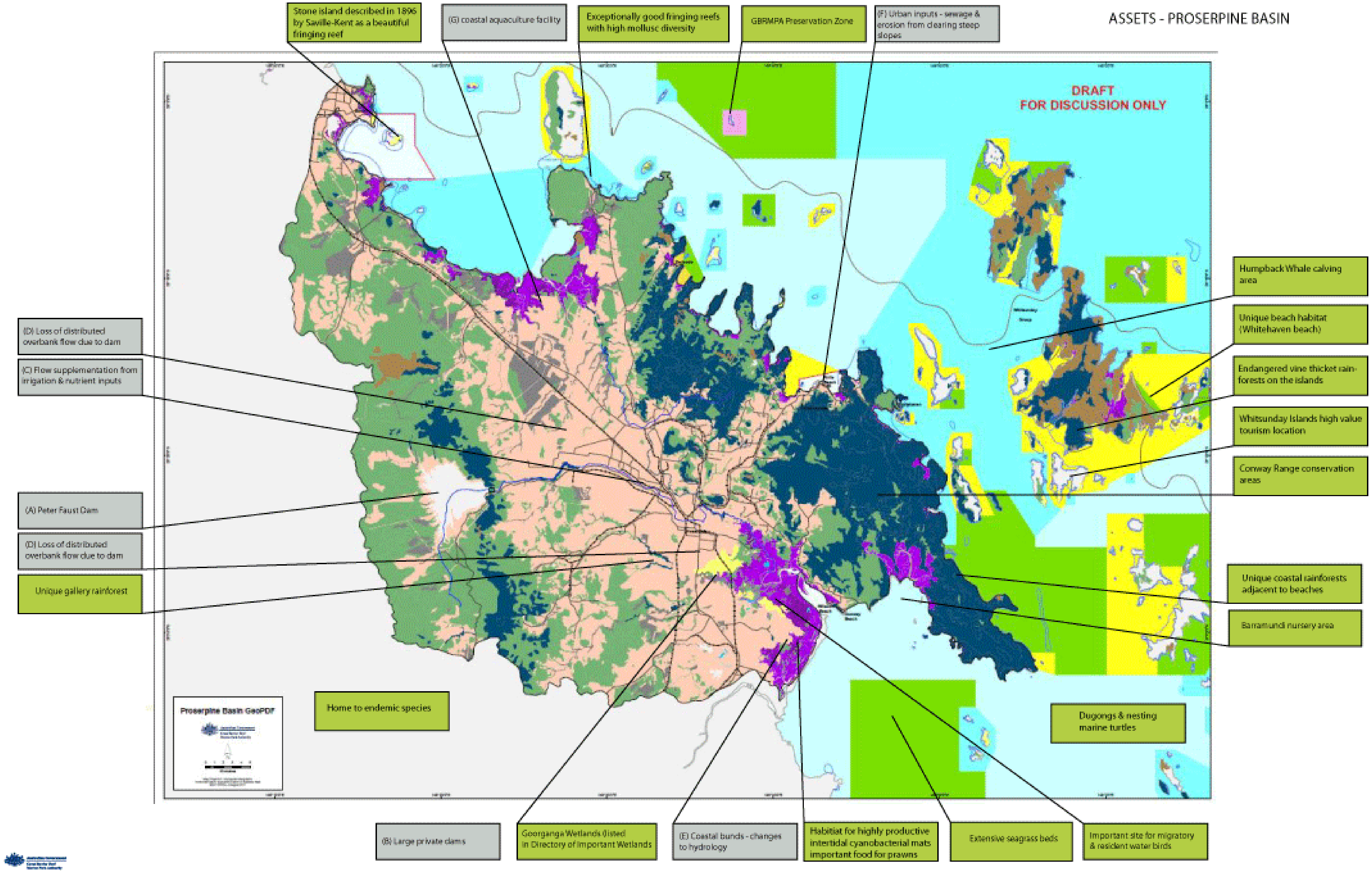
Overtopping of the dam may occur more frequently

Ross River dam water less likely to be used for flushing or environmental flows

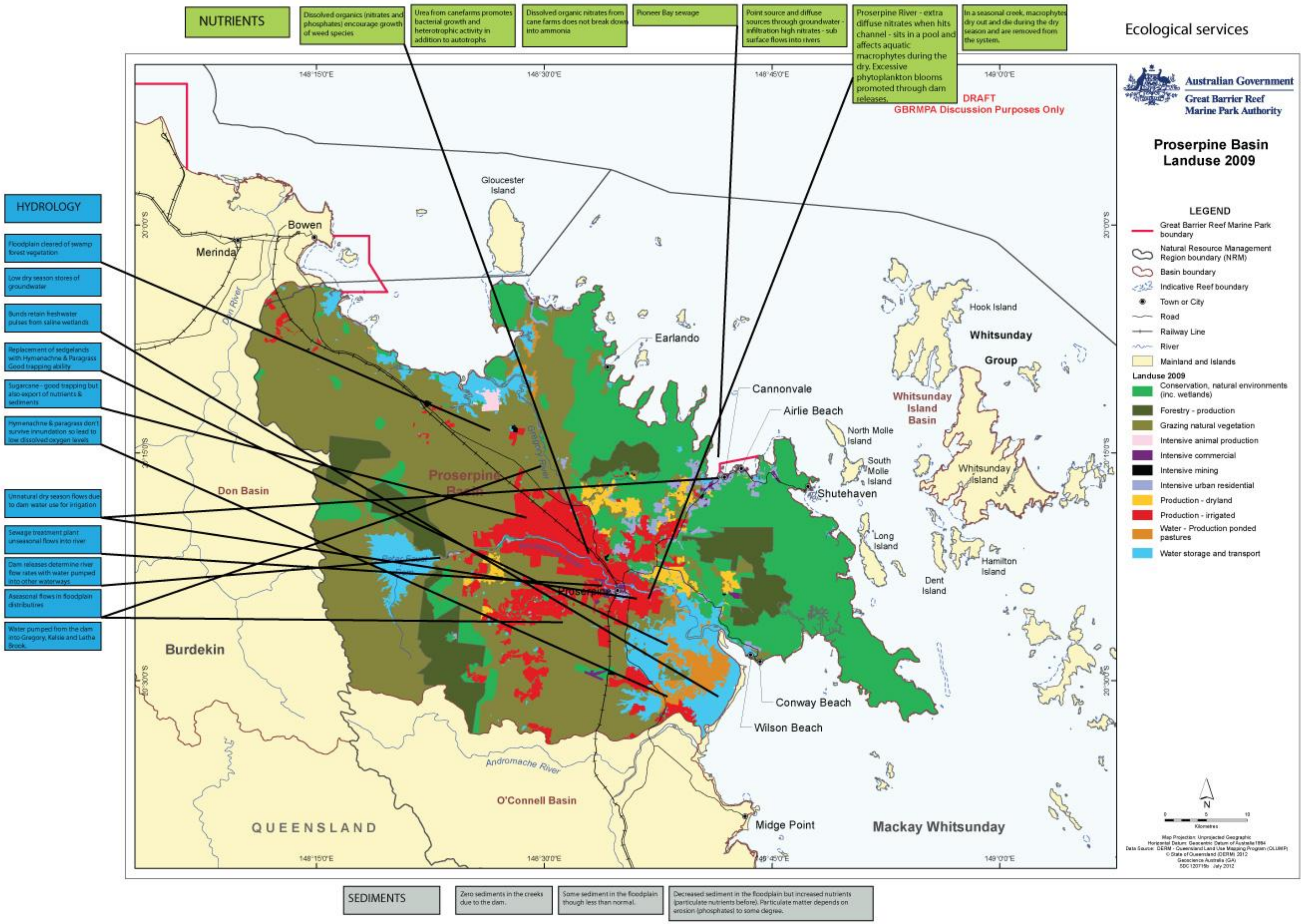
There could be an increased reliance for drinking water from the Burdekin



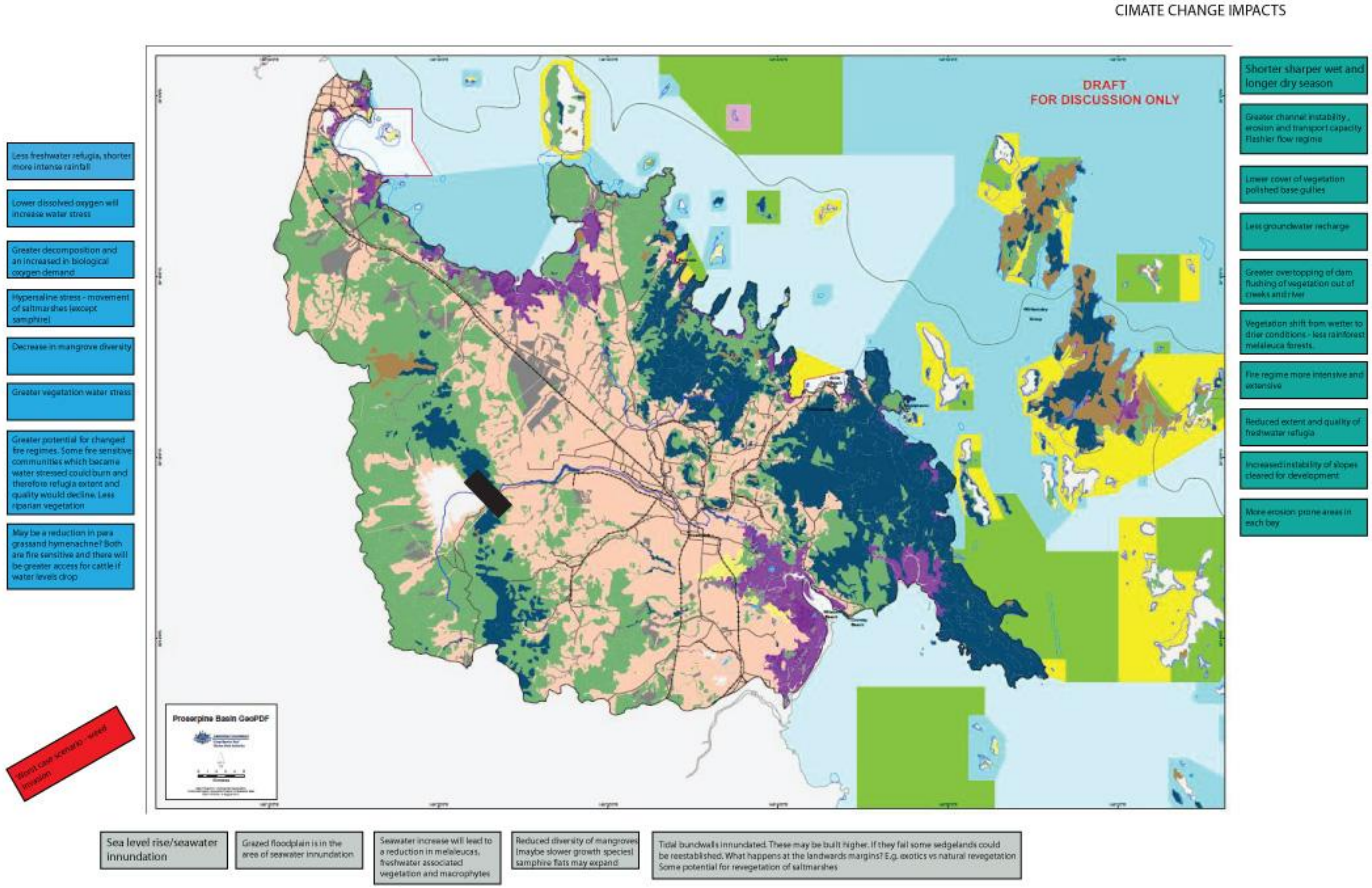
ATTACHMENT 9: PROSERPINE RIVER BASIN VALUES



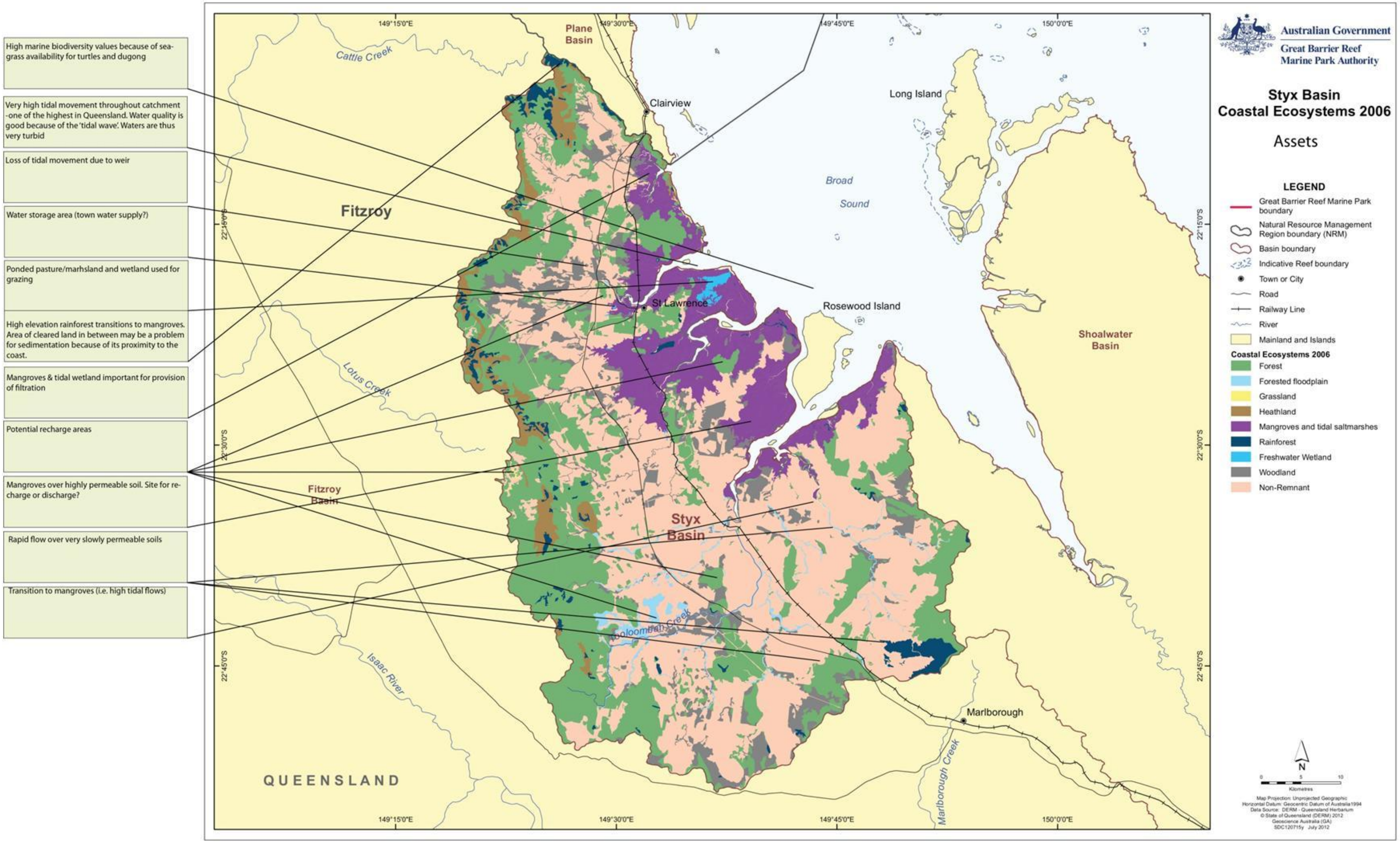
ATTACHMENT 10: PROSERPINE RIVER BASIN ECOLOGICAL SERVICES



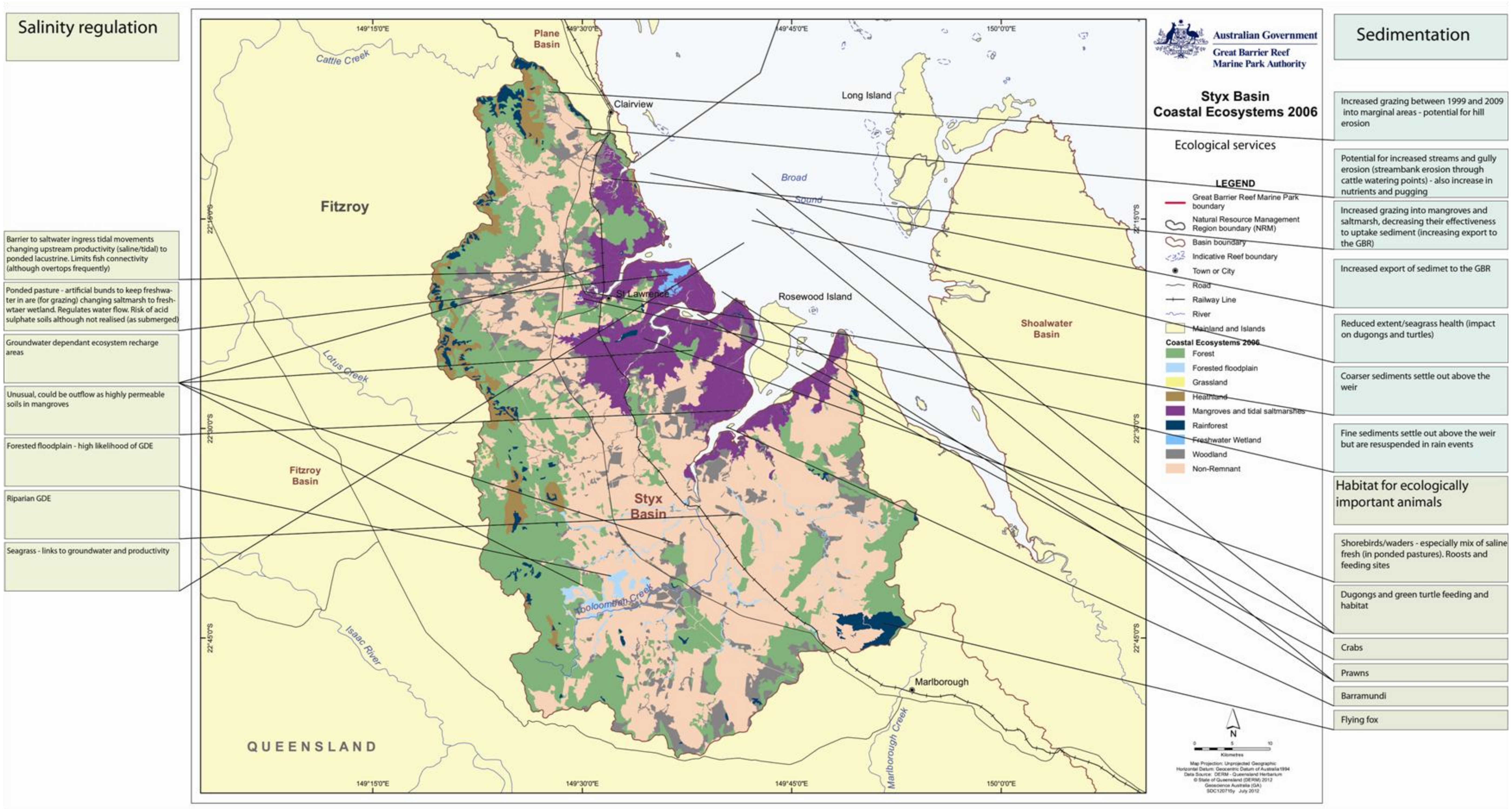
ATTACHMENT 11: PROSERPINE RIVER BASIN CLIMATE CHANGE SCENARIOS



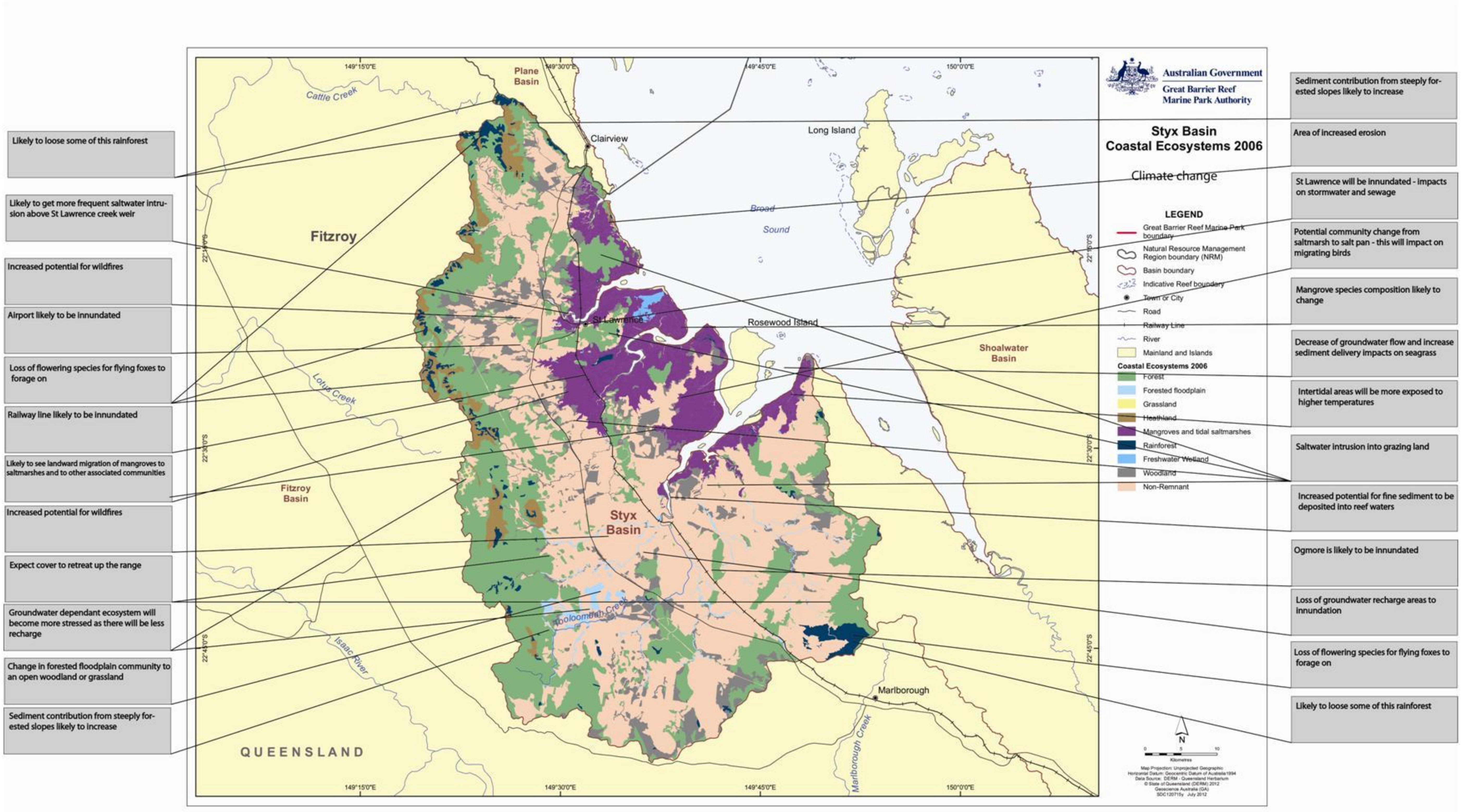
ATTACHMENT 12: STYX RIVER BASIN VALUES



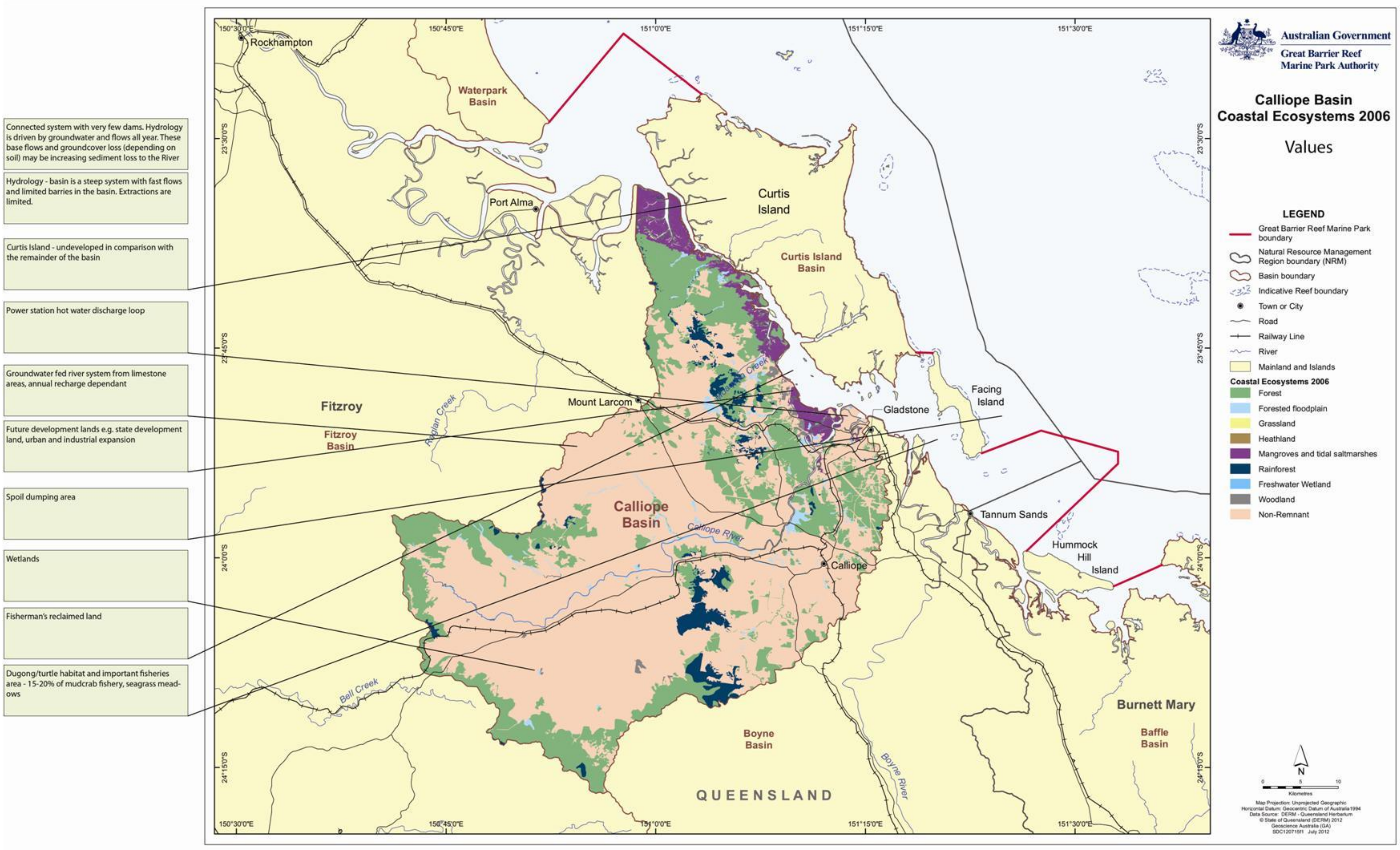
ATTACHMENT 13: STYX RIVER BASIN ECOLOGICAL SERVICES



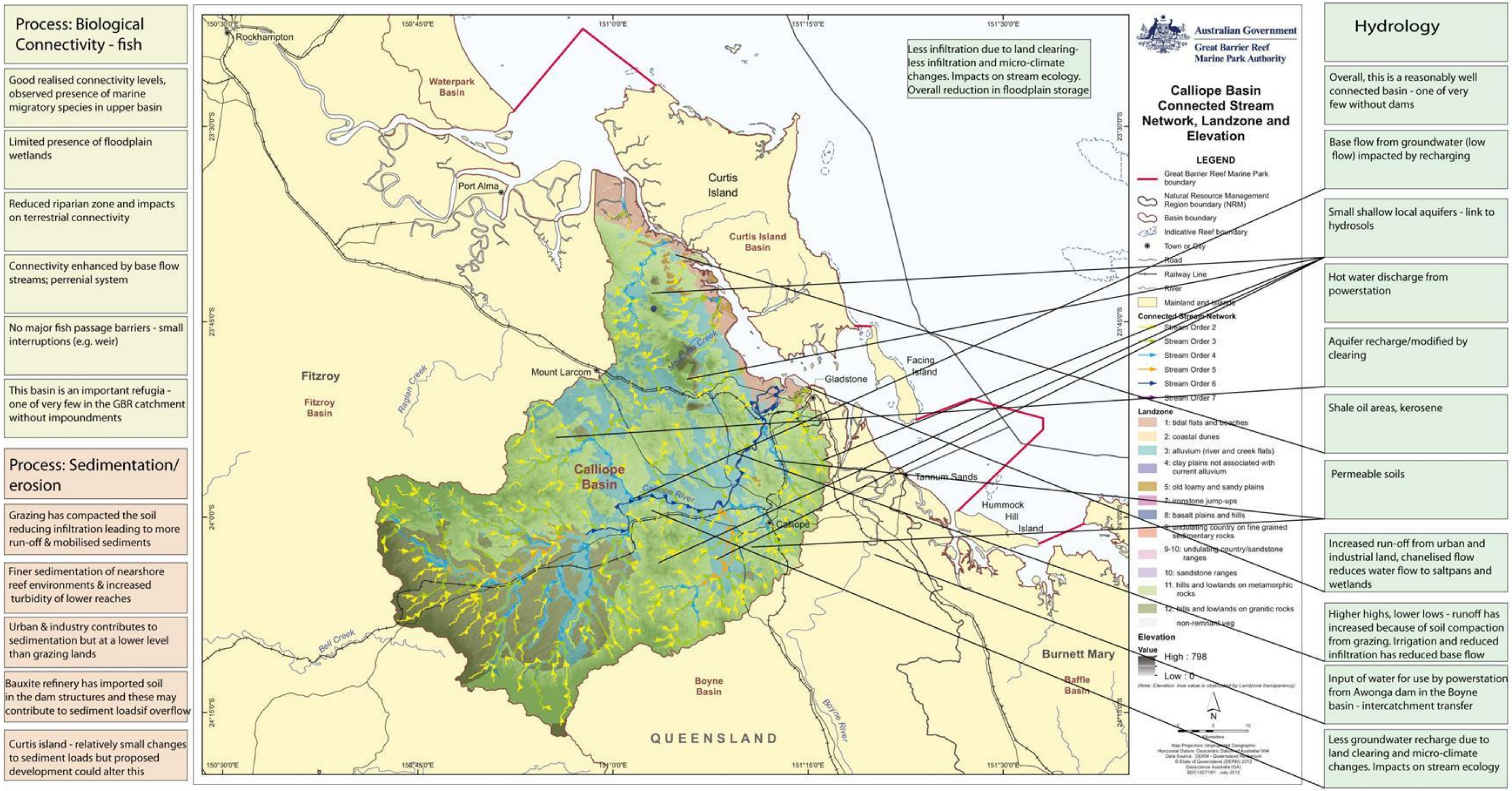
ATTACHMENT 14: STYX RIVER BASIN CLIMATE CHANGE SCENARIOS



ATTACHMENT 15: CALLIOPE RIVER BASIN VALUES



ATTACHMENT 16: CALLIOPE RIVER BASIN ECOLOGICAL SERVICES



ATTACHMENT 17: CALLIOPE RIVER BASIN CLIMATE CHANGE SCENARIOS

Process: Biological Connectivity - fish

Loss of mangroves wll have a major impact on the mudcrab fishery

If lose groundwater flows (due to drier dry) then may turn into an ephemeral system and lower connectivity

Connectivity may be impacted if our response to drier dry seasons is to dam the river

Process: Sedimentation/ erosion

Increased sedimentation/ersoion due to more extreme weather events and less vegetation cover during the dry

Possible management

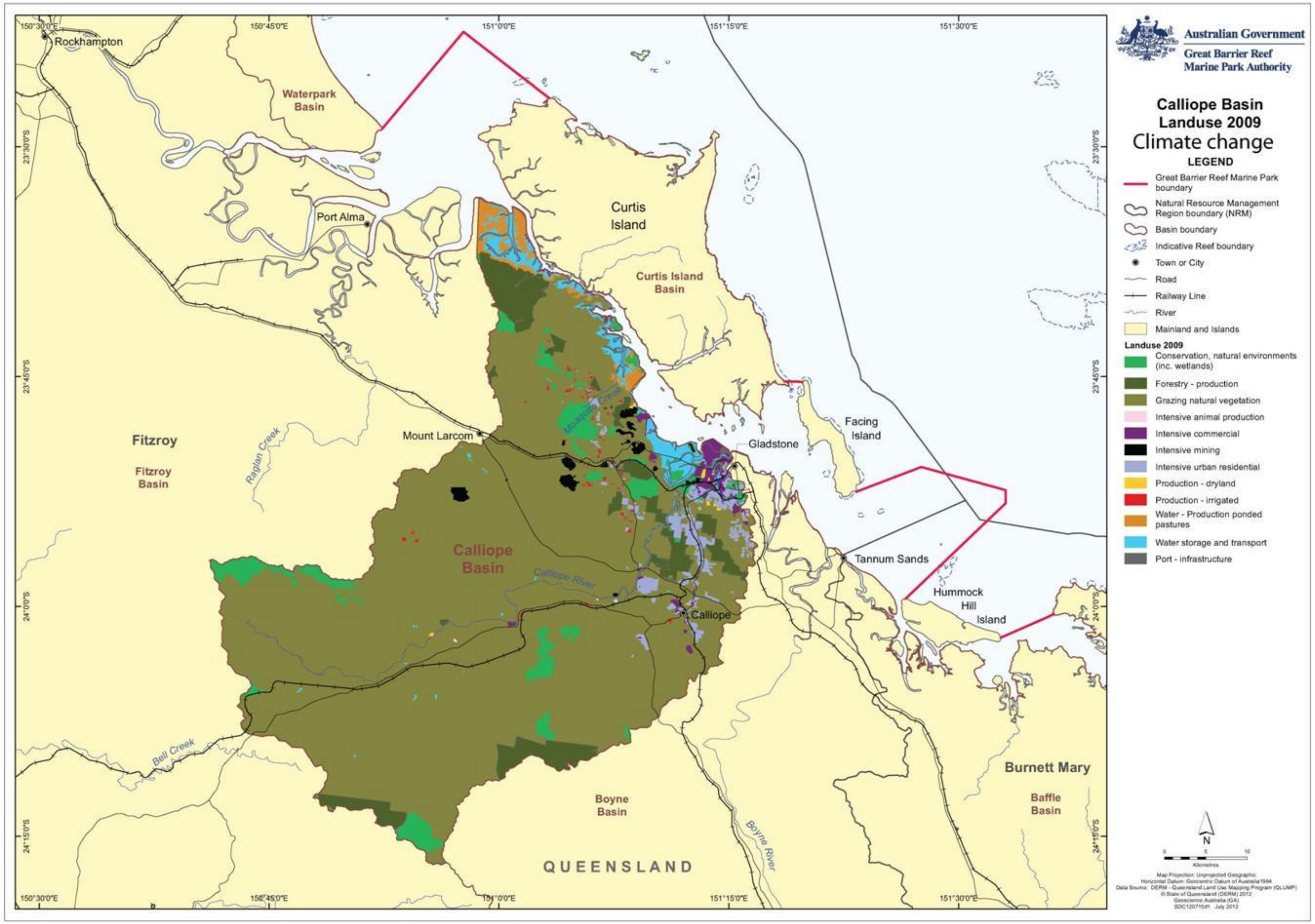
Reconnect fragmented ecosystems

Increase riparian vegetation with future climate change adapted vegetation

Prevent wildfires particularly along areas of sensitive vegetation and fragments

Allow movement of saltmarsh and mangroves landwards (where possible)

Improve groundcover during the dry through grazing management
-may result in high fire risk however



Hydrology

Lower capacity to regulate water as wetter wet season will result in more flash flood flows. Drier dry season will result in less base flows

General vegetaion - sea level rise is important for coastal areas as they may not be able to move landwards due to natural elevation of land

Curtis Island may become a refuge for estuarine vegetation under sea-level rise

Bunding may compound problems of sea level rise for tidal habitats

Habitat fragmentation combined with drier times may lead to a higher fire risk and potential loss of ecosystems

Vegetation may not be able to move due to limits of geology

Innundated areas may provide more habitat for seagrass

Dry season cover in grazing land may become more critical

ATTACHMENT 18: CAPACITY OF NATURAL AND MODIFIED COASTAL ECOSYSTEMS TO PROVIDE ECOLOGICAL SERVICES FOR THE GREAT BARRIER REEF.

Process	Ecological Service	Forests & woodlands	Rainforests	Freshwater wetlands	Grasslands	Heathland	Forest floodplains	Estuaries	Coastline	Seagrass	Reef & Shoals	Lagoon floor	Water column	Groundwater Ecosystems	Irrigated agriculture	Non-irrigated agriculture	Dams & Weirs	Urban	Mining – operational o/cut	Forestry Plantation	Extensive agriculture	Ponded pastures
Physical processes- transport & mobilisation																						
Recharge/discharge	Detains water			H			✓	MH						✓[1]	M			L	M		H	
	Flood mitigation			✓	L		H	M						✓	N		H	L	X		X	
	Connects ecosystems			H			H	✓						H	L			L	N		L	
	Regulates water flow (groundwater, overland flows)	MH	H	H	L		✓	MH	✓	✓	H	L		H	M		H	L	L		M	
Sedimentation/erosion	Traps sediment	MH	MH	H	L			H		M	M	MH	ML	N	M[4]		M	L	M		H	
	Stabilises sediment from erosion	MH	M	✓	L	✓	✓	✓	H	M		✓		✓	M[4]			H	N		H	
	Assimilates sediment	MH	H	H				✓	✓						M			L	N		H	
	Is a source of sediment	MH		M											L			L[11]	M		L	
Deposition & mobilisation processes	Particulate deposition & transport (sed/nutr/chem. etc)			H										✓[2]	L			L	L		H	
	Material deposition & transport (debris, DOM, rock etc)			H											L			L	L		L	
	Transports material for coastal processes			H											N			M	L			
Biogeochemical Processes – energy & nutrient dynamics																						
Production	Primary production	M	H	H				H	✓	H	✓	✓	H	N	N						M	
	Secondary production			✓				H	✓	H				✓[3]	L						H	
Nutrient cycling (N, P)	Detains water, regulates flow of nutrients			H										✓	L			L			M[13]	
	Source of (N,P)	M	H					H	L	M				✓	N						M	
	Cycles and uptakes nutrients			MH	✓	✓		H	L	M	L	H	H	✓	M			✓			H	
	Regulates nutrient supply to the reef	M	H	M			H	H	L	M				✓				✓			H	
Carbon cycling	Carbon source		H	H				H	L	M				✓							M	
	Sequesters carbon			H			✓	H	L	M	✓	H	L	✓							MH	
	Cycles carbon	H	H					H	L	M	L	H	H	✓	✓						H	
Decomposition	Source of Dissolved Organic Matter		H	H				H						✓							L[14]	
Oxidation-reduction	Biochar source	H																			X	
	Oxygenates water							✓	L			H	H	N							L	
	Oxygenates sediments							✓	L	M		✓		N							✓[15]	
Regulation processes	pH regulation			H						M				✓							✓[15]	
	PASS management			H				H													L	
	Salinity regulation																				✓[15]	
	Hardness regulation			H																	✓[15]	
	Regulates temperature		ML	✓			✓	✓	✓												L[16]	
Chemicals/heavy metal modification	Biogeochemically modifies chemicals/heavy metals			H				✓		M	L			✓							X[17]	
	Flocculates heavy metals			H				✓						✓							L	
Biological processes (processes that maintain animal/plant populations)																						
Survival/reproduction	Habitat/refugia for aquatic species with reef connections			H			✓	H	H	✓	H	M	L	N	L[5]	L[5]	L[8]	L[12]	N	N	L	M[18]
	Habitat for terrestrial spp with connections to the reef			H							H			N	L	L	H[9]	L	N	N	L	L[19]
	Food source			✓			H	✓	✓	H		✓		N	N	N	M	L	N	L	M	L
	Habitat for ecologically important animals				✓		✓	H	L	H	H	✓			N	N	L[10]	N	N	N	M	L[19]
Dispersal/migration/regeneration	Replenishment of ecosystems – colonisation (source/sink)			H				H	M	H	H			N	N	N	L	N	N	N	M	L[20]
	Pathway for migratory fish			H										N	N[6]	N[6]	L[8]	N	N	N	✓[15]	L[21]
Pollination														N	L[7]	L[7]	N		N			
Recruitment	Habitat contributes significantly to recruitment			H			H	H	H	H	H				N	N	L	N	N	N	M	N

Capacity of natural and modified coastal ecosystems to provide ecological services for the Great Barrier Reef.

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, storativity); 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 runoff; 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.

ATTACHMENT 19: MANAGEMENT ACTIONS SUGGESTED BY WORKSHOP PARTICIPANTS

Possible management actions	Calliope	Styx	Proserpine	Herbert	Ross
Protect key (relatively) intact corridors and coastal systems					
Increase riparian extent/buffers of appropriate size for stream order	X		X		
Prevent wildfires in sensitive ecosystems/ fire management	X	X			
Human infrastructure – designs to minimise impacts on coastal ecosystem functions					
Sewage disposal on forestry land			X		
Install tidal power stations		X			
Raise infrastructure to allow for sealevel rise		X			
Grazing – implement BMP – improve dry season groundcover, avoid slopes, more watering stations, and reduce stocking rates.	X	X	X		
Cane – implement BMP for fertilisers and pesticides; install cane drainage retention basins for first flush and recycling			X		
Develop land based aquaculture		X			
Avoid developments on steep slopes			X		
Improve connectivity					
Reconnect fragmented ecosystems (defrag the catchment)	X				
Manage groundwater allocations to maintain recharge/discharge			X		
Re-establish environmental flows from dams/end of dry season flows			X		
Improve water quality at beginning of wet when needed for larvae			X		
Improve fish passage			X		
Address development legacy issues wherever possible					
Remove bunds and re-establish wetland vegetation			X		
Managing for climate change					
Allow mangrove/saltmarsh migration	X		X		
Carbon sequestration - forests		X			
Improve understanding of groundwater flows under climate change scenarios			X		
Monitor freshwater flows to maintain dependant ecosystems e.g. terrestrial vegetation and mangroves under climate change					
Move settlements at risk from climate change (St Lawrence)		X			